Chapter 5
The Physical States

Trends and Trade-Offs

5.1 Introduction

It is clear that saltmarshes have a range of values that change with the physical or biological conditions that influence them. The two general approaches to managing and restoring saltmarsh depend on whether the aim is to create or restore saltmarsh habitat, or manage existing saltmarsh vegetation. This Chapter deals with the first of these, which involves the trends and trade-offs associated with the creation, maintenance or restoration of the habitat. The principal concerns here relate to economic and social values, including those associated with flood protection (Section 4.3) as well as nature conservation. These include 'quantitative' parameters such as location, area, width and height of the saltmarsh. The 'qualitative' issues associated with nature conservation, such as the presence of specialist or rare plant and animal communities or vegetation complexity, are covered in Chapter 7.

Changes in those processes, which help promote saltmarsh accretion (sea-level change, tides and tidal range, sediment availability, freshwater flows and channel movements) also cause erosion. The two often exist in a dynamic interaction, with accreting (State 1) or eroding (State 3) occurring within the same site (Section 4.2.2). The balance between the two results in a landward or seaward progression of the saltmarsh front. Depending on this balance, management to promote the former and control the latter are key elements in any management or restoration strategy. This approach operates at a different scale to the manipulation of the vegetation (Chapter 7). It involves not only consideration of the saltmarsh itself, but also the influence of the wider estuarine environment.

This chapter looks at the nature of the processes causing erosion or accretion and the way in which the values associated with each state change, as the saltmarsh moves between them. The distinctions are not hard and fast or mutually exclusive, but represent convenient ways of evaluating appropriate management and restoration policies. This chapter provides a model based on these trends to help identify the most appropriate form of saltmarsh management or restoration. It is a complex process, which can involve promoting accretion through re-establishing surface stability and vegetation colonisation onto tidal flats. It may also include the protection and restoration of existing saltmarsh or alternatively re-creating saltmarsh on enclosed tidal land (managed realignment). Chapter 6 deals with the methods of management and restoration.

5.2 Physical Trends

Establishing the trend in the physical condition of the saltmarsh forms the basis for development of an evaluation model. In this model, erosion is the key factor used to distinguish between the states. It is the scale in relation to the saltmarsh as a whole that determines into which category the saltmarsh is placed. Whether a saltmarsh is eroding, stable or accreting also affects the contribution the saltmarsh makes to the estuarine ecosystem as a whole and hence, to many of the ‘values’ associated with it. In this context, the ‘State Evaluation Model’ also considers the value of saltmarsh to estuarine productivity and stability.

5.2.1 Processes Influencing the Physical State

External forcing factors (pressures) drive the saltmarsh processes towards one or other of the states. Hydrodynamic and sedimentary processes are important in determining the direction of movement. For example, in macrotidal saltmarshes on the French coast, lateral expansion was more prevalent when there was an abundance of new sediment. Relative sea-level rise or changes in hydrological conditions drove vertical accretion (Haslett et al. 2003). Saltmarsh vegetation also has an inherent resilience. However, soil conditions are important and the incidence of pollution may cause degradation of the vegetation surface. Grazing also affects the height of the sward and overgrazing can destroy the vegetation (Chapter 7). Understanding the way these interrelate, is important to the assessment of saltmarsh state as well as to any decision to alter the state. The more important of these interactions are summarised in Figures 38 and 39.

5.3 Values Associated with the Physical State of the Saltmarsh

Accreting saltmarsh (State 1) will have mostly positive values as new marsh ensures the continued existence of the habitat and with it its inherent values. Where erosion and accretion are in balance (State 2), within the saltmarsh there will be both structural and temporal change. These will include sites with significant cliff erosion (Section 4.2.2). These in turn will enhance some values, such as those associated with species diversity. The changes may be negative for some other values, such as sea defence, in some locations.

Overall, the value of the saltmarsh diminishes with time as erosion continues with no significant accretion (State 3). Thus most if not all of the attributes will

