Essex Estuaries

Coastal Habitat Management Plan

Executive Summary

October 2002

1 INTRODUCTION

The coastline is a dynamic environment, where habitats and species, if allowed to function naturally, are able to respond to changes in physical processes (e.g. the balance between sediment provision and coastal form). Man's activities, particularly through the construction of coastal defence systems (flood defence and coastal protection) may interfere with and modify physical processes and, hence, the ability of habitats to respond to external change.

The Essex Estuaries clearly illustrate this classic cause and effect mechanism and the interaction between man's activities, process modification and habitat response. Much of the Essex coastal intertidal area was subjected to extensive reclamation (approximately 42% of the area that existed some 2000 years ago was reclaimed) between the 15th and the 19th Centuries. Integral to this phase of extensive reclamation was the construction of coastal defences in order to protect the fertile agricultural land from flooding. The presence of these man-made defences has constrained the ability of intertidal habitats (notably salt marsh) to move landward in response to sea level rise. This inevitably results in habitat loss; the term 'coastal squeeze' has been coined for this effect. With a predicted significant increase in sea level due to climate change this process is likely to continue, resulting in the loss of greater areas of intertidal habitat. In some areas the coastal defences provide protection to important areas of terrestrial and freshwater habitat to landward. Therefore, any options to remove defences and to allow coastal habitats to migrate landward may cause direct conflict between freshwater and coastal designated habitats.

The Essex Estuaries support significant assemblages of habitats and species which are recognised for their ecological and nature conservation importance through designation as a Special Area of Conservation (SAC) under the European Union Habitats (Council Directive 92/43/EEC) and Special Protection Areas (SPA) under the Birds Directives (Council Directive 79/409/EEC) and Ramsar sites under the Ramsar International Convention on Wetlands (1971).

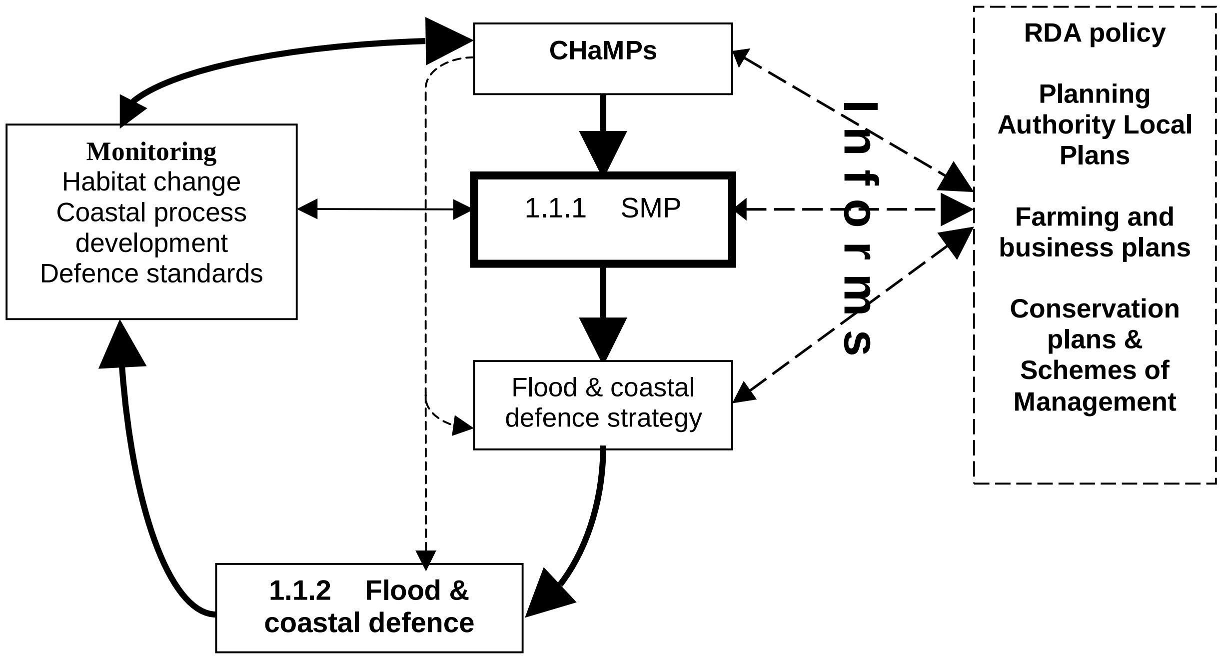
Coastal Habitat Management Plans (CHaMPs) form an important link in the coastal planning process for managing European and Ramsar sites. The primary functions of the Essex Estuaries CHaMP is:

- To offer a long-term strategic view on the balance of losses and gains to habitats and species of European interest likely to result from sea level rise, and the flood and coastal defence response to it;
- To develop a response to these losses and gains by informing the strategic direction for the conservation measures that are necessary to offset predicted losses;
- Identify suitable areas for new habitats that will need to be created; and
- Make recommendations to SMPs to ensure flood and coastal defence options address the requirements of the Habitats and Birds Directives.

Available information has been used to predict geomorphological change and likely shoreline changes over the next 50 years, taking into account predicted climate change and sea level rise over the study time period. Using this prediction, an analysis has then been undertaken of the likely effect of continuing with existing coastal defence policy on the designated ecological interests (cSAC, SPA and Ramsar). Throughout this process, for designated features landward of a sea defence, there is a presumption in favour of maintaining the habitat *in situ*, where it would be sustainable to do so (the sustainability of defences is normally considered over the probable design-life of a structure). Where it is determined that an adverse effect on ecological interests could occur, then the CHaMP sets out measures to either avoid an adverse effect or to compensate for it, including consideration of alternative flood and coastal defence options and the development of suitable replacement habitats.

The CHaMP is a non-statutory document using the best available scientific information, advice and guidance to inform revisions of the SMP and relevant flood and coastal defence strategies. This process is represented graphically in Figure 1.

Figure 1 – The CHaMP planning cycle



The Essex Coast and Estuaries CHaMP covers the area between Hamford Water and Southend-on-Sea (see Figure 2). This area includes the following European sites and their constituent Sites of Special Scientific Interest (SSSI):

- Essex Estuaries candidate Special Area of Conservation (cSAC) (Colne Estuary SSSI, Blackwater Estuary SSSI, Dengie SSSI, Crouch and Roach Estuaries SSSI, Foulness SSSI);
- Hamford Water SPA and Ramsar (Hamford Water SSSI);
- Mid Essex Coast SPAs and Ramsar, including:
  - Colne Estuary SPA and Ramsar (Colne Estuary SSSI)
  - Blackwater Estuary SPA and Ramsar (including Old Hall Marshes SPA/Ramsar, Blackwater Estuary SSSI, Old Hall Marshes SSSI)
  - Dengie SPA and Ramsar (Dengie SSSI)
  - Crouch and Roach Estuaries SPA and Ramsar (Crouch and Roach Estuaries SSSI)
  - Foulness SPA and Ramsar (Foulness SSSI); and
- Benfleet and Southend Marshes SPA (Benfleet and Southend Marshes SSSI).

