Chapter 10
Conclusions

A Place for Saltmarsh and Everything in its Place

10.1 Introduction

This book has described saltmarshes, their development and position in the wider coastal ecosystems (Chapter 1). It has considered the extent of human influence from grazing management, through to enclosure for agriculture (arable and rice cultivation) and the development of infrastructure such as ports, harbours, industry, housing and roads (Chapter 2). Recognition that losses have been extensive, putting at risk both nature conservation and socio-economic interests, led to a change in the view of the role of saltmarshes (Chapter 3). Consideration of the values attached to different physical and biological (vegetated) 'states' (Chapter 4) led to the development of 'models' for habitat restoration and vegetation management. Included in this were discussions of the trends and trade-offs associated with moving between the different physical states (Chapter 5) and ways of achieving these (Chapter 6). Similar considerations apply in relation to grazing management dealt with in Chapters 7 and 8. An additional chapter considers the special case of *Spartina* spp. (Chapter 9).

This final chapter discusses the relationships between managed and restored saltmarshes and their role in the wider tidal environment. The way in which these activities redress the balance between ecosystem and human values of saltmarsh is considered. In particular, it looks at the role of the saltmarsh in maintaining the ecological balance, biological diversity and sustaining human use.

10.2 Time and Tide Wait for No One

To understand the relationship between 'natural' and human change we need to set a context. One of the more important factors affecting saltmarsh development is sea-level change. Sea levels have risen and fallen in response to changes in the coverage of the ice-sheets over millenniums. Since the last glacial maximum about 20,000 years ago, the sea level has risen, from its lowest point, by over 120 metres because of the melting of the ice. From some 15,000 years ago, there was a rapid

Table 25 Estimated rates of global sea-level change during the Holocene. Detailed information on global warming and the implications for sea-level change; including the Intergovernmental Panel on Climate Change report referred to (Houghton et al. 2001)

Period	Rate of change (mm/year)	Reference
15,000–6,000 years ago	10	Houghton et al. 2001
6,000 years ago to the present	0.5	Houghton et al. 2001
3,000 years ago to present	0.1–0.2	Houghton et al. 2001
1880–1980	1.8	Douglas 1991*

* This estimate of 1.8 mm per year derives from 21 stations in nine oceanic regions avoiding tide gauge records, in areas of converging tectonic plates or with substantial uplift or subsidence due to 'post glacial rebound'

rise in sea level. This resulted in an inundation of the coast with the subsequent landward movement of coastal habitats including saltmarshes. From about 6,000 years ago to the present day rates of change slowed dramatically (Table 25). These estimates refer to average changes in global sea level, referred to as eustatic change. The terms 'eustasy' or 'eustatic' refer to changes in the volume of water in the oceans, usually resulting from changes in the global climate.

A reappraisal of these figures confirms the more recent general rate of 1.8 mm per year during a one hundred year period. Despite the fact that this appears to be an order of magnitude greater than in the previous 3,000 years, there is no discernable acceleration in the rate of sea-level rise over the last 100 years (Douglas 1997). Analysis of the relationship between foraminifera and plants in saltmarshes in the Gulf of Maine, however, indicate that since 1800, sea levels have risen by 0.3–0.4 m (c 1.5–2.0 mm per year) here at least. The results suggest this rise corresponds with regional climatic warming and thermal expansion of the Gulf of Maine and North Atlantic sea surface. Despite a temporary slowing during the mid nineteenth century, twentieth century rates are higher than at any time in the last 1,000 years and correspond with global warming trends (Gehrels et al. 2002).

Satellite data seems to confirm this. At a global scale altimetry data from the Topex/Poseidon satellite (1993–1998) shows a 3.2 ± 0.2 mm per year global mean sea-level rise, which is attributed to thermal expansion of the oceans (Cabanes et al. 2001). In the Mediterranean during 1993–1999, data from the same satellite indicates rates as high as 20 mm per year south-east of Crete (Cazenave et al. 2001) though smaller changes were observed elsewhere, including a decrease in the northern Ionian Sea.

The relative rate of sea-level movement on the coast depends on the relationship between changes in the level of the sea and the land levels. A number of factors depress or release the Earth's crust and result in changes in land levels, referred to as Isostatic change. The principal cause is the formation of ice-sheets, which depress the land surface. As the glaciers melt the land recovers with the removal of the weight of ice, a process called 'Isostatic post-glacial rebound'.

The true rate of sea-level change as it affects the coast, thus depends on changes in both the land and sea surfaces. This 'relative sea-level change' can be much greater than the sea-level change alone. Tide gauge records suggest that in Northern Europe between 1900 and 1985 sea levels have fallen. In areas of maximum crustal loading during the last Würm Glaciation, this has been by as much as 10 mm per year in the northern Baltic Sea. In unglaciated areas, such as southern England and parts of northern France, it is rising by as much as 6 mm per year (Aubrey & Emery 1993). In Scotland, a major ice-sheet covered the land and today the surface is rising by 1.6 mm per year. By contrast, Southern England remained unglaciated throughout the glacial period and sinks today at a rate of about 1.2 mm per year. (Shennan & Horton 2002). Other factors, which may influence land levels are sediment deposition, compaction and plate tectonics. The maximum rates are even greater in Japan where the rate of emergence of the land from the sea can be as high as 6 mm per year. In the same area, the rate of submergence in the south-east is up to 20 mm per year. These rates are due to tectonic trends caused by the convergence of two continental plates (Aubrey & Emery 1993).

10.2.1 Can Saltmarshes Keep Pace with Sea-Level Rise?

Against the background of long term global changes in relative sea level the physical conditions, tides and storms determine whether saltmarsh develops or not. Given an adequate supply of sediment, up to a point, saltmarsh can keep pace with sea-level rise. This requires that the rate of accretion minus any lowering of the surface due to compaction is greater than or equal to the rate of sea-level rise. In the early stages of colonisation, rates of vertical accretion can reach 10 mm per year or more (Section 4.2.1.), well in excess of the rate of sea-level rise in most areas. For mature saltmarshes there appears to be a limit above which sea-level rise outstrips saltmarsh growth. This limit is around 6 mm per year in the Wadden Sea (Bakker et al. 2005). Thus, even in areas where land levels are sinking and the maximum rates of relative sea-level rise approach 6 mm per year, as in parts of the southern North Sea, saltmarsh accretion can theoretically keep pace.