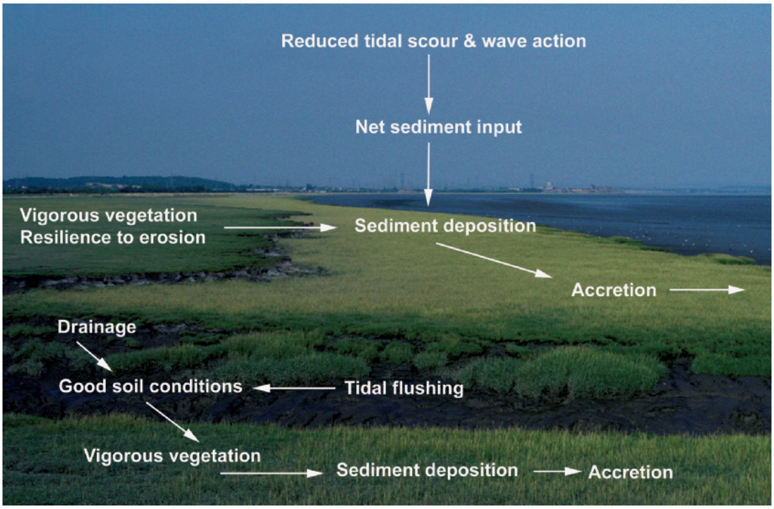

Figure 38 Some of the key physical and hydrodynamic factors promoting vertical and lateral accretion within a saltmarsh

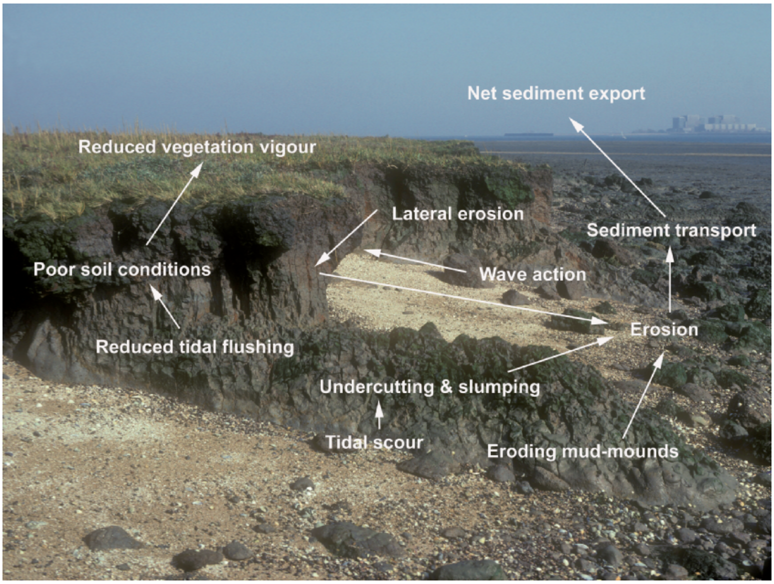

Figure 39 Some of the key physical and hydrodynamic factors promoting erosion within a saltmarsh

have negative values. Note that some of the positive values associated with accreting saltmarshes may also have negative impacts on other features, especially where lateral growth is rapid, as is the case with *Spartina* spp. expansion (Chapter 9). This section provides a summary of the values associated with each state and a description of the way they change with the changing state of the saltmarsh.

5.3.1 State 1–Accreting Saltmarsh

Where conditions are favourable, saltmarshes accrete. In the absence of human interference, this is the natural state of a saltmarsh, essential for the development of the full sequence of vegetation appropriate to the geographical region. Accreting saltmarsh is indicative of a healthy sediment budget and resilience to erosion. The largest saltmarshes tend to occur in meso- to macrotidal areas, with a net sediment budget and/or where relative sea levels are falling. They are associated with mostly positive or neutral trends (Table 12).

Table 12 Positive or neutral trends in some of the values associated with accreting saltmarsh

Value	Trend	Comment
Energy recycling mechanisms	Positive	Potential for greater productivity
Nutrient recycling mechanisms	Positive	Potential for greater efficiency
Water quality improvement	Positive	Potential for greater efficiency
Natural sea defence	Positive	Wider, greater resilience
Keep pace with sea-level rise	Positive	Maintaining or improving natural sea defence
Contribution to the landscape	Positive/Neutral	More expansive vistas
Ecological study	Positive	Presence of primary succession
Geomorphological study	Positive	Opportunities for sediment regime studies
Biodiversity	Positive/Neutral	Depending on the speed of succession and management. Note: Negative trends appear when the trend is towards dominance by a single species
Bird watching	Positive/Neutral	But see below – loss of mudflat
Walking	Positive/Neutral	
Samphire gathering	Positive	Though not where *Spartina* is the colonising species
Boat mooring	Neutral	Could be negative – more difficult access
Pipeline landfall sites	Neutral	
Military training areas	Neutral	

Figure 40 The foreshore along the quayside at Parkgate on the Dee Estuary in 1995. A former sandy beach, used for recreation in the 1920s