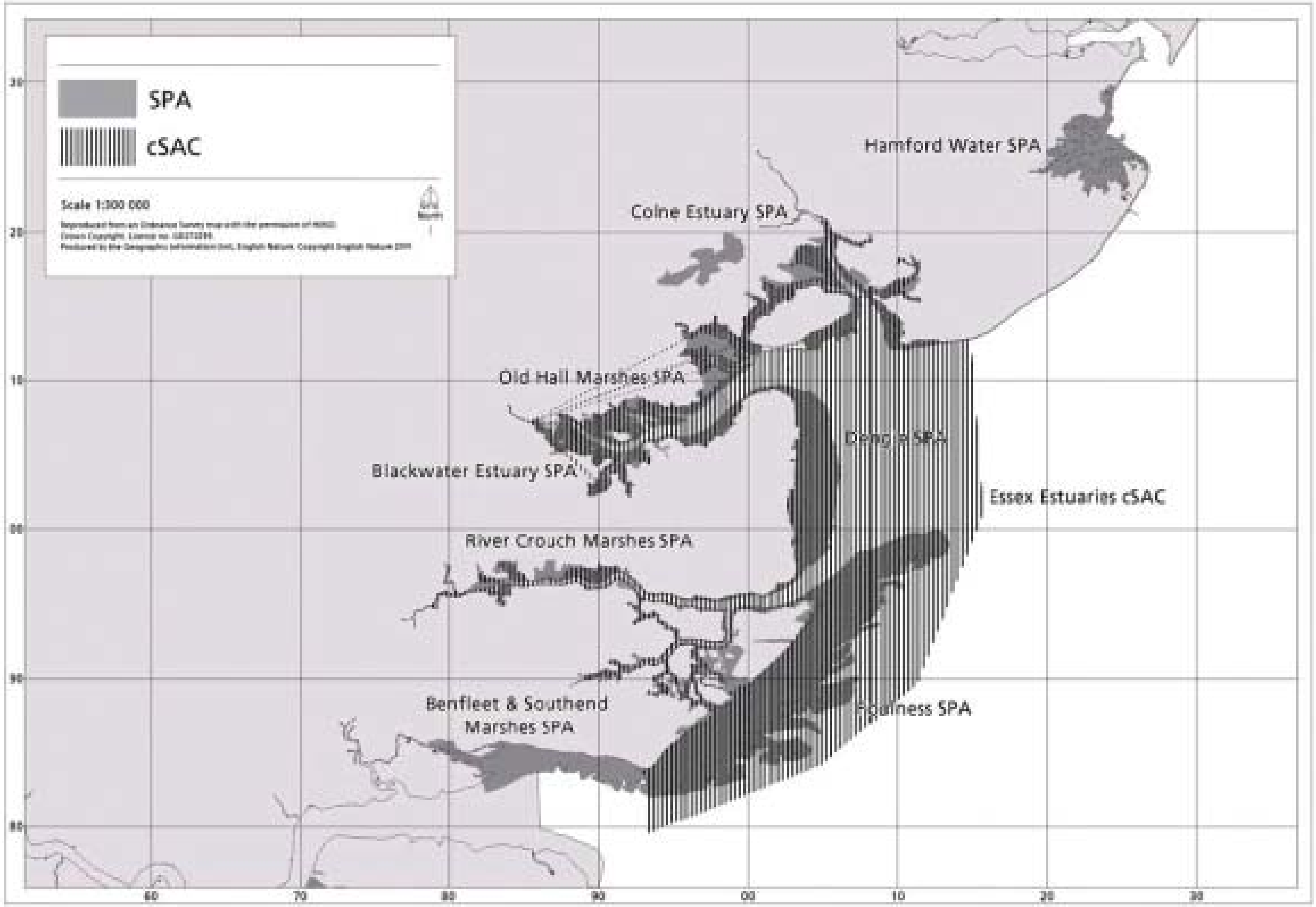


Figure 2. Area and European sites covered by the Essex Estuaries CHaMP

2 INVENTORY OF FEATURES

2.1 Interest Features of the candidate Special Area of Conservation

The Essex Estuaries cSAC contains the major estuaries of the Colne, Blackwater, Crouch and Roach and the open coast tidal flats at Foulness, Maplin and Dengie. The Essex Estuaries have been recommended as a cSAC as they contain the following six Annex I habitat features listed under the EU Habitats Directive.

1. **Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*)** - Atlantic salt meadow is the most frequently encountered salt marsh habitat in the Essex Estuaries covering 3376 hectares (approximately 33 square kilometres), representing over 10 per cent of the UK resource (English Nature 2000). In the Essex Estuaries low to mid-marsh communities predominate, owing to extensive reclamation of the upper marsh due to enclosure by sea walls.

2. **Estuaries** - The Essex Estuaries are part of a low-lying sedimentary coastline with open coast and offshore elements creating an extensive area of continuous marine habitat. The estuaries have formed from pre-existing valleys, which were flooded at the end of the last ice age. The range in tidal heights (average tidal range of 4.8 metres) allows for a vast extent of intertidal sediment flats to become exposed (approximately 169 square kilometres). Though soft substrates of sands and muds predominate, there are areas of hard substrates mainly comprised of small boulders, cobbles, pebbles, or broken shells. The major soft substrates are normal to variable salinity muddy sands and variable to reduced salinity muds. Salinity is the key determinant of plant and animal distribution in the estuaries.

3. **Mediterranean and thermo-Atlantic halophilous scrubs (*Sarcocornetea fruticosi*)** - This scrubby, salt-tolerant vegetation most frequently occurs at the upper limit of tidal inundation and is often found in association with transitions to shingle structures and is formed predominantly of bushes of shrubby sea-blite (*Suaeda vera*), occasionally with sea purslane (*Atriplex portulacoides*). This vegetation community is restricted to the south and south-east of England and reaches the northernmost limit of its distribution in Lincolnshire.

4. **Mudflats and sandflats not covered by seawater at low tide** - The Essex Estuaries represents the range of variation of this habitat type found in south-east England. It includes the extensive intertidal flats of the Colne, Blackwater, Roach and Crouch estuaries, as well as the open coast flats of the Dengie and Maplin Sands, which have an unusually undisturbed nature. The site contains a wide range of sediment flat communities, from estuarine muds, sands and muddy sands to fully saline sandy mudflats with extensive growths of eelgrass *Zostera* spp. The extent of these sediment flats in the Essex Estuaries is approximately 17,000 hectares.

5. ***Salicornia* and other annuals colonising mud and sand** - Pioneer salt marsh comprises a small number of plant species dominated by open stands of glasswort (*Salicornia agg.*), annual sea-blite (*Suaeda maritima*) and sea aster (*Aster tripolium*). This vegetation colonises intertidal mudflats and sandflats in areas protected from strong wave action and is usually an important precursor to the development of more stable vegetation. It develops at the lower reaches of salt marshes around mean high water neap (MHWN) tides and can also be a secondary coloniser of open creek sides, depressions or pans within a salt marsh, as well as disturbed areas of higher salt marshes.

6. ***Spartina* swards (*Spartinion maritimae*)** - There are only two sites in the UK where either the native small cordgrass (*Spartina maritima*) and the naturalised smooth cordgrass (*S.*

alterniflora) occur in significant quantities: the Essex Estuaries and the Solent. Cordgrass is an important salt marsh precursor species, colonising a wide range of substrates, from very soft mud to shingle, in areas sheltered from strong wave action. The species can therefore occur on the seaward fringes of salt marshes and creek sides and may also colonise old salt pans in the upper marsh.

2.2 Interest Features of the Special Protection Areas

There are seven SPAs designated within the Essex Estuaries CHaMP area, as listed in Table 1. Between them these sites support important internationally populations of breeding and wintering waterfowl populations and qualify for designation as SPAs under the Birds Directive as summarised in Table 1.

Table 1 – Summary of designated interests of SPAs within the Essex Estuaries CHaMP area

SPA	Annex I	Migratory species of international importance	5 year peak mean (1995/96-1999/00)
Hamford Water	Avocet, golden plover, ruff and little tern	Dark-bellied brent goose, teal, black-tailed godwit, redshank and ringed plover.	33,892 including: redshank, dunlin, lapwing, wigeon, shelduck, black-tailed godwit, grey plover, ringed plover, teal, dark-bellied brent goose, ruff, golden plover and avocet.
Colne Estuary	Hen harrier, avocet, golden plover and little tern	Dark-bellied brent goose and redshank.	34,812 including: black-tailed godwit, dunlin, lapwing, grey plover, ringed plover, shelduck, cormorant, great crested grebe, redshank, dark-bellied brent goose, golden plover and avocet.
Blackwater Estuary	Hen harrier, avocet, golden plover, ruff and little tern.	Dark-bellied brent goose, shelduck, ringed plover, grey plover and dunlin.	71,736 including: great crested grebe, golden plover, ruff, dark-bellied brent goose, shelduck, ringed plover, grey plover, dunlin, avocet, redshank, curlew, cormorant, wigeon, teal, pintail, shoveler, goldeneye, red-breasted merganser, lapwing, black-tailed godwit.
Dengie	Hen harrier and bar-tailed godwit	Grey plover and knot.	25,957 including: black-tailed godwit, dunlin, lapwing, oystercatcher, dark-bellied brent goose, cormorant, great crested grebe, knot, grey plover and bar-tailed godwit.
Crouch and Roach		Dark-bellied brent goose	
Foulness	Hen harrier, avocet, bar-tailed godwit, golden plover, common tern, little tern and sandwich tern	Dark-bellied brent goose, oystercatcher, grey plover, knot and redshank.	81,716 including: redshank, curlew, black-tailed godwit, dunlin, lapwing, wigeon, shelduck, little grebe, knot, grey plover, oystercatcher, dark-bellied brent goose, bar-tailed godwit, golden plover and avocet.
Benfleet and Southend		Dark-bellied brent goose, ringed plover, grey plover and knot	42,587 including: dunlin, ringed plover, oystercatcher, knot, grey plover and dark-bellied brent goose.

3 GEOLOGY AND GEOMORPHOLOGY OF ESSEX

The Essex Coast can be broadly divided into two geomorphological sections: the first, between Canvey Island and Clacton, forms the northern section of the Greater Thames embayment, characterised by subtidal and intertidal estuarine mudflat and marshes. This area comprises the northern shore of the outer Thames, from Canvey to Shoeburyness; the coastal plains of Foulness and Dengie; and the estuaries of the Crouch/Roach, Blackwater and Colne. The second section, between Clacton and Harwich is characterised by coarse grained sediment forming open beaches, rising to 15m cliffs at the Naze. This section is unpunctuated by estuarine entrances, apart from that of Hamford Water.

The underlying geology of the outer Thames consists of a platform of Eocene rocks, the London Clay, upon which lie a sequence of Quaternary sands and gravels and, above these, the Holocene sands and muds. Although the relief produced by the Eocene and Quaternary rocks is subdued, rising only to around 40m above Ordnance Datum Newlyn (ODN), they have, nevertheless, played an important part in constraining the coastal landform development, limiting the transgression of Holocene deposits both on the open coast and in the estuaries.

The modern geomorphology of the Essex Coast has received scant attention. However, two general topics are of significance in considering the geomorphological development of this coast. These are, the reclamation history of the Essex coastal plain and the sediment budget of the Southern North Sea.

3.1 Reclamation History

The extensive reclamation of the Essex Coast intertidal areas, that began in the Roman era, accelerated in the 15th Century and reached its peak in the 18th and 19th Centuries, is the most significant of all the changes to the geomorphological regime of the estuaries. It is estimated that the total reclaimed area of the Essex Coast represents 42% of the total intertidal area as it existed 2000 years ago.