Why then are most of the world's coastlines in a state of erosion (Pilkey & Cooper 2004), and it appears that apart from areas where *Spartina* spp. is present (Chapter 9) this is also true for many saltmarshes? Part of the reason lies in the fact that erosion is a natural process in saltmarsh development (see Section 4.2.2). Thus, not all saltmarshes exhibiting erosion are undergoing irreversible change. Acceleration in sea-level rise may change the point at which a dynamic equilibrium occurs, causing a fall relative to the tidal frame. Whilst this may result in 'drowning', it causes a change in vegetation rather than a loss saltmarsh. It seems that areas where sediments are depleted are at most risk (Nicholls & Leatherman 1995; Neuhaus et al. 2001). In addition, many surviving saltmarshes lie in areas where massive enclosure has occurred. The fact that this prevents landward migration as sea levels rise (Section 3.5.2) further exacerbates the likelihood of erosion.

Predictions of sea-level rise derived from models prepared by the Hadley Centre in the UK, suggest that a rise of some 3.8 mm per annum is possible between 1990 and the 2080s. This could include significant wetland losses (saltmarsh, mangroves and intertidal areas) of up to 22%, which when added to the anthropogenic losses due to enclosure, could amount to as much as 70% in some places. These losses will influence many sectors and values, including food production (such as loss of nursery areas important for fisheries), flood and storm protection (storm surges will cause flooding further inland), waste treatment and nutrient cycling functions, and as habitat for wildlife. An accelerated sea-level rise could significantly worsen the already poor prognosis for coastal wetlands (Nicholls et al. 1999; Nicholls & Hoozemans 2005). Given this scenario, it seems saltmarsh restoration will become even more significant in the years ahead.

10.3 Saltmarshes and Saltmarsh Restoration

Chapter 4 provides a description of the values associated with saltmarshes, amongst which their coastal defence function is highly significant. The nature of the vegetation can influence the stability of the saltmarsh. However, other factors such as sediment availability, exposure to waves and extent of enclosure may be more significant. Preventing erosion is an accepted, practical way of helping to sustain most of their principal values. This may even extend to promoting accretion onto tidal flats. However, the experience from exporting and planting *Spartina* spp. suggests that inappropriate promotion of accreting saltmarsh can cause problems as detailed in Chapter 9. This, together with the arguments associated with combating 'saltmarsh squeeze' (Section 3.5.2.), provide some of the reasons for undertaking coastal realignment (Chapter 6). Using examples from different parts of the world, Section 10.4 describes how re-creating saltmarshes helps improve sea defence in a cost-effective way, as well as improving landscape and nature conservation values. The key areas considered here are:

- Southern North Sea;
- Mediterranean;
- North America.

10.4 Southern North Sea

Saltmarshes are extensive around the shores of the southern North Sea particularly in the estuaries of south-east England, the Delta and the Wadden Sea (Figure 5). Losses due to human enclosure are considerable (Section 2.4). This has led to 'saltmarsh squeeze' a combination of loss of habitat through enclosure coupled with erosion due to sea-level rise and increased storminess (Section 3.5.2). The losses observed in south-east England led to the promotion of managed realignment as a cost-effective solution to the twin problems of biodiversity loss and the needs of flood management (Morris et al. 2004). The resulting attempts to restore former enclosed tidal saltmarsh by managed realignment and other restoration techniques have developed apace.

Since 1991, in south-east England there have been 11 examples of complete or partial removal of a seawall allowing the tide to reinvade the land. At a further 4 sites there is some form of regulation of the tidal regime using sluices or one-way valves inserted in the embankment to allow control of tidal levels. From the first experimental managed realignment in the Blackwater Estuary to combat erosion (Section 3.5.1), to the scheme at Freiston, which links flood protection with nature conservation (Section 3.5.3) and in the Humber Estuary (Winn et al. 2003) the schemes have grown progressively larger. The Northey Island experiment amounted to only 0.8 ha whereas on the Humber Estuary, the Alkborough scheme completed in 2004 was 400 ha and a further 1,000 ha is planned later (Wolters et al. 2005). Due to the sinking of the land and the rise in sea level, pressure will continue on the sea defences throughout the area. The response will determine the extent to which wildlife values or human uses prevail.

10.4.1 Will it All Come Out in the Wash?

Chapter 3 provides a view of the evolution of thinking on the values associated with saltmarshes. This view rests on an historical appreciation of the functioning of saltmarshes in relation to the natural forcing factors of time, tides and sea-level change. It also provides information on the way human intervention has claimed large areas of land from the sea, causing a 'coastal squeeze'. Looking back at the evolution of the area provides a picture of a once extensive coastal margin, which moved landward or seaward depending on the rate and direction of change in sea level.

Up to about 4,400 years ago, the Fenland Basin was flooded and showed a wholesale landward movement of the sea. During this period, sediment began to fill up the basin, which eventually led to a reversal of the direction of movement such that the shoreline (saltmarsh and tidal flats) began to move seawards again approximately 4,000 years ago. Localised at first, the movement became more widespread until about 3,000 years ago, when it changed once again and became one of a landward transgression by the sea. A reduction in suitable sediment appears to have caused this change in direction (Brew & Williams 2002). The seaward progression of the land, from about 2,000 years ago to the present, is probably as much to do with human activities associated with saltmarsh enclosure (Section 2.3.1) as with natural processes.

The recognition that continued enclosure would result in a loss of intertidal land, coupled with changing economic circumstances, led to the cessation of land claim (Section 3.5). It seems likely that with sea levels rising because of global warming, the next phase in the 'natural' cycle would be a landward progression of the sea. This will inevitably put pressure on the sea defences erected over several centuries. Many of the defences were earth banks, with a crest height insufficient to accommodate the predicted rise in sea level.

The response in past decades was to strengthen these defences by building sea walls that were higher and wider (Figure 69).