There are some negative aspects associated with accreting marshes. The rapid natural expansion of pioneer plants such as *Salicornia* spp., *Suaeda* spp. and in at least one case *Puccinellia maritima* (Edmonson et al. 2001) onto a sandy beach can have negative consequences for recreational activity. In the 1920s, children were able to paddle on open sandy intertidal sediments at Parkgate on the banks of the Dee Estuary (UK). By 1995, a saltmarsh some 1.2 km wide had developed in front of the promenade (Pye 1996; Figure 40). Siltation of the Ribble Estuary in north-west England (van der Wal et al. 2002) led to a similar problem on the Sefton coast, where a sandy beach became invaded by saltmarsh, resulting in *Spartina anglica* control (see Chapter 9). In the Wash, the Freiston foreshore hosted an annual 'summer Sand Fair' between the 1840s and 1870s (Robinson 1987). By 1980, the growth of saltmarsh was such as to allow enclosure and conversion to arable land. The loss of tidal flats can similarly be negative for wintering waterfowl, as new saltmarsh extends onto mudflats. This is particularly pertinent in the case of *Spartina* spp. when they occur outside their natural range or hybridise (Chapter 9).

5.3.2 State 2–Dynamically Stable

The state of 'dynamic equilibrium' is in many ways the desired state, especially in relation to nature conservation values. The functions of the mature saltmarsh from both a nature conservation and sea defence point of view appear to be mostly satisfied (Table 13). Thus, ecosystem values, economic values such as sea defence capability, use for grazing, contribution to fish and shellfish production or water quality improvement, all have positive values or at worse neutral values. This situation holds true so long as the overall status of the saltmarsh (area and elevation) remains in equilibrium. The temporal changes may also impart additional diversity. For example,

Table 13 Positive, neutral or negative trends in some of the values associated with dynamically stable saltmarsh

Value	Trend	Comment
Energy recycling mechanisms	Positive/Neutral	Potential for increased rate of export to coastal waters
Nutrient recycling mechanisms	Neutral	?
Water quality improvement	Neutral	?
Natural sea defence	Positive/Neutral	More flexibility but areas of potential vulnerability
Keep pace with sea level rise	Positive/Neutral	More flexibility but areas of potential vulnerability
Contribution to the landscape	Positive/Neutral	Greater variation as features change
Ecological study	Positive	Presence of primary and secondary successions
Geomorphological study	Positive	Coastal processes in operation
Biodiversity	Positive	Greater number of species
Bird watching	Positive/Neutral	Availability of a wider range of feeding areas within the saltmarsh
Walking	Negative	Presence of wider and more frequent creeks
Boat mooring	Neutral	Could be negative – more difficult access
Samphire gathering	Neutral/Negative	
Pipeline landfall sites	Neutral	
Military training areas	Neutral	
Archaeology	Neutral	May expose and cover features of interest

sequences of erosion followed by regrowth, create a series of steps as new saltmarsh develops to seaward of an eroding microcliff (Section 4.2.2; Figures 27 and 28). Each can have a different sequence of vegetation and hence biological diversity.

Saltpans add to the complex mosaic, and deposits of seaweed on the tide-line may smother the surface vegetation, creating further spatial variation as the strandline deposits rot (Packham & Willis 1997, pp. 101–105). The vertical structure of the vegetation provides further diversification, which helps to support a wider range of animals, especially invertebrates. In addition, the inherent dynamic nature of this state, also imparts an ability to respond to changing environmental circumstances, especially in relation to sea-level change.

5.3.3 State 3–Eroding Saltmarsh

The values associated with State 3, eroding saltmarsh, diminish as erosion takes place. As cliff erosion and in a few locations at the edge of the saltmarsh surface slumping, progressively reduce the saltmarsh area, most, if not all, of the attributes will have negative values (Table 14). Ultimately, all the values are lost, when the saltmarsh erosion reaches a point where only small remnants survive against a sea wall or rising ground.

Table 14 Positive, neutral or negative trends in some of the values associated with eroding saltmarsh

Value	Trend	Comment
Energy recycling mechanisms	Negative	Decreasing rate of export to coastal waters
Nutrient recycling mechanisms	Negative	
Water quality improvement	Negative	
Natural sea defence	Negative	Increase in vulnerability
Keep pace with sea-level rise	Negative	Lack of sediments
Contribution to the landscape	Neutral/Negative	
Ecological study	Negative	Presence of primary and secondary successions
Geomorphological study	Positive/Neutral	Coastal processes in operation
Biodiversity	Negative	
Bird watching	Positive/Negative	Wider tidal flats feeding areas, less breeding bird habitat
Walking	Negative	Presence of wider and more frequent creeks
Samphire gathering	Negative	No accreting saltmarsh
Boat mooring	Neutral/Positive	Could make access to tidal creeks easier
Pipeline landfall sites	Neutral/Negative	Reducing area for burial
Military training areas	Neutral	
Archaeology	Positive	May uncover features

Despite the generally negative values associated with eroding saltmarsh there are at least two positive values. The first of these lies in the creation of larger areas of tidal sand or mud flats. These in turn increase the area available for intertidal invertebrates, prey for species of waterfowl and other predatory animals. Eroding saltmarsh can also expose former surfaces and features, which may have archaeological significance. These include submerged forests, in areas where sea levels were lower than today. In the context of this discussion, these may provide only limited compensation for the losses. Despite this, they represent a value worth considering when deciding whether to intervene or not.