The removal of almost half the intertidal area from the coastal system has had massive impacts. The decrease in estuarine channel has led to higher velocities and increased bed-scour. As a result almost all the modern estuaries are deeper than would be expected for natural stable channels. The reduction in tidal prism (i.e. the volume of water entering an estuary on the flood tide) has meant that the tidal excursion from the estuary mouths has been reduced and ebb-tidal deltas have decreased in volume and extent.

Loss of shallow intertidal areas means that average depths for the channel cross section are increased but, at the same time, cross sectional areas are reduced. The combined effect of these changes is to increase erosion to channel sides and to flood defences. The outcome of all these processes is to reduce both intertidal and subtidal habitat, a loss best shown in the Crouch estuary where canalisation by reclamation has occurred. The loss of intertidal and subtidal habitat incurred as a result of this extensive reclamation means that, today, the Essex coastal system is unable to respond easily to changes produced by natural or human agencies.

3.2 Sediment Budget

Inputs of coarse grained sediment are probably confined to those from *in situ* erosional sources. Suspended, fine grained sediment is derived almost entirely from marine sources. Data indicates that suspended sediment concentration in the Southern North Sea (i.e. the supply for the Essex Estuaries) are between 10-80mg/l depending on season with higher concentrations experienced during the winter months. Suspended sediment concentrations increase towards the coast and are much higher within the estuaries, typically ranging between 100 and 1000mg/l. These high estuarine suspended sediment concentrations are, however, maintained by tidal exchanges with the waters of the open sea. In order to keep pace with sea level rise, sediment outputs to intertidal and subtidal accretion within the estuaries and along the open coast must either be balanced by inputs from marine sources or by redistribution of existing coastal sediments.

Research work suggests that the general estuarine response to sea level rise is one of stratigraphic ‘roll-over’, that is erosion of outer estuary intertidal deposits and deposition of these sediments in the inner estuary. This model fails to operate if the landward transgression is impeded by reclamation and flood embankments, in which case sediments eroded from the seaward margin cannot be re-deposited and the entire sedimentary overlap gradually decreases in area. Since redistribution of sediments is to a large extent prevented by coastal and estuarine flood embankments, most of the sedimentary response to sea level rise must be derived from marine sources. There is the possibility It may be that increased sediment demand, such as that exerted by accelerated sea level rise or even by extensive managed realignment of areas lying at low elevations in the tidal frame may not be met by the sources of supply.

3.3 Sea Level Rise

A continuation of the Holocene transgression, in which the entire sedimentary overlap is moved landward by a sediment roll-over process as described above, seems the most likely process over the next 30-100 years. This roll-over applies equally to the estuaries and to the open coastal margins, but, within the estuaries the roll-over is also accompanied by sediment inputs from marine sources that allow the surface elevations to keep pace with sea level rise.

Transgressive roll-over must therefore be considered in any attempt to understand the development of these estuaries over the next 50 years during which period sea level is predicted to rise by $0.006ma^{-1}$ and, if rates of sea level rise continue to increase, for the 50 year period thereafter. The transgression rates of the estuaries under accelerated sea level rise (calculated at 8-12m/yr) will govern much of the habitat changes that will occur. Unless provision is made for transgression of the landward edge of marshes within the estuaries by removal of impeding flood and reclamation embankments, transgression will mean progressive increases in the rate of salt marsh loss in all the Essex Estuaries.

The relationship between the geomorphology of an estuary and its habitat distribution is a key factor in any attempt to predict future developments and to provide sustainable habitat management. The variation in geomorphological processes among the Essex Estuaries, brought mainly about by geological and human constraints, mean that each estuary must be managed individually.

3.3.1 The Crouch/Roach Estuary

The areas of the major habitat types present in the Crouch/Roach Estuaries are shown in Table 2. The ratio of reclaimed intertidal area to extant intertidal area (1:7.6), the largest among all the Essex Estuaries, demonstrates the extent to which this system has been modified by human impact. As a result of reclamation, the Crouch has the lowest ratio of intertidal to subtidal among the Essex Estuaries and the smallest area of salt marsh.

Nevertheless, geological impacts are also important, in particular the constraint to the development of the channel presented by the abrupt rise in valley side slopes at Burnham, due to the presence of Terrace gravel deposits, and paralleled by lower but significant gravel deposits outcropping on Wallasea Island. This geological constraint means that the channel in this reach is narrower than would be expected for an estuary in equilibrium and results in bed scour and over-deepening. The reclamation of Wallasea Island has exacerbated this natural tendency for scour by decreasing channel width even further.

Table 2 – Coastal habitat areas for the Essex Coast. (Source JNCC 1999; Cooper 2000)

Estuary	Total estuary plan area (ha)	Total intertidal area including salt marsh (ha)	Mudflat area (ha)	Salt marsh area (ha) in 1998	Subtidal area (ha)	Reclaimed area (ha)
Crouch	2754	1536	1229	307	1218	11600
Blackwater	5184	3315	2631	684	1869	2000 [1]
Colne	2335	2002	1381	695	333	1300
Hamford Water	2377	1570	949	621	807	1000
North Thames	Not applicable	11098 [2]	10917	181	N/A	Not known

Despite the almost canal-like nature of the estuarine channels in this system, regime analysis shows that the Crouch/Roach is much wider between Dengie and Foulness Point than would be expected for an equilibrium estuary. The analysis also demonstrates the constraints of the channel between Wallasea and Burnham and the comparatively wide channel west of Black Point. This pattern of channel variation is matched by subtidal accretion taking place at the mouth, erosion along the Wallasea reach and accretion in the inner estuary.

3.3.2 Blackwater

The Blackwater Estuary has the smallest ratio of reclaimed area to total plan area among the Essex Estuaries but despite this, the ratio of salt marsh to mudflat is only slightly greater than that for the Crouch/Roach system. This suggests that, prior to reclamation, salt marsh had not developed as extensively in this estuary as in others in Essex so that the relative area of mudflat was larger here than average.

Geological constraints occur at the mouth of the Blackwater where Terrace gravels at Bradwell and Mersea constrain the estuary mouth, which is over-deepened perhaps due to the location here of the proto-Thames. As a result of the large tidal prism in the estuary the constriction in width at the mouth leads to bed scour so that deposition has not taken place and the channel remains deep here. These geological constraints at the mouth of the estuary mean that the development of both extant and reclaimed salt marsh between Sales Point and St Lawrence Bay is limited to the sheltered bays.

It appears therefore that the present distribution of intertidal habitat in the Blackwater Estuary has developed as a result of a process of natural coastal squeeze in which, the geological constraints imposed by the valley sides and islands have limited the Holocene transgression and resulted in a wide expanse of mudflat with relatively small extent of salt marsh. This natural coastal squeeze has been, to some extent, exacerbated by the coastal squeeze exerted by reclamation and flood embankments.

3.3.3 Colne

The Colne appears to be a relatively stable estuary, little affected by reclamation (as in the Crouch) or by geological constraints (as in the Blackwater and Crouch). In contrast to the other Essex Estuaries, the channel of the Colne is orientated north-south and therefore runs across the

[1] Estimates vary between 2000ha (source Institute of Estuarine and Coastal Sciences (IECS), 1994) and 4100ha (source Environment Agency (M Dixon), 2002, pers comm)

[2] Comprising Chapman and Southend Flats (2248ha) and Maplin Sands (8850ha) Source IECS 1992.

relict Pleistocene and Quaternary valleys. This means that the bed slope of the estuary steepens markedly towards its head and, north of the Wivenhoe Barrier, the estuary dries at low water. This leads to a rapid decrease in tidal prism and in the width of the inner estuary channel. It may be concluded that the morphology of the Colne is close to equilibrium, a conclusion supported by the relative lack of change in its intertidal morphology over the past 150-200 years.

3.3.4 Hamford Water

In comparison to the other Essex Estuaries, Hamford Water is anomalous both in its location and its morphology. It is located within the larger estuarine system of the Stour/Orwell and its tidal dynamics, sediment transport and nearshore relationships are dominated by these larger estuaries. Perhaps more important with regard to its habitat distribution, Hamford Water lies in a geological basin that is in marked contrast to the South Essex Estuaries. The configuration of the London Clay basin in which the estuary is located, means that the estuary was, in the early Holocene, short (7km) and extremely broad at its mouth (3.5km) although this width has subsequently been reduced by the development of the spit at Stone Point to 2.1km. It is for this reason that the distribution of habitat types in Hamford Water also contrasts with the other Essex Estuaries as it has the highest ratio of salt marsh to mudflat (65%).

The short length of Hamford Water means that the tidal prism is small and thus the power available at the mouth is also low. As a result, longshore sediment transport along the open coast moves sediment northwards from the Naze to form the spit at Stone Point and extending to Pye Sands, so restricting the width of the estuarine channel and allowing extensive salt marshes to develop on either side.

3.3.5 North Thames

The Thames Estuary is an extremely complex system in which major anthropogenic forces have reduced the extent of natural habitat significantly, but in which, nevertheless, extensive areas of intertidal salt marshes, mudflats and reclaimed grazing marshes continue to provide an important habitat resource.

Research suggests that the Thames reached a dynamic equilibrium with tidal and wave forces over the Holocene, despite the continued human interference in the system including industrial and urban development on its banks and navigation dredging of subtidal channels. Mudflat accretion in the estuary has kept pace with sea level rise over the past 100 years although its salt marshes have suffered considerable losses in area, a factor that continues to cause concern.