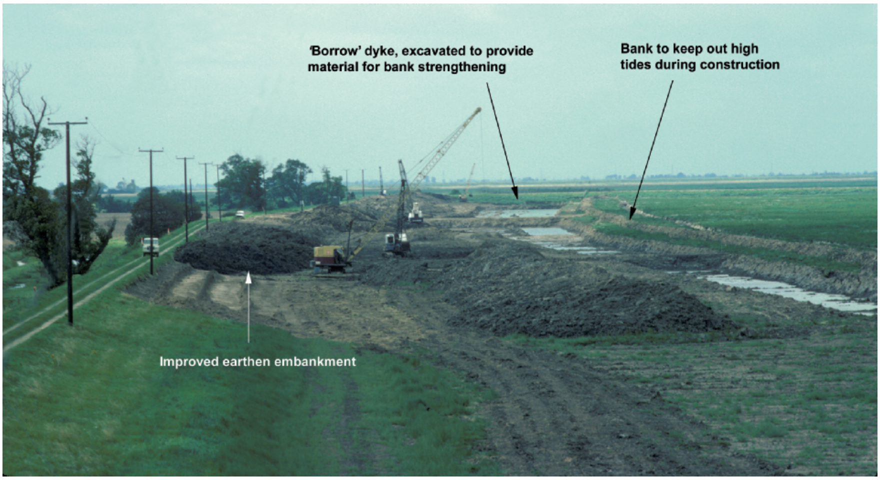

Figure 69 Raising the Wash banks in September 1980. Part of the last major rebuilding programme involving excavating mature saltmarsh to provide material for the 'improved' sea bank

Since this programme of repair, no further enclosures have taken place and in a few places, there has been a reversal of the process. It is ironic that the last enclosure on the Wash in 1985 at Freiston, should be the first managed realignment, designed to take account of the risk of flooding and to improve the nature conservation aspects of the site (Section 3.5.3). It is unclear as to the extent of further realignments around the seaward margins of the Fenland Basin. However, given that most of the land is below the normal High Water Mark of Spring Tides, with some areas below mean sea level (Figure 70), the threat from sea-level rise is considerable. The prognosis under various global warming predictions into the 2050s and beyond, suggests inundation of considerable areas of East Anglia, because of coastal and river flooding (Nicholls & Wilson 2001). A storm surge such as occurred in 1953, given the higher tide levels, has the potential to have even greater impact, despite the improved sea defences.

Within the former peatlands around the inland edge of the fen, a 'Great Fen Project' (see http://www.greatfen.org.uk/) is unfolding. Here, the local Wildlife Trust and others are promoting the extension of wetlands around two existing nature reserves, in an attempt to re-create a self-sustaining reserve through the reclamation of arable farmland. This project is the largest and most ambitious of a number of wetland restoration schemes taking place around the landward margins of the Fenland Basin.

It is unlikely that this initiative will link up with the existing and proposed managed realignments on the current coastal margin of the Wash, because of the high quality agricultural land and the number of settlements that lie in between. The continued protection of the land from flooding by the sea will remain a priority. However, if some of the extreme predictions of global warming and the associated rise in sea level are realised, then protecting this land will become more and more

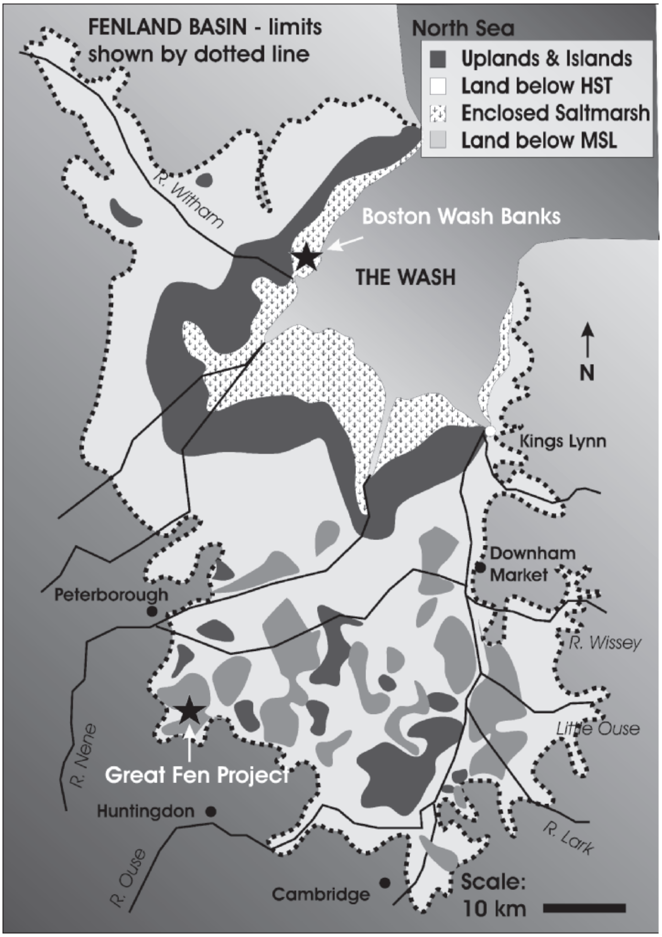

Figure 70 Land in the Fenland basin, sea levels and two of the restoration sites. [MSL, Mean Sea Level; HST, level of normal High Spring Tides]

difficult and costly. Projecting into the future, we may yet see extensive areas of farmland, currently lying below mean sea level, with their attendant wildlife, stretching from the former landward extremities of tidal influence, to the sea.

10.4.2 Realignment in Belgium

In the Yzer River mouth, Belgium attempts to restore intertidal land met with some success. During the twentieth century on the eastern bank of the river, building a military harbour, together with dumping of dredged material from the harbour,

Figure 71 Developing saltmarsh on mudflats where a naval base once stood, within the Yzer-rivermouth restoration, Belgium coast, 2005

resulted in the destruction of all the saltmarshes and sand dunes in the area. A plan to restore this site, drawn up in 1996 and put into practice from 1999 onwards, formed part of an 'Integrated Coastal Conservation Initiative', funded under A LIFE Nature project (LIFE96 NAT/B/003032). The works involved removing the military buildings and harbour and the removal of the 'protecting' sea walls, a form of managed realignment (Deboeuf & Herrier 2002). This phase of the work was only partially successful in recreating saltmarsh, as the absence of any protection (the sea walls were removed) resulted in erosion of the tidal flats within the site. The final phase of the work involved excavating the dredged material, leaving some of the walls in situ to provide protection for the developing tidal flats. The resulting habitats included the development of pioneer *Salicornia* spp. and *Suaeda maritima*, after only one year (Herrier et al. 2005; Figure 71).

10.4.3 The Wadden Sea

In the Dutch Wadden Sea, the main consideration is habitat creation for the enhancement of nature conservation and landscape values. There have been four deliberate breaches of sea walls ranging between 23 ha on the island of Terschelling to 135 ha in Friesland, as well as two examples where regulated tidal exchange has been used (Wolters et al. 2005). There appears to be little information on managed realignment schemes in the Danish part of the Wadden Sea. Stricter planning controls within the coastal zone, coupled with a more or less stable relative sea level make the problems of flooding and erosion less politically sensitive (Anon 2002).