5.4 Summary – A Physical Model for Change

It is possible to derive a State Evaluation Model taking each of the above states in turn. This seeks to summarise the key directions of change, and from this to analyse the relative merits of promoting saltmarsh accretion, protecting existing habitat or trying to reverse erosional trends. The approach involves assessing each state in relation to the principal concerns of the manager, whether for flood or sea defence,

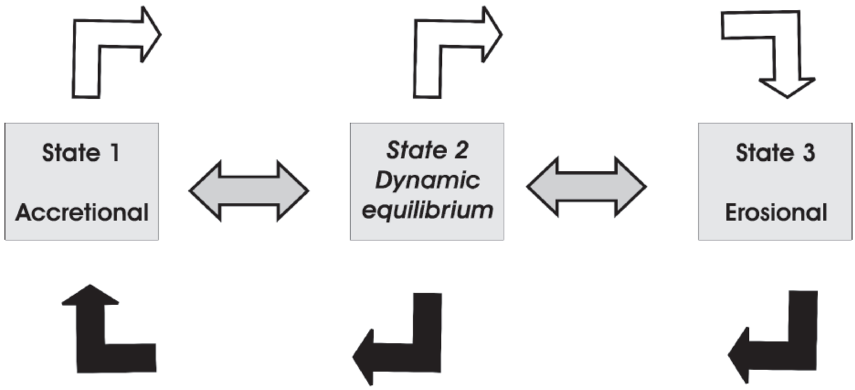

Figure 41 A summary of the 'pathways for physical change' within an individual saltmarsh. Note 'creating erosion', i.e. moving directly from a State 1 to State 3, which mostly involves control of invading *Spartina* is not shown, but see Chapter 9

water quality objectives, cultural or socio-economic values and for nature conservation at any given site.

In order to determine the appropriate management option, it is important to assess the **desired** state in relation to the principal values affected by any move from the **existing** state of the saltmarsh. The 'Physical State Evaluation Model' provides a simple illustration of the possible directions of change in relation to any move from an accretional to an erosional saltmarsh (Figure 41). The model shows the main pathways for adverse change (open arrows) dealt with in this chapter and the 'routes' to restoration (black arrows) described in Chapter 6. Note that State 2 saltmarshes can incorporate both States 1 and 2, indicated by the grey arrows. Although these changes can lead to adverse effects, they are also part of the natural dynamic as described above.

The Physical State Evaluation Model identifies erosion as the principal reason for wishing to change the existing state of a saltmarsh. This involves reversing trends where erosional forces dominate over accretional ones. The trend is towards saltmarsh loss with accretion either non-existent or below that required to sustain the area of habitat in the medium to long term.

5.4.1 Rates of Accretion and Loss

If conditions are suitable, saltmarsh will accrete, even in areas where sea levels are rising. Vertical accretion rates in the outer Bay of Fundy, for example, ranged over the last two centuries from 1.3 ± 0.4 to 4.4 ± 1.6 mm per annum, similar to the recent rate of sea-level change recorded at Eastport, Maine (Chmura et al. 2001). In estuaries and other enclosed or partially enclosed embayments, where there is an abundance of sediment, rates of up to 7.7 and 6.3 mm per annum respectively have been recorded at the saltmarsh surface at Surville and Lessay on the West Cotentin Coast of Normandy. These are well in excess of the sea-level rise of 3.9 mm per annum determined from a tide gauge on the nearby island of Jersey, from 1952–2001 (Haslett et al. 2003). Vertical sedimentation over 5- and 40-year timescales in Blyth estuary, Suffolk, also easily outpaced a post-1964 sea-level rise of 2.4 mm per annum (French & Burningham 2003). In the Wadden Sea similar accretion rates of 5 mm and 10 mm per year were recorded over a 25-year period for barrier island and mainland saltmarshes respectively (Dijkema 1997)

Rates of expansion can be considerable under favourable conditions. The saltmarshes in the estuaries of the French coast are expanding laterally, in one estuary, at a rate of 4,400 m^2 per annum. This is attributed, partly at least, to the cessation of offshore sediment extraction and the presence of a more abundant supply (Haslett et al. 2003).