3.4 Open Coast Geomorphology

3.4.1 Supratidal areas

Shingle ridges occur at Colne Point, where the spit complex extends for 2.5km between Jaywick and Sandy Point. This spit appears to be a relic of a more extensive series of shingle ridges that extended between Walton and Colne Point but which largely disappeared in the mid-19th Century (IECS, 1994).

Chenier ridges on the Essex Coast are mainly confined to areas at a number of locations along the North Thames foreshore, and at Foulness Point, Colne Point and Sales Point where, although they lie on intertidal salt marsh, their maximum elevations extend to supra-tidal levels. Cheniers are banks of coarse-grained sediment, mainly carbonate shell fragments and silica gravels, that are washed over a salt marsh surface by wave action. They are orientated parallel to the marsh edge. They form one of the few supra-tidal gravel shorelines in Essex and as such are an important habitat for annual drift line species.

3.4.2 Intertidal areas

Three areas of open coast are located within the region; Foulness /Maplin, The Dengie Peninsula and Colne Point/Clacton/Naze.

Foulness/Maplin: To the south of the Whitaker Channel, Foulness Sands extends south to the Thames estuary, forming part of the Maplin Sands, the largest continuous intertidal area in Britain with a total area of 8858ha (Joint Nature Conservation Committee (JNCC), 1999). The intertidal mudflats extend to a width of 6km but salt marsh is restricted to an area of 88ha mainly located behind the shelter of a chenier ridge between Northern Corner and Foulness Point.

The Dengie Peninsula: Intertidal mudflats on the Dengie Peninsula extend over 2590ha with widths of over 3km. The flats are dissected by a number of drainage channels flowing from reclaimed marsh sluiced-outfalls. The salt marshes on the upper intertidal have been eroded away in the south of the area but an area of 474ha remains between Deal Hall and St Peter's Church. The outer edge of this marsh is deeply dissected into 'mud-mounds' probably a response to wave erosion and appear to be eroding at a rate of between 2 and 3 m per year.

Colne to the Naze: This area falls largely outside of the designated cSAC and SPA sites covered by the CHaMP. Between the Naze and Clacton-on-Sea the coast is characterised by sea cliffs which have been retreating relatively rapidly, in contrast Colne Point is a depositional beach ridge composed of fine sand and mud behind which salt marsh has developed and which continues to exhibit signs of active growth.

4 HISTORIC HABITAT GAINS AND LOSSES

The evidence for changes to the distribution and extent of coastal habitats over so large an area as the Essex Coast is necessarily of a fragmentary nature. However, evidence for change can be drawn from a variety of sources, notably field surveys (e.g. Environment Agency), scientific studies and Ordnance Survey maps.

4.1 Intertidal Salt Marsh Change

The erosion of the seaward edge of the intertidal salt marshes of the Essex Coast has been seen as one of the most important concerns for coastal management over the past decade. As a result of this erosion a number of studies have been made of its causes and rates.

Rates of salt marsh erosion have been recorded using aerial photography by Burd (1992) and Cooper (2000). These two studies provide a comprehensive analysis of the rates and distribution of salt marsh erosion in Essex and their main conclusions are summarised in Table 3.

Most significant are the changes in marsh erosion rates between the two measurement periods, expressed as a percentage of the 1973 total. The estuaries of the Blackwater and Crouch both showed significant reductions in erosion of almost 50% but Hamford Water showed a 100% increase and the Colne estuary, in which minimum rates were observed up to 1988, exhibited an increase of 25%. The Dengie marshes showed a slight increase in erosion of 20%. Reasons for these changes and the large amount of variation shown between the Essex Estuaries are not apparent and they may merely reflect random variability in the system rather than any long term trends.

Salt marsh loss on the north shore of the Thames Estuary during the period 1973-1988 totalled 105.6ha: a 23% loss (Burd 1992) higher than that for any other east coast estuary. Shore profiles surveyed for the Environment Agency on the Dengie Peninsula, showed that these changes in the area of the salt marshes are associated with horizontal edge erosion which in the case of the Dengie marshes, averaged 3.3m per year between 1992 and 2001.

In contrast to the horizontal recession of the salt marsh edge along most of the Essex Coast, evidence from a limited number of areas suggest that, at the same time, vertical accretion is occurring on the salt marsh surface (e.g. 8mm/yr on the marshes at Mill Point, Blackwater Estuary). Evidence from Environment Agency profiles on the Dengie marshes shows that over the period 1992 to 2001 the central Dengie Marshes experienced vertical accretion rates averaging 2cm/yr. Both these accretion rates are considerably in excess of the rate of sea level rise and it may be concluded that accretion is more rapid due to the presence of the flood embankments that limits the area over which deposition can take place. Thus the coastal squeeze process on the Essex Coast is concentrating the existing sediment volumes into a smaller area as sea level rises and in so doing increasing local rates of vertical accretion.

Table 3 – Rates of salt marsh erosion in Essex (source Cooper 2000)

Location	Salt marsh area in 1973 (ha)	Salt marsh area in 1988 (ha)	Salt marsh area in 1998 (ha)	Difference in area 1998-1973 (ha)	Difference in area 1998-1988 (ha)	Mean annual erosion rate 1973-1988 as % of 1973 total	Mean annual erosion rate 1988-1998 as % of 1973 total
Hamford Water	876.1	765.4	621.1	110.7	144.31	0.8	1.6
Colne	791.5	744.4	694.9	47.1	49.5	0.4	0.6
Blackwater	880.2	738.5	683.6	141.7	54.9	1.1	0.6
Dengie	473.8	436.5	409.7	37.3	26.8	0.5	0.6
Crouch	467.1	347.4	307.8	119.7	39.6	1.7	0.8
N Thames	365.9	197.0	181.0	N/A	35	N/A	N/A

4.2 Intertidal Mudflat Change

The changes in mudflat extent on the Essex Coast have not been quantified directly. Variations in the area of mudflat are approximately the inverse of salt marsh loss since the loss of a given area of salt marsh, as a result of the horizontal landward retreat of the salt marsh-mudflat boundary, will result in an equal amount of mudflat gain. Such an assumption, although broadly correct, must be qualified since, firstly, the low water mark will also vary over time (e.g. through accretion/erosion) and secondly, salt marsh losses may include internal dissection, a process that results in an area of bare mud that, nevertheless, may not be recognised as intertidal mudflat.

On the Dengie Peninsula the surveys of shore profile show that the intertidal slope has flattened. Despite minor variations in the rates of accretion and erosion across the Peninsula, the results show that, over the past decade, a decrease in intertidal slope has taken place, resulting in a wider foreshore and an increase in the extent of the mudflat habitat.

4.3 Grazing Marsh Change

Grazing marsh is defined as periodically inundated pasture or meadow with ditches containing standing brackish or fresh water. Freshwater coastal grazing marshes have been created since the Roman times by the enclosure of high salt marshes. These areas are traditionally used for summer grazing and provide an attractive habitat for breeding and wintering birds.

Historically, grazing areas were created initially as pasture for dairying or livestock production, but have through changing agricultural practice been largely replaced by arable production. It has been calculated that between the 1930s and the 1980s, the coastal grazing marshes in Essex have declined by as much as 72% (Williams and Hall, 1987). Loss of marshes for urban and industrial development in Essex has mainly occurred along the Thames Estuary and it is estimated that between 1970 and 1980 26% of the marshes were lost in the Essex Greater Thames Estuary Area for this reason. By the end of the 1990's it is estimated that there were 6,500 hectares of grazing marsh in Essex in all the coastal districts, which compares with 7,030 ha in the 1980s and 25,402 ha in the 1930s.

5 PREDICTED CHANGES TO THE SHORELINE

One of the main objectives of the CHaMP is to provide a prediction of habitat changes on the Essex Coast for a period of between 30 and 100 years. The varied geomorphology of the Essex Coast makes generalisation over such a long period extremely difficult, if not misleading. Nevertheless, an attempt has been made to provide broad predictions of changes to the two major coastal types: estuaries and open coasts using specific examples from each. Regime modelling has been applied to predict the steady state (or equilibrium) for an estuary system and changes likely to result from sea level rise. The Intergovernmental Panel on Climate Change (IPCC) prediction of 6mm sea level rise per year has been used. However, since IPCC predictions are only available for the next 50 years, model predictions have been restricted to this single time period.

5.1 Estuarine Changes

5.1.1 The Blackwater Estuary

The regime model results for the Blackwater estuary indicate that the estuary is constrained at the estuary mouth (Mersea to Sales Point), 2km landward of the mouth (Shinglehead Point to Bradwell) and the head of the estuary (between Northey Island and Maldon).

The constrictions at the head and mouth of the estuary are due to geological constraints and it is interesting to note that at the mouth the width constriction of the actual channel is paralleled by over-deepening compared to the predicted depth. The constriction at Shinglehead Point and in the inner estuary are, however, due to the presence here of flood embankments and are not compensated by increased depths. This results in increased velocities and stresses on the estuary banks at these locations, stresses that have been resisted by the artificial defences here.

In response to sea level rise the estuary would increase in width along its entire length, increasing towards the sea. The total area of potential intertidal loss as a result of the increased stress applied by sea level rise would occur at the salt marsh/mudflat boundary and is predicted from the analysis to be 600-700ha over the 50 year period.