In Germany, there are two managed realignment sites in the southern North Sea, both in the Wadden Sea; these involve an 80 ha breach in 1994 and a further 280 ha in 1995 both using regulated tidal exchange. Further breaches are planned (Wolters et al. 2005). Also in the German Wadden Sea, embankment of 3,342 ha of Nordstrand Bay (within the Schleswig-Holstein Wadden Sea) took place in 1987 to reduce coastal erosion and shorten the sea defences. The new polder (Beltringharder Koog) included a salt-water lagoon of 846 ha, designed to help compensate for the substantial loss of tidal flats and saltmarshes, within an important wildlife area. For the first few years, there was no tidal inundation and the saltmarsh vegetation soon gave way to grasses such as Rough Meadow-grass (*Poa trivialis*) and Yorkshire-fog (*Holcus lanatus*), not tolerant of sea water (Wolfram et al. 1998).

From 1990, two sluices linked the lagoon to the sea. In 1994, an improvement to the sluices allowed control of flows during natural tidal cycles of the Wadden Sea. This resulted in a tenfold reduction in the tidal range when compared with the outside (0.2–0.4 m tides), which reduced scour near the sluices and did not cover the higher levels within the lagoon. To achieve this, opening the sluices about twice a month to simulate storm-flood conditions, raised the levels to 0.8 m. Studies of the vegetation succession revealed that after 10 years, the semi-natural tidal regime in the lagoon did create saltmarsh vegetation, which became a refuge for rare halophytes (Wolfram et al. 1998). However, it did not compensate for the loss of former Wadden Sea habitats, in particular for wintering waterfowl, although it provided an important roosting area for birds during high tides (Hötker 1997).

10.5 Restoration in North America

From the time of the early settlers during the 1700s, wetlands were disease-ridden swampy lands of little use to frontier survival. The Federal Government encouraged land drainage and wetland destruction through a variety of legislative and policy instruments. By the 1960s, most political, financial, and institutional incentives to drain or destroy wetlands were in place. However, since the 1970s increasing awareness that wetlands are valuable areas has helped to reverse Federal and State policies (Dahl & Allord 1997). The 1972 Coastal Zone Management Act and the 1982 Coastal Barriers Resources Act provided for the protection of coastal wetlands. The ‘Restore America’s Estuaries’ campaign (see http://www.estuaries.org/) goes further by setting the framework for restoration of wetlands, including saltmarshes. As the leader in national efforts to protect and conserve the nation’s estuaries, it is working to ‘restore 1 million acres of estuarine habitat by the year 2010’. In the face of global warming and the associated sea-level rise, this may be a much too cautious approach. Titus (1991) suggests that the USA could afford to lose an ‘area the size of Massachusetts’ as part of an effort to cope with sea-level rise.

10.5.1 The State of Louisiana and the Mississippi Delta

The growth of the Mississippi Delta results from periods of major sediment transport to the system, occurring over several thousand years. In the last few decades, there has been a reversal of this wetland expansion because of human activity. This amongst other things has greatly reduced the input of sediment (Day et al. 1995), such that today regional subsidence in the Delta is about 10 mm per year. As a result, the State of Louisiana has lost up to 40 square miles of marsh a year for several decades, representing approximately 80% of the nation's annual coastal wetland loss. At this rate, by the year 2040, an additional 800,000 acres of wetlands could disappear with the Louisiana shoreline advancing inland by as much as 33 miles in some areas.

These rates of loss prompted Congress to pass the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) in 1990, which provides funds for planning and implementing projects. It aims to acquire, restore, manage, or enhance coastal wetlands to help restore the efficiency with which the shoreline adjusts to wave and tidal energy, aiding coastal defence and flood alleviation. In this context, there is recognition that saltmarshes, as part of the coastal wetlands habitat, help provide a coastal protection function.

Approximately $50 million is spent annually on the restoration projects. The official Coastal Protection and Restoration Authority (CPRA) web site (see http://lacoast.gov/) lists 159 projects throughout the State of Louisiana. Between 1991 and 2006, there were 78 projects completed, in the course of construction or approved. Of these, techniques helping to restore saltmarshes include vegetation planting, hydrological restoration and marsh creation. A summary report provides information on the past, present and future status of the Task Force (Louisiana Coastal Wetlands Conservation and Restoration Task Force 2006).

In the wake of Hurricane Katrina (2005), Congress directed the Corps of Engineers, New Orleans District, together with the State of Louisiana, to develop the 'Louisiana Coastal Protection and Restoration (LACPR) Project'. The project has to 'identify, describe and propose a full range of flood control, coastal restoration and hurricane protection measures for South Louisiana'. It is a sign of these more enlightened times that the value of Louisiana's coastal wetlands, including their saltmarshes are in the front line of defence. To quote from the report, 'The people of coastal Louisiana are engaged in a battle against the encroaching Gulf of Mexico. A tenet of efforts to restore and sustain coastal ecosystems dictates that *risk reduction measures not destroy these resources*. As such, plans to restore coastal features as natural lines of defence are an integral part of an overall storm risk reduction and survival plan for Louisiana' (US Army Corps of Engineers 2006).

The events in New Orleans caused by Hurricane Katrina, have also given strength to the consideration of other major projects, one of which involves restoring Louisiana's vanishing wetlands by deconstructing the levee system that controls the Mississippi River. 'Time to move the Mississippi', said a group of experts in coastal management at a meeting in April 2006 reports Cornelia

Dean of the New York Times. Discussion centres on instigating a major river diversion, below New Orleans, that would allow the silt-laden river to flood large areas of the state's sediment-starved marshes. Get more information from the campaign web site to save coastal Louisiana, 'Restore America's Wetland' (see http://americaswetland.com/).

10.5.2 San Francisco Bay

The San Francisco Estuary Project (see http://sfep.abag.ca.gov/) is one of more than 20 National Estuary Programme projects. It includes a specific wetlands restoration programme for the San Francisco Bay area (see http://www.sfwetlands.ca.gov/). The history of restoration has moved from a few small scale areas in the 1960s to the thousands of ha envisaged today (San Francisco Estuary Project 2005). The South Bay Salt Pond Restoration Project, for example, includes the restoration of commercial salt production areas in the north of the Bay, which has expanded to over 6,000 ha in the south. Reopening many of the evaporation ponds to tidal influence will facilitate this change. The remaining ponds will have their water levels managed for the benefit of wildlife.

In the San Joaquin-Sacramento River Delta, much of the area was enclosed and drained for agriculture in the late 1800s and early 1900s. Restoration includes setting back levees from the river and restoring tidal influence to the lower, western sections of the delta (San Francisco Estuary Project 2000).