Despite the obvious ability of saltmarsh to accrete at a rate equal to, or greater than the rate of sea-level rise, there is little evidence for lateral accretion of new pioneer saltmarsh at many sites. In south-east England, there is a preponderance of erosion over accretion (Section 3.4.2). Saltmarshes in the Odiel Estuary, south-west Spain, show patterns of erosion exacerbated by human influences (Castillo et al. 2002).

Localised losses, in Jamaica Bay, New York, show erosion due to sea-level rise, accelerated by human activities, such as tidal dredging, which has increased the average water depth and with it tidal scour (Hartig & Gornitz 2001). Here major losses continue to occur because of increased waterlogging within saltmarsh interiors, slumping along their edges and widening of tidal inlets. Studies suggest that the losses will continue, as they appear likely to be unable to keep pace with accelerated rates of sea-level rise in the future (Hartig et al. 2002). Further evidence from the USA suggests that at its simplest, a saltmarsh that accretes at a rate greater than relative sea-level rise can keep pace with sea-level rise. One that cannot drowns (Schwimmer & Pizzuto 2000). The situation in the USA is particularly acute, as the combined effects of natural erosion and 'drowning' due to sea-level rise; exacerbate the more direct losses due to land enclosure and drainage.

Coastal wetlands are lumped together in the USA, as are the losses due to 'drowning' or human activity. For example in 1991, the Gulf of Mexico Coastal Wetlands included some 1,049,700 ha 'marshes' (fresh, brackish, and saltmarshes) (NOAA 1991). A review of a series of case studies provided information on the scale of losses within this area (Johnston et al. 1995). These included, Galveston Bay Marshes (fresh and non-fresh), which decreased from about 67,000 ha in the 1950s to about 52,800 ha in 1989, representing a net marsh loss of about 21% (White et al. 1993). For Coastal Louisiana, where coastal wetland loss represented 67% of the nation's total loss, some 177,625 ha were lost between 1978 and 1990. For the period 1956–1978, net wetland loss was even greater, at 267,800 ha. In Mobile Bay, non-freshwater marshes declined by 4,047 ha between 1955 and 1979; an overall loss of 35% (Roach et al. 1987).

There appear to be no worldwide estimates of saltmarsh loss due to erosion. The more localised studies in south-east England recorded direct losses through erosion (Section 3.4.2). Other studies, such as there are, refer to coastal erosion in general (e.g. in Europe the EURosion Project, see http://www.eurosion.org/). However, the losses highlighted above, coupled with the impact of direct human intervention (Chapters 2 and 3) and the effects of sea-level rise, which result in a saltmarsh squeeze (Section 3.5.2) help to confirm the view that eroding saltmarshes dominate over accreting ones.

5.5 Monitoring is an Essential Tool

Deciding on whether intervention is necessary, or desirable, leads to a first question for the manager: what is the current state of the saltmarsh? The description of the principal states (Section 4.2) provides the first level of assessment. It is possible in the short term to identify accreting or eroding saltmarshes. In most circumstances, it will be obvious. Cliffed edges appear in the saltmarshes, they may have slumping sides and where they occur, sea walls are undermined (Figure 42).

Determining the medium- to long-term trends requires monitoring. Anecdotal evidence may suffice when identifying potential problem areas, but it is more likely there will be a need for detailed work.

The position and area of a saltmarsh are the most obvious initial information requirements in any assessment. Remote-sensing using repeat aerial photographs,

Figure 42 Eroding saltmarsh undermining a sea wall, Essex

and satellite images, or measurements from fixed-point markers, can provide first order assessments of change. The studies of change in the saltmarshes in Essex and North Kent using aerial photographs taken at different times (Burd 1992), helped determine a change in policy (Section 3.4.2). Satellite imagery has also proved useful in identifying long-term changes in the lateral extent of saltmarshes, in Jamaica Bay, New York (Wang & Christiano 2006). These involved identifying changes in relatively distinct, simple *Spartina* communities, other more complex communities are more challenging. In Australia, saltmarshes are important indicators for State of the Coast Reporting. Their extent can be mapped using aerial photography and satellite imagery. Ground-truthing helps differentiate between saltmarsh and areas of tidal mudflats (see http://www.ozestuaries.org/indicators/changes_saltmarsh_area.jsp).