5.1.2 The Crouch Estuary

For the Crouch, the actual mouth width is wider than the predicted equilibrium form, in contrast to the geologically constrained Blackwater estuary. Geological constraints exert an influence on the channel between Wallasea and Burnham where the actual channel width is smaller than the predicted equilibrium. Further inland, the existing inner estuary channel is wider than the predicted equilibrium form.

With sea level rise potential changes in bank stress suggest that potential increase in width appears to fall into two distinct groups with a boundary at the junction between the Roach and

Crouch (5km from the mouth). Maximum increase in channel width occurs at the mouth and totals 60m over the 50 year period. The combination of a wider channel needed to achieve equilibrium with present day sea level plus the impact of 50 years of sea level rise at 6mm per year, would mean a total increase of 321ha in the channel area of the Crouch. This widening process would involve the erosion of salt marsh where it existed and therefore, in theory, all of the existing salt marsh area of 308ha could be lost over the next 50 years.

5.1.3 The Colne Estuary

The equilibrium form for the Colne estuary is predicted to be almost identical to the existing morphology. Overall, the Colne is predicted to have a surface area 40ha smaller than the ideal equilibrium form. The impact of 50 years of sea level rise on the morphology of the Colne estuary is predicted to be similar to that of the Blackwater and Crouch estuaries. The increased tidal prism in the Colne is predicted to lead to enlargement of its channel, a change achieved mainly by retreat of the salt marsh boundary. The predicted increase in channel width over the 50 year period at the Mersea Stone section is 250m decreasing approximately linearly to zero at the Wivenhoe Barrier. The potential loss of salt marsh as a result of sea level rise over the next 50 years is predicted to be 116ha.

5.1.4 Summary of predictions for the Essex Estuaries

The response of the estuaries of Blackwater, Colne and Crouch to sea level rise is governed largely by the nature of the existing constraints on their channels. Since, in the Blackwater and Crouch, a large proportion of the existing constraints on equilibrium channel form is geological, it is unlikely that their full equilibrium form will evolve over periods measured in centuries and certainly not in the 30-100 years under consideration here. That being so, the response of the estuaries to sea level rise can be described as ‘sub-optimum’: that is sea level rise will increase the stresses on the channel but these stresses would not result in channel changes, apart from those areas where human constraints are removed either deliberately or accidentally.

These predictions are made on the assumption that the upper intertidal area of the estuaries is composed of cohesive sediment that is capable of erosion. Clearly if the upper shore were composed of resistant materials, such as Terrace gravels, or were protected by flood embankments then erosion would not take place. For this reason the predictions given here must be regarded as potential rather than actual changes in estuary shape as erosion would be confined to salt marshes or high intertidal mudflats that lie seaward of protecting flood defences. Since only a small proportion of the upper intertidal zone of the main channels of these three estuaries is formed of salt marsh the potential increase in channel width under sea level rise is unlikely to be realised.

In contrast the Colne is in a dynamic equilibrium with its tidal inputs at the present time, with changes taking place only due to continued increases in sea level. The predicted accelerated sea level rise over the next 50 years in this estuary may result in a real, as opposed to a potential, change, in the estuarine morphology since most of the western banks of the estuary and some of the eastern bank, are formed of salt marsh that will initially respond to sea level rise by retreating.

5.2 Open Coast Changes

Model predictions show that mudflats on the open coast at Dengie will decrease in slope angle over the next 50 years due to the accelerated rise in sea level. Once the mudflat has attained a lower slope wave energy will be dissipated and the salt marsh boundary will begin to accrete. These results suggest that the impact of sea level rise on the open coast is quite distinct from that within the estuaries. The effect of sea level rise is to increase the accretion rates, due to the reduction of bed shear in the deeper water and increased deposition due to a deeper water column. The predictions indicate that the rate of lower intertidal accretion will drop after 50 years, apparently towards some form of steady state, but the accretion at the salt marsh boundary will continue for an unspecified period.

At Foulness, the Futurecoast project (Halcrow 2002) predicts that under an unconstrained scenario there would be large-scale inundation of the reclaimed backshore areas by tidal water. As sea level continues to rise however, existing and newly created salt marshes would experience landward transgression enabling the area of salt marsh and tidal flats to maintain their position relative to the increasing tidal frame. Due to the presence of flood defences under increased rates of sea level rise the foreshore would narrow due to coastal squeeze and this would result in less attenuation of wave and tidal energy and increased damage to flood and coastal defences.

These predictions are in contrast to those provided by the modelling exercise, which show a recovery of the salt marshes of the Dengie (and by implication of Foulness) within the next 50 years. The explanation for this difference in predicted outcomes is that Futurecoast relies on extrapolation of existing rates of change whereas the predictive model for Dengie incorporates feedback between sedimentary processes.

For the relatively narrow foreshore between Jaywick and Seawick Futurecoast predict that under the unconstrained scenario that there would be a high probability of segmentation and breaching causing large-scale inundation of the low-lying backshore. This would create ‘a new tidal inlet with flats and salt marshes landward of this frontage’. Under the constrained scenario Futurecoast predicts ‘the position of the shore would be held but the foreshore would widen locally due to sand accumulation in the lee of the existing fishtail groynes.

6 PREDICTED IMPACT ON DESIGNATED FEATURES

The recent history of the Essex Coast and the information derived from the results of the predictive regime modelling both indicate that profound changes could occur in the distribution and extent of coastal habitat over the next 50 years and beyond. These changes include:

- Significant loss of salt marsh within the estuaries;
- Concomitant increase in the area of mudflats;
- Landward transgression of habitat throughout the estuaries;
- Increased width of open coast intertidal areas and slight recovery of salt marsh areas; and
- Further ecological isolation of freshwater/estuarine habitats landward of flood defences from the main estuaries.

These changes are all based on the assumption that sea level rise will accelerate to 6mm per year over the next 50 years and that existing flood defences would be maintained on line for that period. As with the physical change, predicted changes on habitats and species at a broad, system level can be made. For this purpose the main designated interest features of the Essex Estuaries have been grouped into three broad categories reflecting their position and role within the overall system.

6.1 Subtidal Features

Potential changes in erosion and accretion within the estuaries, as a result primarily of changes in the tidal prism, would alter the existing distribution and pattern of some subtidal communities. Modifications in community structure would probably be localised and take place in areas where there was significant change in the parameters controlling sedimentary processes and therefore substrate type. Such change would be most likely in parts of the estuaries where deepening of the estuary channels and an increase/decrease in current velocity occurs as a result of tidal volume change. For instance, in areas of increased current velocity fine sediment would be preferentially winnowed out and coarser sediments would come to predominate. At the whole estuary level, with sea level rise and predicted estuary transgression landwards and upwards, fine sediment accretion would be likely to increase at the head of the estuary and tops of creeks. Conversely, at estuary mouths increased wave activity (associated with predicted climate change) and sea level rise would lead to a likely increase in the predominance of coarser sediment.

It is unlikely, however, that there would be any diminution in the existing range of community types as broad-scale and significant changes in the existing sedimentary regime and physical make-up of the estuaries and open coast (apart from the loss of salt marsh) are not predicted. On this basis it is considered that the predicted changes in estuary morphology and processes over the CHaMP time period are unlikely to have any significant consequences for subtidal habitats and communities within the Essex Estuaries cSAC.

6.2 Intertidal Features

Estuary transgression under accelerated sea level rise will govern much of predicted intertidal habitat change. Based upon both modelling results and extrapolation of present day rates of change (see Table 4) it is predicted that by 2050, assuming the IPCC prediction for sea level rise applies, the residual area of salt marsh in the Essex Estuaries compared to present day areas will decrease significantly. Model results for the Blackwater and Crouch indicate that there would be no salt marsh remaining, while extrapolation of recorded rates of loss suggest that no salt marsh would remain in Hamford Water. For the Colne, model results indicate that 83% of existing salt marsh area would be present in 2050 or 64% if present trends were extrapolated. Clearly, this predicted loss would represent an adverse impact upon the ecological integrity of the entire Essex Estuaries cSAC, as a major component of the ecological diversity would be lost. The loss of salt marsh would have a number of ecological implications with respect to the designated features of the cSAC and the SPAs:

- Direct loss of salt marsh habitat, vegetation communities and associated fauna;
- Loss of habitat used by breeding and feeding birds (e.g. avocet, teal, redshank);
- Reduction in estuarine roosting sites for wintering waterfowl; and
- Loss of a significant source of nutrient input to intertidal mudflats.

As salt marsh is both a designated interest feature of the cSAC/Ramsar and an important habitat supporting wintering populations of waterfowl (SPA/Ramsar interest), its loss from the estuaries would affect the integrity of all of the designated sites. Maintaining the integrity of this ecological interest would therefore require significant habitat creation to be undertaken.

Evidence suggests that the extent of intertidal mudflat habitat may be increasing on the open coast. Similarly, with the erosion and loss of salt marsh habitat there would be a concomitant increase in the area of intertidal mudflat within the estuaries, although the gain may not match the total loss of salt marsh. This predicted increase in the area of intertidal mudflat would provide a greater area for colonisation and establishment by characteristic benthic communities. Besides the obvious benefit of an increase in the extent and possible range of these communities a gain in intertidal mudflat and associated benthos would increase the feeding resource upon which waterfowl depend and potentially the Essex Estuaries could support greater numbers of migratory waterfowl.