10.5.3 Restoration in Canada

Enclosure and drainage for conversion to agriculture, since European settlement began, has destroyed 65% of saltmarshes in the upper Bay of Fundy, Canada. Other activities that exclude the tide resulted in further losses. Attempts to restore these lost areas follow some of the methods used in north-west Europe. Thus, breaching sea walls, reintroducing tidal flows, or simply enlarging culverts and plugging drainage ditches occur. Details of these approaches and projects can be found on 'Environment Canada' web site (see http://www.atl.ec.gc.ca/wildlife/salt_marsh/toc_e.html), which is specifically devoted to saltmarsh conservation and restoration.

10.6 The Wider Role – Management and Restoration

The book shows how it is possible to change the direction of development in saltmarshes in such a way as to alter the states and values of the habitat. Justifying intervention on nature reserves, by way of grazing management is relatively easy, although there may be a debate as to the level of intervention and the precise regime appropriate to a given site (Chapter 8). Suggesting that further enclosure, development or other forms of habitat loss should cease is less easy. However, the examples of saltmarsh restoration described above show an increasing acceptance in some places that saltmarshes, either in their own right or as part of a wider coastal wetland, are valuable assets. Despite this, there is reluctance in many areas to adopt anything other than small-scale 'experimental' projects.

10.6.1 Approaches to Restoration in the Wadden Sea, the Netherlands and Germany

The situation in the Wadden Sea provides a general overview of the problems associated with allowing the sea to 'reclaim' extensive areas of former tidal land. The whole of the area is of high nature conservation value and has important fishery, recreational and other economic values. The three countries concerned with the area, namely The Netherlands, Denmark and Germany, have been working together since 1978 to protect and conserve the area (see the Wadden Sea web site http://www.waddensea-secretariat.org/). With most of the tidal land under various nature conservation designations, long-term sustainability of the socio-economic and conservation integrity of the area, as well as securing the protection of the hinterland from flooding by the sea are primary objectives (Stade Declaration 1998).

So far, there is acceptance that reducing grazing pressure and drainage on saltmarshes is important for nature conservation purposes. This change also recognises the landscape and cultural value of saltmarsh. Although the primary aim is to maintain the habitat, it also contributes to sea defence.

In Lower Saxony, Germany, the maintenance of 'summerdikes', formerly important in allowing extended agricultural use of saltmarsh (for grazing), is now weighed against their value for nature conservation or sea defence (Ahlhorn & Kunz 2002). Where possible the overall aim is to maintain and extend saltmarsh and enhance their natural development (Bakker et al. 2005). However, this may not be enough. The rigid line of sea walls prevents the dynamic development of intertidal habitats, including saltmarshes, such that there is a diminution in the ability of the Wadden Sea to accommodate a rise in sea level, increased storminess and tidal surges. Thus, in addition to the restoration of 'natural' saltmarshes and other forms of 'soft' sea defences, future prospects may require approaches that are more radical. These could include moving structures such as harbours offshore, raising houses above high-tide levels, or creating areas for floodwater storage (Reise 2005).

In both the Netherlands and Germany (Niedersachsen) some limited realignment has taken place for nature conservation purposes (see above). These include approximately 120 ha from the naturally breached Peazemerlannen polder in the Wadden Sea (Bakker et al. 2002). However, Schleswig-Holstein, Germany includes coastal flood-prone lowlands, assets at risk and over a third of a million people. There is also a long history of coastal defence and good quality sea walls, making abandoning any of these areas, through re-integration with the sea a difficult choice. Whilst there is recognition that saltmarsh forms part of the sea defence along the coast and has nature conservation values, the recently adopted ‘coastal defence master plan’ specifically says:

> “The relocation or abandonment of sea walls remain exceptions (Hofstede 2004).”

10.6.2 Depoldering, the Delta Region of the Netherlands

In order to ensure the accessibility of the harbour of Antwerp (Belgium), through the Westerschelde estuary (the Netherlands), the shipping channel is regularly maintained and has been deepened over the last 50 years in order to allow bigger ships to pass through it. This has resulted in coastal erosion on both sides of the estuary with a loss of tidal sand and mud flats and saltmarshes. (These habitats form part of a Special Protection Area, designated under the European Union Birds Directive). Under the terms of the Habitats and Species Directive, the Dutch Ministry of Transport, Public Works and Water Management proposed compensation for this loss through a strategy of managed realignment in 1998. The works proposed included cutting dykes into several polders (themselves derived from former tidal land) allowing them to become tidal again.

Fearing that a repeat of the 1953 floods, killing many people and thousands of cattle might occur, local people resisted the proposal. In 2000, the local authorities rejected the ‘depoldering’ plan. The government withdrew the proposal soon after. It is clear that in the Netherlands the extent of flooding and loss of life in 1953 remains a powerful force, which militates against allowing the deliberate breaching of existing sea defences in the Delta Region. Several other breaches proposed for the Westerschelde in 1995 were not been carried out (Wolters et al. 2005). By contrast, an unplanned breach in a brackish part of the Scheldt estuary occurred during a severe storm in 1990, returning tidal influence to about 100 ha of the Sieperda polder. There was no attempt to repair the breach and in 10 years, the former polder changed into a brackish tidal marsh with a wide range of typical plants and animals (Eertman et al. 2002).

10.6.3 The Situation in the UK, Winning Hearts and Minds

The identification of ‘Coastal Cells’ provides the basis for defining the boundaries of management units (Figure 72). These represent a series of interlinked systems where sediment movement by waves and currents defines sediment transport cells. The cells and subcells identified for England and Wales and Scotland comprise an arrangement of:

- Sediment sources (e.g. eroding cliffs, river, sea bed);
- Areas where sediment is moved by coastal processes;
- Sediment stores or sinks (e.g. beaches, estuaries and offshore banks).

Figure 72 Shoreline management units for the coast of Great Britain

The Government has promoted the formation of voluntary coastal defence groups around these coastal cells, made up of maritime district authorities and other bodies with coastal defence responsibilities. Shoreline Management Plans help provide, at a large-scale, an assessment of the risks associated with changes in the coastal environment. They aim to reduce the risks to socio-economic infrastructure, as well as the historic and natural environment, from flooding and coastal erosion.

Amongst the policy options is managed realignment, already described. Schemes such as Freiston (Section 3.5.3; Figure 24) and Alkborough (Section 6.4.2; Figure 52) in particular, bring together flood alleviation, with other environmental benefits. Amongst these benefits is the re-creation of saltmarsh. Detailed information on the development of these policies is available on the UK Department of Environment, Food and Rural Affairs (2001); see web site (http://www.defra.gov.uk/environ/fcd/policy/smp.htm).