Sequences of vegetation maps may be the only requirement when deciding the physical state of a saltmarsh. However, deciding on other forms of management (not just in relation to promoting accretion or controlling erosion), will require detailed survey and monitoring. In the Netherlands detailed 'Reference Conditions' have been established for saltmarshes in relation to the European Union Water Framework Directive. These include parameters for assessing changes in area and quality of the vegetation. The reference condition for the former is set against an estimate of historical acreages. The latter considers succession, zonation and quality characteristics. An assessment is made of the 'Potential Reference Condition' in relation to area and the 'Potential Good Ecological Status' of the vegetation (Dijkema et al. 2005).

The Massachusetts Office of Coastal Zone Management has produced 'A Volunteer's Handbook for Monitoring New England Saltmarshes' (see http://www.mass.gov/czm/volunteermarshmonitoring.htm). Aimed at helping local volunteer groups, this provides relatively simple approaches to collecting and recording data in a scientifically consistent way. The aim is to monitor the health of the saltmarsh as well as the effectiveness of protective measures and restoration actions. The Gulf of Maine Council on the Marine Environment has developed more rigorous standards (see http://www.gulfofmaine.org/habitatmonitoring/). The protocol for monitoring regional saltmarsh change, which also assesses the effectiveness of habitat restoration uses a tiered approach:

1. Tier I: minimal monitoring of core variables (hydrology, soils and sediments, and vegetation) occurring on most sites;
2. Tier II: recommended monitoring (Tier I plus one animal indicator (nekton, birds or invertebrates) where possible;
3. Tier III: intensive monitoring, all core variables, occurring at a small number of sites;
4. Tier IV: research into cause–effect relationships.

Whether this level of detail is required is a matter of judgement. It will inevitably depend on the available finance or other resources available in the area in relation to the 'value' of the assets at risk.

5.6 Assessing the Need for Intervention

The problem of assessing the balance of erosion over accretion is most difficult in larger sites. Erosion due to movement of tidal channels (Section 4.2.2) could suggest the need for intervention. Other factors such as seasonal patterns in wind direction, surface deposits, which smother vegetation or other natural forces that drive change, may cause short-term localised losses. Determining whether these represent short-term cycles or long-term trends may require both extensive and intensive survey. In the Tagus estuary, situated on the Atlantic coast of Portugal, despite losses due to human intervention the overall the balance of erosion over accretion was found to be neutral (Portela 2002). The loss trends identified in the USA due to the effects of 'drowning' caused by the consolidation of sediments, sinking due to tectonic movement, restriction of sediment supply or sea-level rise also appear clear. However, local considerations can result in the employment of inappropriate and counterproductive measures. It is therefore important that when making decisions, they take into account an estuary-wide perspective.

The need for intervention will also depend on the focus of the individual or organisation making the assessment. Whatever the actual change, intervention will depend on the social, economic or environmental reasons (singly or in combination) for taking action. The 'assets at risk' will in turn help determine the effort and financial commitment. As the nature of the saltmarsh changes so do the **values** attached to it, as described above. Thus changing the state requires an evaluation of the **desired state**, in relation to the **existing state**. The discussion that follows provides pointers to this evaluation.

5.6.1 Accreting – State 1

Accreting saltmarsh (State 1) is, under **most** circumstances desirable. It is positive, especially in relation to sea defence, or at worst neutral in respect of most of the attributes identified above and in Table 12. There is a **cost** as open tidal sand and mud flats are 'invaded'. Though even from an ornithological perspective, despite the potential loss of waterfowl feeding grounds it is unusual for a negative view to be taken, except in the case of *Spartina* invasion (Chapter 9).

Benefits also accrue in relation to the natural functioning of the ecosystem such as the contribution to primary productivity. Economic values (Section 4.3.2) and cultural assets (Section 4.3.3) are also favoured. In the absence of enclosure, it helps ensure the presence of all stages in vegetation development, through upper saltmarsh to brackish marsh and transitions to non-tidal vegetation. This in turn leads to the potential for the colonisation of animals at these higher levels, including breeding birds and invertebrates especially where grazing is moderate or light (Sections 4.4.2 and 4.4.3 respectively). In the absence of grazing succession can lead to the dominance of a single species, which is a particular issue in the Wadden Sea (Dijkema pers. comm.).

The expanding marsh will also provide greater opportunities for feeding and shelter for juvenile stages in fish development (as described in Section 4.3.2). From a management perspective, maintaining the conditions of sediment availability, protection from wave action to aid plant establishment and growth and preventing damaging developments such as enclosure, may be all that is required.