Table 4 – Changes to the area of salt marsh in the Essex Estuaries by 2050. (Note these figures do not include the open coast salt marshes of the Dengie and Foulness frontages)

	Area in 1998 (ha)	**Extrapolated present erosion rates to 2050 (ha)**	**Residual area in 2050 (ha) extrapolation**	**Model prediction change in area by 2050 (ha)**	**Residual area in 2050 using model prediction**	**Residual area using model prediction + extrapolation**
Crouch/Roach	308	-198	110	-321 (0)	-13 (0)	0
Blackwater	684	-274	410	-1040 (0)	-356 (0)	0
Colne	695	-247	448	-116 (0)	579	579
Hamford Water	621	-722	-101 (0)	N/C	N/C	0
North Thames	181	-175	6	N/C	N/C	6
Total (ha)	2489	N/C	974	N/C	N/C	585
Creation need (ha)			1515			1904

6.3 Terrestrial Features

Under an overall strategy of hold the line, existing designated features to landward (SPA and Ramsar interests) would be maintained relatively intact. Clearly, this may not be a sustainable solution as it is likely that significant works would need to be undertaken to ensure that defences within the estuaries could be maintained in the face of sea level rise and the loss of natural defence provided by the salt marsh fronting them.

If this were the case, defences would need to be engineered to withstand greater stresses and prevent overtopping and flooding and an artificial situation would develop with further isolation of areas of low-lying land behind flood defences. This situation would have a number of ecological consequences affecting both SPA and Ramsar designated features, the main one being a potential diminution in the extent of brackish water habitat due to restricted saline seepage. Such a reduction would affect a number of ecological interest features, but in particular plant and invertebrate communities (designated Ramsar interests) that depend on the maintenance of brackish conditions. The impact on SPA designated bird populations cannot be easily determined, but terrestrial habitats of the SPA/Ramsar which support specific bird species would generally be maintained intact as it is management from the landward side which largely influences the presence of these species (e.g. dark-bellied brent goose, ruff, hen harrier).

The more sustainable option is to allow the system to adapt to the forcing processes. However, with respect to the balance between intertidal and terrestrial habitat within the estuaries, there is a significant issue concerning the consequences of managed realignment on the wider estuarine system.

7 MANAGEMENT OPTIONS

The changes envisaged over the next 30-100 years on the Essex Coast can be summarised as continued coastal squeeze in the estuaries but a trend towards equilibrium on the open coast. This generalisation is, however, complicated by the existence of areas of natural coastal squeeze, in which geological constraints will continue to cause loss of intertidal habitat as sea levels rise. Any overall strategy for the management of the Essex coastal habitat must therefore consider:

- The differences between estuarine and open coast responses to sea level rise;
- The variation in response to sea level rise within each estuary (the roll-over effect);
- The differences between estuaries due to variations in geological and reclamation history (natural versus artificial coastal squeeze); and,
- Interaction between estuarine and terrestrial/freshwater habitats.

7.1 Management techniques

Faced with the continued loss of salt marsh habitat on the Essex Coast and estuaries, management strategies can incorporate a number of techniques designed to reduce, halt or even reverse the process. These include:

Managed re-alignment (or managed retreat) which involves the restoration of reclaimed intertidal areas by the partial or complete removal of the existing flood embankment. In many cases the process must be complemented by construction of a secondary flood defence landward of the initial embankment, in order to prevent flooding of adjacent land and infrastructure. Potential re-alignment sites need to be carefully considered as areas that appear geomorphologically suitable for restoration may be valuable for agriculture or other purposes (e.g. nature conservation) and the impact of restoration of a reclaimed area on the adjacent coastal areas may be as great as that caused by the initial reclamation.

The erosion of salt marsh or mudflat intertidal areas can be offset by **sediment nourishment**. The direct placement of sediment on intertidal areas has the effect of restoring the morphology of the area but without modifying the processes that caused erosion to occur. Unless the introduced sediment is resistant to such erosion it may therefore necessary to carry out re-nourishment at regular intervals. Alternatively, sediment can be introduced indirectly e.g. through trickle charging where sediment is introduced to the water column. The placement of sediment on designated areas (i.e. intertidal areas designated as cSAC/SPA/Ramsar) has to be carefully undertaken in order to ensure that minimal impact to existing infaunal communities occurs.

The more traditional approach to intertidal erosion is to provide some form of **hard defence**. These may include nearshore wave breaks, shore normal groynes, upper shore embankments or channel training walls. In all cases the hard defence resists the natural coastal processes often resulting in deflection of the erosion to adjacent areas. Maintenance of defences is a major issue since it has been found that very few can be regarded as sustainable.

Regulated Tidal Exchange (RTE) is a technique to develop intertidal habitats behind permanent sea defences, particularly where walls will remain in place and/or as part of a phased realignment strategy (Lamberth and Haycock 2002). The technique involves the regulated exchange of seawater to an area behind fixed sea defences through engineered structures such as sluices, tide-gates or pipes. RTE does not directly involve the establishment of a new defence line and is a short-term option with a limited lifetime and is not sustainable unless used as part of a longer-term coastal strategy. In the long term, RTE may act as a more effective coastal defence strategy if it is undertaken to facilitate land level accretion through sedimentation of low-lying areas after which flood defences could be progressively removed.

7.2 Estuary Transgression

The process of estuarine transgression as a response to sea level rise must be superimposed upon any management strategy. The roll-over model suggests that, under sea level rise, outer estuary upper intertidal areas would erode and that sediment released will be re-deposited within the inner estuary so allowing the estuary to transgress landward. Managed re-alignment of inner estuary areas requires that a similar area of outer estuary retreat is provided in order to release the necessary sediment to bring the inner site surface up to modern high water levels. The corollary of this process is that, if outer estuary managed re-alignment sites are provided and, critically, their existing flood embankments are removed, then it is predicted that the marsh sediments would rapidly erode away and be re-deposited in inner estuary sites which may lead to deposition in subtidal channels.

Several managed re-alignment sites have already been established or are being planned in the Blackwater: at Orplands, Abbotts Hall, Tollesbury and Northey Island, and the results from these trials have indicated the feasibility of the techniques.

7.3 Management Options

Within the estuaries, the twin processes of natural and artificial coastal squeeze are predicted to result in the almost total loss of salt marsh in the Blackwater and Crouch and major loss of salt marsh in the Colne and Hamford Water. The most sustainable option to counteract predicted salt marsh loss would be to undertake managed re-alignment, possibly incorporating some form of sediment nourishment. However, this would need to be carefully designed in order to prevent collateral damage to the existing habitat in the estuary. The two major problems facing this option are:

- Restoration of inner estuary sites can result in major channel widening throughout the estuary to its mouth involving loss of existing salt marsh.
- Restoration of outer estuary sites results in sediment release which, without suitable inner estuary depositional sites can result in increased subtidal deposition and impacts on water quality, navigation, fisheries etc.

This means that location is perhaps the most critical issue facing any restoration scheme. The most obvious way to avoid both the problems summarised above is to design a restoration programme that provides restored sites along the entire length of the estuary and thus incorporates outer sediment source sites, inner depositional/transgressive sites and the necessary channel widening between the two in order to accommodate the increased tidal flow regime. Such a theoretical scheme is, of course, rarely possible. Moreover, the practicalities of any intertidal restoration scheme relies on agreeing and obtaining suitable land, so that location of a restoration site may have to be independent of geomorphological considerations. These basic considerations lead to the identification of four major management options for the Essex Estuaries.

7.3.1 Holistic restoration

In this instance **holistic restoration** would represent the restoration of reclaimed marshland along the entire length of an estuary in order to accommodate the morphological changes associated with sea level rise.

It is predicted that, if an equilibrium form were achieved in each estuary, then salt marsh loss due to coastal squeeze would be reduced, so minimising the need for compensatory habitat to be created elsewhere. If such an equilibrium form were not achieved then considerable areas of compensatory habitat would be required. Table 4 shows, for example, that over the past decade salt marsh losses of between 40ha (Crouch) and 144ha (Hamford Water) have been identified. If such rates of salt marsh loss were to continue for the next 50 years then restoration in each of the Essex Estuaries of between 200ha and 720ha, and a total of 1515ha in the four estuaries (Crouch/Roach; Blackwater; Colne and Hamford Water) would be required by 2051. If a combination of extrapolated loss is combined with predicted loss using the regime model approach is used then the total loss within the estuaries could be as high as 1904ha (see Table 4).

This option depends upon the existence of suitably located sites for restoration and could present major problems of land acquisition. In practice, to restore an estuary length in its entirety may involve a sequential operation over a period of years, so that this option would be indistinguishable from the progressive restoration option.

7.3.2 Progressive restoration

Progressive restoration is defined here as the sequential restoration of reclaimed marshlands over a period of years beginning in the outer estuary and progressing landward. This would aim to provide a channel width capable of accommodating tidal prism impacts once more landward sites are restored and ultimately achieving a morphology in equilibrium with sea level. This option involves similar problems of land availability and location as for the Holistic Option and the ecological issues associated with this option are similar. However, with a progressive programme of restoration the overall rate of loss of salt marsh vegetation within an estuary could be reduced due to the effects of the tidal prism being effectively confined to the immediate area of the re-alignment site.