Even in the UK where there are now 59 managed realignment schemes (Wolters et al. 2005) only three are over 100 ha in extent. Each proposed scheme requires a detailed (and expensive) feasibility study and includes extensive local consultation amongst stakeholders. The Alkborough project in the Humber Estuary, in particular, provides an example of this inclusive approach. The review of shoreline management in the Humber Estuary, in 2001 included proposals to realign an area at Alkborough.

'Selling' the proposal involved extensive consultation with local stakeholders about the project's aims and objectives. Specifically it should offer:

1. A sustainable solution;
2. Reduce flood risk;
3. Create new wildlife habitats;
4. Develop new economic opportunities;
5. Provide new recreational opportunities.

The arguments included the effects of climate change, which would increase high-tide levels in the Humber Estuary. As a result, leaving the defences as they are would put the homes of 300,000 people living in the area at risk from flooding. Overall, the scheme also provided significant environmental enhancement, including restoring part of the functioning of the estuary. The key to its successful completion lay partly in providing greater certainty about the sustainability of nature conservation, economic and recreational opportunities in the face of rising sea levels. The extensive consultation was instrumental in gaining acceptance of a scheme that appeared to involve the loss of 440 ha of prime agricultural land.

This enabled the Government Minister (Elliot Morley) in 2005 to claim that the UK had taken 'a new direction in flood risk management'. 'Alkborough is a fine example of a sustainable approach to reducing flood risk by working with the forces of nature. Such long-term solutions are essential if we are to protect the lives and homes of people who live and work in the area, as well as the many businesses that are based around the estuary.'

Finally launched in September 2006, the scheme cost £10.2 million. The money came from a range of governmental organisations and the sources included the Department of Environment, Food and Rural Affairs, the Regional Development Agency, English Nature, the Heritage Lottery Fund and the European Union (via the Interreg programme). The scheme will re-create an intertidal area with saltmarsh and mudflats, providing a focus for education and access for local communities.

10.6.4 The Mediterranean, Sediments and Deltas

In the Mediterranean, recognition of the issues surrounding global warming and sea-level rise does not appear to be a major concern. However, a Global Vulnerability Analysis suggests that the Mediterranean coast is generally more prone to sea-level rise than many other parts of the world, both in relation to economic and environmental costs (Nichols & Hoozemans 2005). The larger saltmarshes occur in the Po Delta and the Venice lagoon, Italy, the Ebro Delta, Spain, the Rhône Delta (Camargue), southern France and the in the Axios Rivers, Greece. A combination of factors including deltaic subsidence, reduced sediment supply (through river damming) and enclosure of tidal areas, including saltmarshes, contribute to the high rates of relative sea-level rise occurring in these areas. The extent of loss due to human intervention, the inability of the habitats to accrete in this microtidal sea and the restriction on landward movement due to artificial defences, prevent them keeping pace with sea-level rise. Most of the deltas have rates of relative sea-level rise, which could reach 10 mm per year over the next century. These are comparable to those experienced in the Mississippi Delta (Day et al. 1995). Some individual examples highlight the issues.

10.6.5 The Ebro Delta

The Ebro Delta saltmarshes include transitional reedbeds (*Phragmites australis*) and a *Salicornia* community (*Arthrocnemum fruticosum*). As elsewhere these and other tidal habitats have been enclosed and developed, in this case mainly for rice production (57% of the total area). Damming the Ebro River has resulted in reduction in river flows and a major reduction in the sediment supply (Ibàñez et al. 1996). With an average rate of relative sea-level rise of 3 mm per year it is only in the wetlands around the river mouth that accretion rates (4 mm per year) exceed this figure. As a result, there is wetland loss, coastal erosion and saltwater intrusion. The reversal of these trends is essential if the wetland habitats and rice cultivation areas can grow vertically and keep pace with the relative sea-level rise. The solution to this lies in reinstating the flow of sediments from eroded land in the hinterland, through the river dams where it is currently trapped (Ibàñez et al. 1997).

A review of the conservation issues as they affect the area took place in September 2000 (Viñals et al. 2001). Amongst the many problems identified was the lack of sediment delivery (95% reduction) mainly due to the river dams. The resulting erosion and saline intrusion threatened many aspects of the wildlife of the area. The Spanish National Hydrological Plan would further exacerbate these problems if, following approval by Congress in 2001, they were to be implemented. This plan was an attempt by the Spanish Government to assure constant water supply all over Spain. In the Ebro Delta, the proposal involved the transfer of the ‘surplus flow’ in the Ebro watershed to other, southern river basins.

The issue was highly contentious. The Worldwide Fund for Nature (WWF) and others campaigned against what they saw as an ‘immensely dangerous project’. The Spanish government announced an alternative plan in June 2004 to replace the Ebro Transfer project, although it is not clear if this is the end of the threat. The RiverNet web site provides a comprehensive description of the scheme and the outcome of the opposition (see http://www.rivernet.org/Iberian/planhydro.htm). Although it appears that this last threat is no longer extant, the site will continue to suffer from the effects of relative sea-level rise. Its long-term sustainability both for wildlife (including the saltmarshes) and rice cultivation depends on the reinstatement of the sediment flows to the Delta.

10.6.6 The Venice Lagoon

In the Venice lagoon, where sea-level rise is 2.5 mm per year, saltmarshes in the central area erode due to sea-level rise, and although vertical accretion takes place, this is at the expense of sediment derived from the eroding saltmarsh edge (Day et al. 1998). Climate change and sea-level rise are likely to lead to the complete disappearance of these saltmarshes over the next 30–50 years, if natural and artificial adaptive responses are not implemented (Brochier & Ramieri 2001).

A plan for the restoration of the lagoon by the Consorzio Venezia Nuova (CVN) includes reinstatement of sediments lost to the system. Accompanying this is the construction or repair of physical structures as well as natural features such as channels, shallows, saltmarshes and mudflats. The plan to reverse the environmental deterioration also aims to improve sediment and water quality. Today an extensive and ambitious series of restoration measures are underway. These include ‘Environmental defence: protection and reconstruction of mudflats and saltmarshes habitat and structure’. Methods include the use of dredged material to aid the restoration of saltmarsh and mudflats. For more information, see (http://www.salve.it/uk/default.htm). During the process of restoration the discovery of a fourteenth century galley sunken in a previous attempt at coastal protection (Merali 2002), suggests that the problems of erosion and flooding are not new. It is interesting to speculate what future historians will make of the sunken Thames Barges off the Essex coast (Section 6.2.6; Figure 47)!

