COLONISATION BY SALTMARSH OF FORMER AGRICULTURAL LAND FOLLOWING REALIGNMENT OF A SEA-WALL AT PAWLETT HAMS, BRIDGWATER BAY

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SUMMARY

In 1994, following realignment of a sea-wall at Pawlett Hams, 4.8ha of pasture and arable land were opened up to inundation by seawater. Colonisation of the area by saltmarsh is being investigated through a joint English Nature/Environment Agency monitoring programme.

Within three years *Puccinellia maritima* and *Suaeda maritima* had colonised throughout the area, along with *Spergularia marina, S. media* and *Parapholis strigosa* at higher elevations (6.2–6.7m above Ordnance Datum (AOD)) and *Salicornia europaea* agg. mainly at lower elevations (5.7–6m AOD). The most rapid colonisation was along the toe of the new sea-wall, where by 1997 there was a 3–6m strip dominated by *Puccinellia.* Several uncommon species have become established on the sea-wall and around the fringes of the developing saltmarsh, including *Seriphidium maritimum, Hordeum marinum, Trifolium squamosum* and *Limonium procerum.*

In 1997 the following National Vegetation Classification (NVC) saltmarsh communities were present on the realignment land: SM8 (annual *Salicornia* saltmarsh), SM9 (*Suaeda maritima* saltmarsh), SM10 (transitional low-marsh vegetation), SM13 (*Puccinellia maritima* saltmarsh) and SM23 (*Spergularia marina-Puccinellia distans* saltmarsh). Adjacent areas of long-established saltmarsh comprised mainly SM6 (*Spartina anglica* saltmarsh) and SM10 in the low-marsh (4.5–6.2m AOD), SM13 in the mid-marsh (6.2–6.5m AOD) and SM16 (*Festuca rubra* saltmarsh) in the upper-marsh (>6.5m AOD). On the realignment land extensive stands of SM8, SM9 and SM10 are at higher elevations than equivalent SM10 in neighbouring saltmarshes, indicating that they are probably early-successional communities that will ultimately be replaced by SM13 and, at highest levels, SM16.

KEYWORDS: SEA-WALL REALIGNMENT, MANAGED RETREAT, SALTMARSH, HABITAT CREATION.

INTRODUCTION

Tidal flood defences in the UK are coming under increasing pressure from coastal erosion, with many sea-walls now in considerable danger of being breached or overtopped during storms. Some people argue that we should 'hold the line', with defences repeatedly strengthened to withstand the onslaught. But most agree that a more pragmatic approach is required (English Nature 1992; Burd 1995) – while many sea-walls need to be retained along their existing lines, others could be dismantled and replaced by sea-walls further back, which would then gain protection from the new areas of intertidal land in front of them.

Background to the Realignment Scheme at Pawlett Hams

The sea-wall realignment at Pawlett Hams is one of several pilot managed retreat schemes currently being monitored in the UK. It formed part of a National Rivers Authority (now Environment Agency) scheme to improve flood defences along the eastern bank of the River Parrett, between Dunball Clyce (NGR ST309408) and Huntspill Sluice (NGR ST293457) (National Rivers Authority 1993). The purpose of the flood defence scheme was to protect approximately 1200ha of low-lying agricultural land on Pawlett Hams and Pawlett Level. There is a history of flooding in this area, with severe inundations in 1609, 1798, 1903, 1936, and most recently in December 1981 when flooding occurred as far inland as the M5 motorway (3–4km inland) (National Rivers Authority 1993).

Initially it was envisaged that flood defences would be maintained along the existing line. However, changing priorities led to other options being investigated, including several with a measure of managed retreat. Five options were examined, ranging from 'do nothing' to a full retreat to Pawlett Hill. Having carried out cost-benefit analyses, the favoured option was one that included construction of 1.4km of sea-wall set back from the old line by about 40m, leading to approximately 4.8ha of agricultural land being opened up to inundation by seawater.

Construction of the New Sea-wall

Engineering works on the new flood defences were carried out in 1994. The phased removal of the old sea-wall provided material for use in construction of the new bank. The berm in front of the bank was set at about 6.2m AOD. A delft ditch was constructed to landward of the sea-wall, the purpose of which was to provide further construction material, and to capture flood water in the (unlikely) event of the bank being overtopped during storms. Additional material for construction was won from a borrow pit excavated in a nearby field. The total cost of the realignment scheme was £550,000.

Opportunities for Nature Conservation

From the outset, English Nature and the Environment Agency viewed sea-wall realignment as an opportunity to create a substantial area of new saltmarsh. This is a key habitat within Bridgwater Bay SSSI, providing important winter feeding/roosting areas for wildfowl (especially Wigeon, *Anas penelope*) and waders. The SSSI forms part of the Severn Estuary Special Protection Area (SPA) and Ramsar site on account of its outstanding ornithological interest. The Bridgwater Bay saltmarshes are also included within the Severn Estuary possible Special Area of Conservation (pSAC), as prime examples of so-called 'Atlantic salt meadows' (European Commission 1996). Thus, it was considered that the creation of new saltmarsh at Pawlett Hams would, if successful, add further interest to this internationally important SSSI.

MONITORING METHODS

Baseline Survey

The proposed managed retreat site, comprising a narrow coastal strip between between NGR NT265433 and NGR NT277438 (Cobb's Leaze Clyce), was visited in October 1993. Each of the three fields to be included in the scheme was examined. In the two arable fields (which, during later monitoring and in the Results below, were divided into three areas – Sections 1, 2 and 4) the botanical survey was confined to the sea-wall, field margin and any adjoining saltmarsh, while in the pasture field (Section 3) it included the sea-wall and 2ha of grassland lying within the realignment corridor.