5.6.2 Dynamic Equilibrium – State 2

Saltmarshes in a state of 'dynamic equilibrium' will, under most circumstances also require no intervention. Here, the three States form a virtuous interaction with all stages represented within the one saltmarsh. Overall, they would normally show no overall change in total area in the medium to long term. Saltmarshes in a dynamic equilibrium hold a range of **values** (Table 13) associated with each of the principal 'States'. From a nature conservation perspective, they will have spatial and temporal variations that help to create a range of physical conditions suitable for a diverse flora and fauna. The landscape is likely to be similarly diverse. The values associated with economic interests, such as fisheries, are also catered for. Socio-economic, biological and nature conservation interests are all likely to be positive. From a coastal defence perspective, although small-scale erosion may cause problems locally, the dynamic nature of the habitat may be acceptable. Thus, from almost all perspectives, so long as the medium- to long-term assessment indicates no overall change, little or no intervention will be needed, under most circumstances. Note that where enclosure has taken place, even though the remaining saltmarsh may be in balance, issues such as sea defence may dictate intervention to re-create saltmarsh.

5.6.3 Eroding – State 3

Active intervention is more likely to be appropriate where saltmarshes are eroding on a wide geographical scale, or individual marshes are disappearing altogether. Eroding State 3 saltmarshes are undesirable under most circumstances, having negative values for most interests (Table 14). Reversing this trend (State 3 to State 1 saltmarsh) whether via State 2 or not, will be deemed to be positive (black arrows in Figure 41). This will represent a positive trend for those **values** associated with accreting or dynamically 'stable' saltmarsh.

Intervention to help encourage accretion is one course of action. Where this form of restoration is not possible, due to limitations on space or the suitability of the prevailing environmental conditions, there are other techniques. These involve protecting the remaining saltmarsh in situ, preventing further erosion by adopting protective measures. In other areas where erosion is severe, especially where sea level is rising relative to the land, saltmarsh re-creation may be the only option. Finally, if these fail, or are unsuitable then the creation of saltmarsh on land above the high water mark may be required. This may include terrestrial areas where the habitat has not occurred before. There are several approaches to reversing this trend.

5.7 Approaches to Restoration

Given the values recognised for saltmarsh and the positive trends associated with its restoration, it is not surprising that there are many examples of this activity. Chapter 6 describes the methods employed and their efficacy in some detail. At this point, it is sufficient to confirm that the restoration of saltmarsh is a clear benefit in securing sea defence, landscape and recreational, wildlife conservation and other objectives identified as having positive values and showing positive trends in Tables 12, 13 and 14.

In order to reverse erosional trends, which dominate in many areas and help to restore the values associated with the habitat there are several approaches:

- Moving seaward;
- Protecting and restoring saltmarsh;
- Moving landward, including creating new saltmarsh.

5.7.1 Moving Seaward, Creating New Saltmarsh

In the past, creating 'new saltmarsh' or intervening, to accelerate its accretion were common activities. According to the processes summarised in Section 1.3.1, given a reasonable supply of sediment new saltmarsh will become established or existing saltmarsh expand with or without human intervention. In the normal course of events, accreting saltmarshes (State 1) will eventually reach a mature state of dynamic equilibrium (State 2), when the forces promoting accretion are in balance with those promoting erosion.

The value of saltmarsh for sea and flood defence, even with relatively small widths of saltmarsh (Section 4.3.2) is clear. It may therefore appear that the creation of saltmarsh through the construction of sediment fields, 'warping' or *Spartina* planting (Section 2.4.3) will continue to represent a positive trend for coastal defence. The mechanisms designed to promote saltmarsh accretion onto tidal flats include reasonably well defined methods used in historical times and dealt with in Chapter 2.

The provision of biofuel, food and animal fodder are also reasons for saltmarsh creation. Scott et al. (1990) for example, reviews the use of *Spartina* as a biofuel. *Spartina* spp and *Phragmites* are both included as plants with the potential for providing biofuel material (Bassam 1998). Expanding the range of mangrove colonisation forms part of a practical approach to provide feed for sheep and goats and increase the Eritrean food supply (the Manzanar Project, see http://www.tamu.edu/ccbn/dewitt/manzanar/default.htm).

Promoting accretion in order to create **new saltmarsh** habitat, over bare tidal flats remains an option. However, there is a growing recognition that this is not an easy task, despite the inherent ability of saltmarshes to keep pace with sea-level rise. Human actions, notably saltmarsh enclosure, sediment deficits and the resulting foreshore steepening, can make establishment of pioneer plants difficult. In some cases, as in the case of planting non-native *Spartina* spp. it is undesirable (Chapter 9).