10.7 The Future

It appears that the case for saltmarsh restoration, as part of wider wetland re-creation and creation, is accepted policy in many parts of the world. Saltmarshes are important components of protected areas and nature reserves. They are no longer looked at just for their value in the creation of agricultural land or ‘wastelands’ fit only for dumping rubbish or enclosure for industrial and housing development. Rather their values are much more wide ranging. They are important nature conservation habitats both in their own right and as components of interrelated coastal ecosystems. They help provide protection from coastal flooding and erosion. They add to the overall landscape and recreational experience.

Whether the trend towards abandonment of land to the sea becomes more widely accepted as an effective means of sea defence, especially in areas of rising sea level, is unclear. The evidence from around the world, not least in the Mississippi Delta, suggests there is an increasing realisation, if current trends continue some

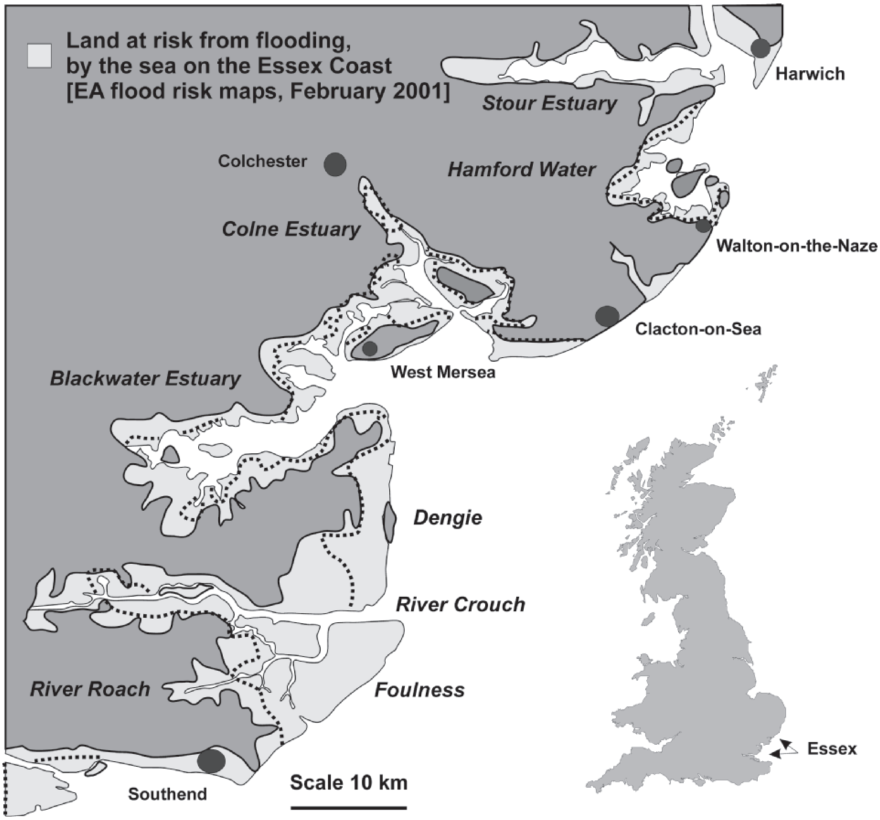

Figure 73 Coastal Essex, Great Britain. Land at risk from flooding by the sea, Environment Agency Flood Risk Maps (shown in light grey) in relation to the area flooded during the 1953 storm surge, which took place in January/February. The dotted line shows the approximate limit of flooding in 1953, derived from a map in Grieve (1959)

areas will be lost or rendered uninhabitable. It is almost certainly better to plan for this by strategic retreat, than continue the battle with the sea! Many of the realignment schemes in the UK are concentrated in south-east England. The area of land lying on the coast of Essex that has the potential for flooding when another storm surge such as 1953 occurs, could be viewed as land of potential value for restoring saltmarshes (Figure 73).

10.7.1 A European Initiative

At a European level under the European Union Community Initiative Programme Interreg IIIB for the North Sea, includes a project which aims to create multifunctional flood management schemes with a more gradual transition from sea to land. The project 'ComCoast' runs from April 2004 to December 2007 at a cost of €5.8 million. It embodies some of the principles already incorporated into the realignment schemes such as Alkborough and Freiston. It focuses on embanked coastal areas and aims to provide 'economic, sustainable alternatives to the traditional single line flood defence'. Further information on the project is available from the web site (see http://www.comcoast.org/).

If this is the adopted course of action, there are fundamental questions for coastal defence authorities as well as nature conservation organisations. Not least of these, is the way in which trade-offs will need to be made. For the coastal defence authorities land will not always be sacrosanct! It is unlikely we will reach the 'Water-world' depicted in the film by Kevin Costner. However, given the area of agricultural and other land potentially at risk from flooding in low-lying areas, it is inevitable that re-integration with the sea will take place over larger areas, in order to secure cost-effective sea defences.

10.7.2 A Historical Perspective

The history of human involvement on the coast has moved from one where living **by** the sea meant living **with** the sea. The earlier settlers found the coastal margins, particularly those of coastal embayments, some of the richest areas to find food and shelter. During the early stages of the Holocene, when sea levels were much lower than today there is evidence of many settlements below the present low water mark. In Denmark, for example, there is a well-preserved settlement of Mesolithic age at the Tybrind Vig site. The site is 300 metres from the shore and 3 metres below the surface, and includes well-preserved artefacts from the Ertebølle Culture (Malm 1995). In the Mediterranean, there are Neolithic remains between 0.5–5 m below present day sea level dating from 7,100–6,300 years ago. Other remains dating back to 8,180–7,550 years ago occur at Atlit-Yam, situated some 200–400 m from the coast of Israel, at a depth of 8–12 m (Information from the Israel Antiquities Authority web site, see http://www.antiquities.org.il/home_eng.asp). Settlements were, however, at the mercy of the sea-level change, tides and storms. These and many other sites, along with the forests that occurred there have long since been overwhelmed by rising seas.

As sea levels began to stabilise around 7,000 years ago, coastal human settlements grew. Coastal habitats, especially saltmarshes, provided pasture and hay for domestic animals, in Europe probably before Roman Times. In heavily wooded areas, such as the early settlements in America, the value of this crop as fuel for horses may have been particularly significant. As engineering techniques became more sophisticated and machinery more powerful, the ability to alter the coastal margin and 'control' the sea became easier. This not only led to the expansion of agriculture at the expense of saltmarshes, but also to the enclosure of tidal lands for ports, harbours, industrial, other infrastructure and housing development (Chapter 2). Until the middle of the twentieth century, the implications of these losses for the environment were secondary to the economic benefit that accrued.