7.3.3 Opportunistic restoration

Opportunistic restoration is the restoration of reclaimed marshland as and where sites become available. In effect this option would represent a continuation of existing policy with respect to habitat creation within the estuaries and would be driven by a number of factors, including, significantly, the economic benefit of maintaining, or not, any one stretch of defence. There is no doubt that re-alignment of areas of reclaimed land where defences are uneconomic to maintain delivers benefit with respect to ecological interests through the creation of new habitat (intertidal, i.e. of potential SPA/Ramsar and cSAC interest). However, opportunistic re-alignment has to be viewed within the wider context (both physical and ecological), in that the changes in estuarine processes associated with re-alignment may have adverse impacts on the wider estuarine system through changes in tidal prism. This is unlikely to be a significant issue where re-alignment involves relatively small areas of land (and therefore relatively small increases in the tidal prism).

This factor becomes an issue with respect to the predicted total area of salt marsh habitat that would need to be replaced over the next 50 years in order to achieve no net loss within the Essex Estuaries. Additionally, there is also the possibility that the Essex Estuaries could also act as a potential area for intertidal habitat creation for areas further afield where the potential scope for re-alignment is more limited. As such, opportunistic restoration does not present a strategic approach to habitat creation where potential wider impacts can be minimised and ecological benefits maximised. Having said this, opportunistic restoration does offer some benefits:

- Land for re-alignment may only be available on an opportunistic basis;
- In the short-term (5-10 years), continuation of this approach offers the best means of undertaking habitat creation within the estuaries while further strategic planning and determination of land availability is undertaken;
- The potential wider effects of re-alignment in the upper and mid sections of estuaries can be minimised through management techniques. Sediment nourishment, for instance, enables land surfaces to be raised, thus reducing but not eliminating impacts on tidal prism and potential effects on existing areas of intertidal mudflat and salt marsh.

This form of restoration has similar ecological consequences as the holistic option and may require the re-creation of terrestrial SPA/Ramsar features if such existing areas are used for re-alignment. With respect to existing estuarine faunal and floral interests, if re-alignment and habitat creation occurs throughout an estuary system then it would be expected that the range of designated interest features would be maintained although there could be a shift in the distribution of some habitats within individual estuaries.

With respect to this option the view would be taken that the sections of seawall with a low cost benefit ratio present the best locations for re-alignment from an economic perspective. The further upstream within an estuary these sections are located, however, the less suitable these areas are with respect to tidal volume increase and potential impact on the maintenance of intertidal habitat (notably salt marsh). If re-alignment within these areas were to be undertaken then sediment nourishment could be used as a mechanism to reduce the tidal volume impact and allow opportunistic restoration in these areas to proceed.

7.3.4 Compensatory restoration

Compensatory restoration assumes the maintenance of estuarine flood defences on line with associated loss of existing marshland due to coastal squeeze, and would involve the restoration of open coast or outer estuary reclaimed marshlands in order to provide compensatory habitat. Areas of reclaimed marsh suitable for restoration would not require sediment nourishment and would not have an impact on the existing habitat of the estuaries. Restoration could be achieved in a piecemeal fashion as and where suitable sites became available.

The most obvious location that could provide adequate areas for restoration while minimising impacts on existing resources, is the Dengie Peninsula. The reclaimed marshes on the Dengie extend to almost 4500ha, almost twice the combined area of the existing salt marsh on the Essex Coast (2717ha). The reclamation history of the Dengie has resulted in a series of shore-parallel secondary defences that could be used to undertake a progressive restoration programme developed in phases to allow for assessment and consolidation.

This option has two significant ecological consequences associated with it:

- Maintenance of the existing defence line within the estuaries would continue to provide protection to designated areas of SPA/Ramsar wetland habitat landward of flood defences. However, the loss of salt marsh in the estuaries and increased need to build higher and stronger defences may lead to the isolation of terrestrial habitats from the estuaries. This could result in a diminution in the brackish water interest of these areas and loss or reduction of plant and animal communities dependant on these conditions; and

- Restoration on the open coast may replace the area of salt marsh habitat lost, but it may not be an adequate replacement for the community types and therefore value of the habitats lost. Open coast intertidal habitat tends to be less sheltered from wind and waves than estuarine habitats and therefore support a slightly different species assemblage. This is particularly true with respect to bird species, with the open coast tending to favour species. With the long-term loss of salt marsh in the inner and central parts of estuaries there would therefore be a shift in the population assemblage, with implications for the designated SPA/Ramsar status of all of the Essex Estuaries.

7.4 Issues Associated with Re-alignment over Areas of Terrestrial Ecological Interest

As discussed above, one of the main considerations with respect to the Essex Estuaries is the balance between existing intertidal and terrestrial habitat. The prediction is for a significant loss of intertidal salt marsh habitat, unless large-scale re-alignment of flood defences is undertaken. In some instances this may require re-alignment onto areas of land designated as SPA/Ramsar for terrestrial/aquatic ecological interests. This would only be the case where it would make sense from a geomorphological perspective (i.e. in the outer to central section of the estuary) and therefore could include potential sites such as Old Hall Marshes and Tollesbury Wick.

The potential loss of areas such as Old Hall would represent a significant shift in the balance of terrestrial vs. estuarine habitats within estuaries like the Blackwater. This could have significant implications for overall ecological interests particularly where there are strong links between intertidal and terrestrial areas (e.g. bird feeding and roosting areas). However, given the identified loss of salt marsh habitat to coastal squeeze and the predominance of coastal processes as the driving force behind change, the future for sustainable habitat management lies in enabling adaptation at the coastal/terrestrial interface to occur. Maintaining the balance of ecological interests and promoting estuarine function may therefore require that, in certain instances areas of terrestrial ecological interest may have to be 'sacrificed' and returned to tidal influence. However, in order to seriously consider any internationally designated terrestrial sites as potential areas for re-alignment a significant amount of thought would need to be given to the potential for replacing/re-creating the ecological interests likely to be lost.

At a practical level, where there is a strong economic reason for maintaining a seawall then there is greater potential for allowing either habitats to landward to be maintained or for the creation of terrestrial/freshwater habitats to occur. This does not, or should not preclude the view that existing designated sites to landward may be protected solely for their ecological interest. An analysis of basic criteria for the creation of grazing marsh habitat (including seawall cost benefit data) within the Essex Estuaries area indicates that:

- There is potential scope for replacing existing areas of designated terrestrial wetland interest;
- Freshwater input may not be a limiting factor in the creation of habitats such as grazing marsh and wetland systems; and
- Some areas could potentially be used for either terrestrial or intertidal habitat creation; and

From an ecological perspective the creation of grazing marsh habitat with transition to estuarine habitats would be of greatest benefit. However, this would require specific physical parameters to be met (e.g. topographic levels which would prevent complete and frequent tidal inundation within the site) which may not be present within the CHaMP area. Creation of grazing marsh habitat adjacent to an estuary would also have to take into account predicted sea level rise so that future tidal flooding was not going to be a significant management issue and detrimental to the habitats created.

The alternative to the creation of large areas of grazing marsh habitat adjacent to the estuaries is to examine the ecological interests of the habitat and determine whether an estuarine location is actually required. Re-creating grazing marsh which supports typical brackish water plant and animal communities (particularly invertebrates) requires a coastal/estuarine location and could effectively only be undertaken is such locations. However, many of the bird species associated with the coastal grazing marshes of the Essex Estuaries are typical of lowland wetland grassland habitat within the UK.

The situation may therefore require that the focus in the estuaries should be on the recreation of terrestrial areas lost to re-alignment where transitional saline-freshwater habitats (e.g. borrowdykes, inundation grassland etc.) are re-created rather than the expansive areas of grazing marsh which support wider ranging and mobile bird populations. The exact recreation of areas such as Old Hall may therefore not be required if ecological niche replacement is progressed. In this instance the re-creation of the brackish-freshwater habitats in order to support plant and invertebrate communities could be undertaken in areas of rising land and where freshwater sources/seepages were open to tidal inundation. This type of re-creation would be self-sustaining and require minimal management through traditional agricultural grazing practice. Alternatively, brackish-freshwater habitats could be created through artificial means and as part of managed re-alignment schemes.

In order to ensure that bird species and populations utilising existing grazing marsh habitats could be sustained it may be necessary to create extensive areas of low-lying grazing marsh (i.e. a like for like habitat replacement) adjacent to an estuary. For some species such as brent geese, the creation of suitable areas can be quickly undertaken through the conversion of arable to grassland. For other species (e.g. migrating ruff) the creation of suitable conditions may take longer. Clearly this option would require the selection of areas where flood embankments would be maintained in position (e.g. potentially for wider estuarine morphological or socio-economic purposes). Alternatively, as many of the bird species using coastal grazing marsh for feeding and breeding are wetland specialists rather than specialist intertidal feeders there is the possibility that replacement grazing marsh habitat for terrestrial species could be located away from the estuaries. Suitable locations would be in river floodplains feeding into estuaries or areas of extensive low-lying land e.g. the East Anglian fens or land surrounding The Broads.

8 MONITORING

An essential component of the development of a CHaMP is the need to monitor the predictions of coastal change (morphological change) and resulting ecological impacts and measures put in place to deal with predicted change (e.g. habitat creation measures). CHaMP specific monitoring strategies must aim to manage the risk of any impact arising from the implementation of CHaMPs on the maintenance of the ecological interests of Natura 2000 and Ramsar sites.

8.1 Physical Monitoring

The key parameters of morphological change are the form of the estuaries themselves and the equilibrium between salt marsh and intertidal mudflat. These, therefore, form the main components requiring monitoring to demonstrate whether the predicted changes, both temporally and spatially, are occurring.