5.7.2 Protecting and Restoring Saltmarsh

Whilst the techniques for promoting accreting (State 1) saltmarshes are, in many cases, well-tried and tested, their sustainability, in all but the most favourable circumstances, is less clear-cut. Protecting existing saltmarsh represents a second option in any programme designed to reverse erosional trends. On the face on it, these appear to be wholly positive and desirable activities, especially when flood protection is a key issue. Preventing damage or loss of habitat, caused by human intervention also lies at the core of any nature conservation effort. However, a question arises about the sustainability of individual actions designed to prevent erosion, particularly in the face of rising sea levels, adverse hydrological conditions or depleted sediment supply.

The most commonly used techniques involve attempts to protect surviving habitat, repairing or restoring eroded saltmarsh vegetation. The methods include a variety of approaches including the erection of protective structures seaward of any remaining saltmarsh and replacing lost saltmarsh, ‘in situ’ through sediment placement and planting. The discussion in Chapter 3 shows how attempts to protect eroding saltmarsh used the ‘warping’ techniques borrowed from the Wadden Sea (Section 2.4.3) largely failed when applied to the eroding saltmarshes of the Essex coast (Section 3.5.1). Nevertheless, techniques to protect saltmarshes from erosion remain part of the armoury of measures employed throughout the world (Figure 43 and Section 6.2).

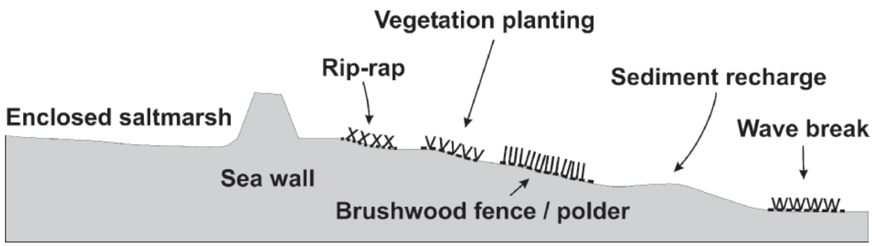

Figure 43 Summary of some of the techniques for saltmarsh restoration seaward of an existing sea wall

Due to the extent of the losses resulting from human activities (Chapter 2), coupled with erosion forcing ‘saltmarsh squeeze’, simply maintaining the existing saltmarsh (what is left) may be insufficient. In order to retain the saltmarsh values, such as those associated with sea defence, requires re-creation of the habitat. Note the distinction between activities that seek to protect or restore saltmarsh where it has eroded from tidal flats (restoration, Figure 43) and those areas involving re-integration with enclosed tidal land, which is dealt with next.

5.7.3 Moving Landward, Re-integration and Habitat Creation

Many of the historical techniques for restoring saltmarsh are well known. Reversing the process of enclosure through re-integration with the sea involves a relatively new set of approaches (Figure 44). These include removal of all or part of an enclosing sea wall, embankment or dyke, originally built to create new land for agriculture or other development (Section 2.4). Note that the nature of the use of the land following the original enclosure is critical to the ability to re-create saltmarsh. Areas remaining below high water without buildings, roads and the like, such as land in agricultural use, have the greatest potential for re-integration. The precise methodology depends on the physical situation. However, some or all of the approaches summarised in Figure 44 are used. In some circumstances, built structures such as roads need not be an impediment to re-integration. In the USA, for example, enlarging culverts under roads and removing tidal flaps may be all that is needed.

Decisions to create, protect or restore saltmarsh will need to have information on the status of the sediment regime, tidal range, exposure, relative sea-level change (rising or falling), efficacy of the techniques and the ‘knock-on’ effects for other interests. Having made a decision to restore saltmarsh, there are several methods. Chapter 6 considers these as they apply to restoring saltmarsh (re-creation and re-integration) and creating new saltmarsh.

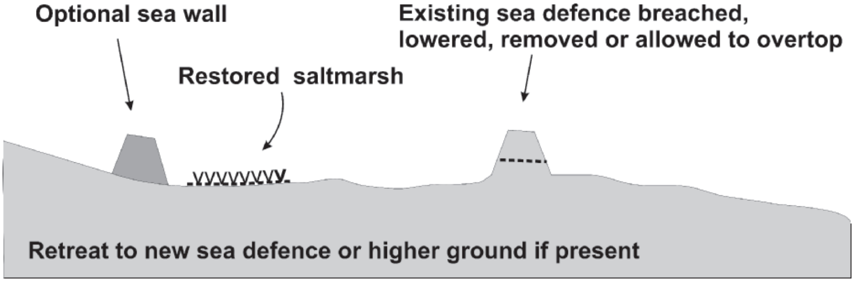

Figure 44 Summary of some of the approaches to the landward restoration of saltmarshes and tidal flats