10.7.3 A New Perspective on Saltmarsh Conservation?

Even in the early 1990s notions that we should (or could) give up land to the sea were an anathema to many. In the field of engineering, for example, the River Engineering Section of the United Kingdom Institution of Water and Environmental Management (IWEM) on 1 February 1991 politely received a review of the relationship between sea defence and nature conservation. The presentation argued that we may have "devoted too much effort to the 'battle with the sea' ". and that adopting a more flexible approach to coastal defence 'might provide opportunities for positive nature conservation action and more cost effective sea defences.' Compliance with a request for the author to submit the paper to the IWEM Journal resulted in its rejection.

The editorial panel in assessing the paper 'agreed that (it) puts forward a fresh and interesting idea, but did not convince them that we could safely leave coastal protection to natural processes, except in a few fallible situations'. In fact, the author suggested a policy involving developing a strategy where the allocation of resources was to "areas where the needs of sea defence and coast protection were paramount, provides opportunities for 'soft' engineering and increases the size of the zone in which the natural sea defences can operate" (Doody 1992).

Advocating this more flexible approach, and with it a recognition of the role of natural habitats in coastal defence, is not new. In this context, it is instructive to read part of the final report of the UK Royal Commission on Coastal Erosion, 1911:

> "The rate of erosion varies with the geological formation of the coast, but is most marked along the east and south coasts of England. On the other hand there have been considerable gains, particularly in the mouth of the Humber and the Wash. Natural protection is afforded to the coast by the foreshore and beach material produced by erosion and it is essential that such material should not be removed. In some places erosion has been aggravated by the erection of defences of the wrong type. The Central Authority, aided by scientific experts, should make systematic observations of coastal changes. In late years the gains had generally outweighed losses, but this took no account of the value of the property, especially as many accretions were below high-water level. There had been some serious losses calling for effective measures of prevention. The cost of protecting purely agricultural land will usually exceed the value of the land and such works should be undertaken only when they preserve a considerable area of low-lying land."

Chapter 3 suggests that in the short space of 30 years, a reversal of the notion that we could continue to 'win' land from the sea with few environmental consequences, has taken place. Initially, the drive towards this in the UK was the recognition of nature conservation losses, including those of saltmarsh. Over 1,000 ha of saltmarsh (one quarter of the resource) suffered erosion on the Essex coast between 1973 and 1998 (Cooper et al. 2001). This was in addition to the approximately 3,000 ha lost to enclosure in historical times. Other calculations suggest that sea-level rise will result in the further loss of 8,000–10,000 ha of mudflats and hence potential areas for saltmarsh development, in Britain between 1992 and 2012 (Pye & French 1993). These actual and predicted losses are unacceptable.

Against this background, maintaining the existing resource in the UK, or elsewhere in the world is not enough. This derives not only because of the implications for nature conservation but also for its many other values. Not least amongst these, are those associated with sea defence and the functioning of the tidal ecosystem. The reversal in policy, which allows breaching of the existing sea walls, represents a major change in the approach to sea defence. Amongst the reasons for this change in attitude are the following, realignment sites:

1. Provide sustainable and effective flood and coastal defence;
2. Are essential for a long term strategy of coping with sea-level rise;
3. Provide environmental benefits in terms of habitat creation;
4. Support the Habitats Regulations (by providing a means of compensating for intertidal habitats lost elsewhere through coastal squeeze);
5. Reduce costs of flood and coastal defence;
6. Are better than dealing with an accidental breach;
7. Are a low cost means of re-creating natural habitats (Anon 2002).

In this wider context, by adopting a more flexible approach to habitat and species protection, it is possible to see new and more innovative solutions to the conservation of saltmarshes and coastal systems more generally. These build on:

1. A better understanding of the geomorphology of the coast and the role of saltmarshes in the functioning of the estuary and the relationship with the catchment **and** near shore marine environment;
2. Recognition of the value of saltmarsh, not just for wildlife but also for other environmental and socio-economic interests;
3. An acceptance that change is a natural part of the saltmarsh development, particularly in response to changes in sea level;
4. Restoration of saltmarshes, which not only re-creates inherent values, but also helps heal degraded coastal systems.

This book has attempted to identify the common ground between those concerned with nature conservation and other forms of coastal use in relation to managing saltmarshes. From both perspectives, it would appear that protecting saltmarshes in the traditional sense is, in many areas, ultimately doomed to failure. With the existing rise in sea level, even with the curtailment of destructive land-based uses, they will continue to be lost. However, accepting that the natural ability of the coastline and coastal habitats to adapt to change should be encouraged is not easy.

Innate prejudices and fears about the local impact on lives and property militate against allowing the sea to invade the land, either through neglect or as a deliberate policy. From a nature conservation perspective, the approach is no less easy to accept especially when it involves the sacrifice of one treasured habitat, such as coastal grazing marsh, for another.

10.8 What Does the Future Hold?

Saltmarshes will continue to form a link between the land and the sea and a self-regulating coastal defence. However, as sea-level rises and sediment deficits continue, a question arises as to their long-term viability. As already indicated the prognosis is not good (Nicholls et al. 1999; Nicholls & Hoozemans 2005). Saltmarshes are amongst the first habitats affected by rising sea levels due to global warming. We appear to have two choices:

1. Continue to believe that we can 'hold back the sea' in most instances and build bigger and 'better' sea defences. This will inevitably result in continuing saltmarsh losses as 'coastal squeeze' takes place;
2. Recognise that saltmarshes play an important and valuable role in many aspects of human activity. Making space for them to do what comes naturally, and move in response to changing environmental conditions, may yet help to deliver sustainable economic, social and environment benefits.

In the face of global warming, there is a move to increase the use of renewable forms of energy generation, including tidal energy. However, these are not benign and saltmarshes are likely to be one of the more affected habitats (Clark 2006). This poses a final dilemma for the saltmarsh specialist, can we accept the loss of this fascinating habitat for the greater good of the world. The answer is an emphatic **no!** Saltmarshes form an integral and significant part of the general development and flexibility of our coastal ecosystems. Without them, the coast would be aesthetically poorer as well as lacking many of the ecosystem service values they support. It is in all our interests to continue to protect and manage them and where necessary restore and re-create them.