8.1.1 Estuaries

The ratio between tidal prism and cross sectional area provides a measure of morphological equilibrium. The measurement of this property requires, first, that a baseline is established and second that this baseline is regularly updated through bathymetric survey data. The survey should provide, as a minimum, cross sections of the estuary channels between High Water Spring Tides (HWST), at 1km intervals along the estuary long axis. Repeat surveys should ideally be at annual intervals. The TP/CA ratio can be analysed over time for significant deviations from the established baseline.

8.1.2 Salt marsh morphology

The extent, distribution and attributes of creeks and surface elevations of salt marshes may be measured using remote sensing. The aerial reconnaissance programme, currently undertaken by the Environment Agency, has several advantages over other methodologies including the existence of a long-term archive in Essex, a well established technique and the ability to determine surface elevations. Other methods, including CASI and LIDAR offer individual advantages but not the range offered by aerial survey. A monitoring programme should therefore use this technique with reconnaissance of the entire coastal area continuing to be undertaken on a five-year basis, with subsequent analysis of the photographs.

Surface elevations of the salt marshes are more accurately surveyed using conventional ground survey techniques and these are currently used within the Environment Agency Anglian Region Strategic Monitoring Programme. This programme includes bi-annual beach profiles, extending across salt marshes where they occur.

8.1.3 Intertidal mudflats

The extent and topography of the intertidal mudflats on the open coast can be derived from the surveys currently undertaken within the Environment Agency Anglian Region Strategic Monitoring Programme. This programme includes the capture of colour, 1:5000 scale, stereoscopic aerial photography of the coastal strip including intertidal areas as well as the ground survey of intertidal profiles. This monitoring is undertaken at periods of low water once every five years.

8.2 Biological Monitoring

As previously stated, predicted changes in morphology are effectively the driving force behind any potential ecological change and therefore the CHaMP should focus on the monitoring of physical components. However, in isolation, the monitoring of physical attributes would not provide an indication of any changes in habitat quality or species populations. It is suggested that these components should be monitored through separate programmes developed to inform and ascertain favourable condition for the designated features rather than as a specific element of the CHaMP. Information from the biological monitoring programme would, however, be important in providing an integrated picture of system change and confirming, or not, the predictions outlined in the CHaMP.

9 CONCLUSIONS

The geomorphological assessment of the Essex Coast and estuaries has demonstrated that transgression rates of the estuaries under accelerated sea level rise will govern most of the habitat changes over the next 30-100 years. The overall conclusion from modelling predictions is that if existing flood defences within the estuaries were to be maintained significant areas of salt marsh would be lost from the estuaries by 2050. The situation for the open coast is rather different where the effect of sea level rise is expected to increase rates of accretion.
The loss of salt marsh from the estuaries would represent an adverse impact upon the ecological interests of the entire Essex Estuaries cSAC and the SPAs present within the CHaMP area as a major component of the ecological diversity would be lost. This loss would have a number of ecological implications with respect to the designated features of the Essex Estuaries cSAC and the SPA/Ramsar sites:

- Direct loss of salt marsh habitat, vegetation communities and associated fauna;
- Loss of habitat used by breeding birds (e.g. avocet, redshank);
- Reduction in estuarine roosting sites for wintering waterfowl; and,
- Loss of a significant source of nutrient input to intertidal mudflats.

Eroded salt marsh would be replaced by intertidal mudflat, although there would probably not be an exact areal replacement. This could have benefits with respect to intertidal mudflat communities and wintering birds, as there would be an increased food resource. However, the loss of a critical element of the entire estuarine ecosystem could have implications beyond the intrinsic value of salt marsh habitat itself (e.g. a decrease in biological productivity).

Designated features to landward could be maintained *in situ*, but to do so would further isolate these elements from the estuarine system, require extensive coastal defence works and also potentially restrict the ability to undertake re-alignment in a progressive and strategic manner. Where it is apparent that re-alignment over areas to landward designated as SPA/Ramsar interest is sustainable, both from an ecological and physical perspective, then habitat replacement would be required to offset loss. This issue is most apparent for areas where the existing flood defences are in need of maintenance or repair in the short term (<10 years).

Using predictive modelling and extrapolation of existing trends it is estimated that an area of 1500-1900 ha of salt marsh habitat would be lost within the Essex CHaMP area over the next 50 years. Replacing this area of salt marsh habitat through managed re-alignment could require a significantly larger area of land to be used. If 50% salt marsh coverage were to be achieved within all re-alignment sites then upwards of 3000-3800ha would be required in order to replace the habitat lost. Potentially sites could be selected or engineered to enable a greater extent of salt marsh to become established, but clearly the figure of 1500ha is the minimum area that would be required for restoration over the 50 year period.

Beyond the 50 year period used in this study, further re-creation of salt marsh habitat within the estuaries maybe required. The extent of creation requirements depends on a number of factors the main ones being the rate of accelerated sea level rise beyond the initial 50 year period and whether the estuaries reach equilibrium during this period (taking into account proposed habitat creation requirements). This aspect can only be addressed when further information and data on sea level rise predictions are available and can be incorporated into future reviews of the CHaMP or SMP.

Replacing such extensive areas of salt marsh vegetation within the Essex Estuaries requires significant decisions to be taken, not just with respect to the ecological interests of the designated European sites but also with respect to economic and social issues. This CHaMP considers the management of the estuaries from an ecological perspective and proposes four potential options that could be progressed in order to offset the predicted loss of salt marsh habitat.

The proposed management options are ‘designed’ around a number of significant issues or considerations, notably the ‘conflict’ between the landward and the seaward components of European sites, and secondly, the value (in ecological terms) of replacement habitat. The first issue may be solved by either maintaining the landward component *in situ* and restoring the intertidal habitat in other parts of the CHaMP area (or potentially further afield), or by re-align over the landward component and recreate the landward features elsewhere.

In order to undertake intertidal habitat creation (for all options) the method which would result in least hydrodynamic impact would be the re-alignment of sites from the open estuary upstream. The emphasis of habitat creation would therefore be in the outer estuaries rather than inner and central sections of estuaries where a significant amount of salt marsh loss would take place. This would have implications for existing designated ecological interests as potentially species more adapted to open coast/outer estuarine conditions would be favoured. A more opportunistic approach to re-alignment, based on economic considerations, as currently undertaken, could be taken which would enable intertidal habitat creation within inner and central sections of estuaries to be advanced, particularly if sediment charging is used as part of the process. It is suggested that this approach could be continued with at a relatively small-scale in the short term. However, due to the potential scale of re-alignment required in the longer term a more structured and strategic approach, which could still make use of opportunities as they arise, will be required. With all options there is the potential that the re-creation of landward features would be needed.

From consideration of the various management options available it is apparent that the existing designated interest features of the Essex Estuaries cSAC and SPA cannot be maintained in their present configuration. Ecological change is inevitable due to changes in the distribution and extent of habitats under a sea level rise scenario. However, the potential for the management of this change does exist.

10 SELECTED REFERENCES

Brooke, J., Meakins, N., and Adnitt, C. (1999) The restoration of vegetation on salt marshes. Environment Agency R&D Technical Report W208.

Burd, F. (1992). Research and survey in nature conservation No. 42: Erosion and vegetation change on the salt marshes of Essex and north Kent between 1973 and 1988, Nature Conservancy Council, Peterborough.

Coastal Geomorphological Partnership (2000). Geomorphological Investigations for the Rivers Crouch and Roach. Report to Environment Agency. University of Newcastle.

Centre for Ecology and Hydrology (2001). Managed realignment at Tollesbury and Saltram, Annual report for 2000, edited by DEFRA. CEH Project C 00356.

Cooper, N. (2000). Erosion of the salt marshes of Essex between 1988 and 1998. Report to Environment Agency.

English Nature (2000). Essex Estuaries European marine site. English Nature’s advice given under Regulation 33 (2) of the Conservation (Natural Habitats &c.) Regulations 1994.

Futurecoast (2002). Draft Report. Halcrow.

Gramolt, D.W. (1961) The coastal marshlands of East Essex between the 17th and mid-19th Centuries. Unpublished MSc thesis, University of London.

HR Wallingford (2001). Southern North Sea Sediment Transport Study, Phase 2. Inception Report. Report produced for Great Yarmouth Borough Council by HR Wallingford, CEFAS/UEA, Posford Duvivier and Dr Brian D’Olier. Report EX 4341.

IECS (1992). Research into salt marsh erosion on the Dengie Peninsula. Report to Environment Agency. Institute of Estuarine and Coastal Studies, Hull University.

IECS (1992). The Thames estuary: coastal processes and conservation. Report to English Nature. Institute of Estuarine and Coastal Studies, Hull University.

IECS (1994). Essex Sea Walls Management Strategy. Report No S015-94-D. Institute of Estuarine and Coastal Studies, Hull University.

JNCC (1999). Estuaries Inventory. Joint Nature Conservation Council, Peterborough.

Lamberth, C., Haycock, N. (2002). Regulated Tidal Exchange: An Intertidal Habitat Creation Technique. Report to RSPB and Environment Agency by Haycock Associates Limited, St. Albans

Pethick J.S. (2001). Rivers Crouch and Roach: Estuary Modelling Study 3: Geomorphological implications of managed retreat onto Flood Compartments. Report to Environment Agency.

Williams, G. and Hall, M. (1987). The Loss of Coastal Grazing Marshes in South and East England, with Special Reference to East Essex, England. Biological Conservation 39 91987) 243-253.