Areas of saltmarsh adjoining Sections 1 and 4 were described with the aid of 20 subjectively located 2 x 2m quadrats (Table 1), five in each of the four communities recognised. In the grassland in Section 3, ten 2 x 2m quadrats were recorded (Table 2): five on the flat pasture, three (Quadrat nos. 2, 6 and 10 in Table 2) in grassland close to the toe of the sea-wall and two (Quadrat nos. 5 and 8) along drainage 'gutters' which crossed the area at 12–14m intervals. In all quadrats species' cover-abundances were recorded using the Domin scale.

Monitoring of the Realignment Land, 1994 to 1997

The site was visited in September 1994, following construction of the new sea-wall and after the realignment land had been inundated several times by seawater. From 1995 onwards the site was visited each year during the period late June–early August.

As already noted, for monitoring purposes the area was divided into four sections. On each visit, the presence/absence of species within 120 randomly located 1 x 1m quadrats were recorded, 30 from each of the four sections. Sampling points were established using computer-generated random numbers, with positions on the ground located by pacing rather than by use of measuring tapes. Percentage-cover of bare ground was also recorded, estimated by eye. The quadrat frame was 'nested', with cell-sizes of 10 x 10cm, 20 x 20cm, 30 x 30cm, 40 x 40cm, 50 x 50cm and 100 x 100cm. Cells were searched sequentially, commencing with the smallest, and for each species a note was made of the cell-size at which it was first encountered. For sake of simplicity, in this paper data are presented for the largest cell-size only (i.e. the entire 1 x 1m quadrat).

Topographical Monitoring

Elevation is critically important in determining the frequency and duration of tidal immersion and, through this, the spatial arrangement of species and communities within the developing saltmarsh (e.g. Ranwell 1972; Adam 1990; Gray 1992).

Repeat surveys of surface topography and elevation were carried out by the Environment Agency, along transect lines aligned perpendicular to the new sea-wall. These surveys showed almost no change in surface elevation during the study period.

In this paper results of the topographical monitoring are not presented, but height data from cross-sectional profiles have been used to delimit approximate elevational ranges for species and species-assemblages, both on the realignment land and in neighbouring areas of long-established saltmarsh.

BASELINE SURVEY

Sections 1 and 2 – Arable

This field, comprising the western third of the study area and bisected by a pylon line (Section 1 to the south-west of the pylon line and Section 2 to the east of it), was cropped for wheat and flax in 1993. The sea-wall was ungrazed, supporting dense stands of *Elytrigia atherica*[1] (=*Elymus*

[1] Nomenclature follows Stace (1997), though on first mention of a species 'old' names are also given in brackets where these are still widely used.

Table 1 Two by 2m quadrats recorded from areas of long-established saltmarsh adjoining realignment land (five quadrats from each community type)

	1	2	3	4	5	Constancy & Domin range
1. Low-marsh SM10 (Section 1)						
Puccinellia maritima	7	8	8	7	6	V(6-8
Suaeda maritima	6	5	6	7	6	V(5-7)
Salicornia agg.	4	6	4	5	2	V(2-6)
Aster tripolium	3	3	2	1	1	V(1-3)
Spergularia media	2		2			II(2)
2. Low-marsh SM6 (E. of Section 4)						
Spartina anglica	8	9	8	7	6	V(7-9)
Suaeda maritima	3	1	4		6	IV(1-6)
3. Mid-marsh SM13(Section 1)						
Puccinellia maritima	9	8	9	9	9	V(8-9)
Triglochin maritima	2	1	3	1	4	V(1-4)
Aster tripolium	3	5	3	3		IV(3-5)
Festuca rubra				2		I(2)
Plantago maritima				2		I(2)
Agrostis stolonifera					1	I(1)
4. Upper-marsh SM16 (Section 1)						
Festuca rubra	7	5	8	8	8	V(5-8)
Juncus gerardii	5	6	2	4	3	V(2-6)
Agrostis stolonifera	5	4	4	5	2	V(2-5)
Aster tripolium	2	4	3	3	1	V(1-4)
Plantago maritima	2	3	4	1	3	V(1-4)
Cochlearia anglica	1	2	2	1		IV(1-2)
Triglochin maritima	3	2		2		III(2-3)
Puccinellia maritima	2		2			II(2)
Spergularia media	2				2	II(2)
Elytrigia atherica	2				4	II(2-4)
Parapholis strigosa					3	I(3)
Seriphidium maritimum					2	I(2)
Limonium procerum					1	I(1)
Hordeum marinum					1	I(1)

pycnanthus, =*Agropyron pungens*) (SM24, *Elymus pycnanthus* saltmarsh[2]). In shorter vegetation at the western end of the sea-wall in Section 1 *Puccinellia distans* and *Hordeum marinum* were noted (possibly SM23, *Spergularia marina-Puccinellia distans* saltmarsh). Along the landward 'toe' of the sea-wall (mainly within Section 2) there were some large patches of *Petroselinum segetum*.

Saltmarsh adjoining Section 1 was comprised principally of SM10 (transitional vegetation with annual *Salicornia*, *Suaeda maritima* and *Puccinellia maritima*) in the low-marsh (5.2–6.2m AOD), SM13 (*Puccinellia maritima* saltmarsh) in the mid-marsh (6.2–6.5m AOD) and SM16 (*Festuca rubra* saltmarsh) in the upper-marsh (>6.5m AOD) (Table 1). In the upper-marsh *Apium graveolens*, *Hordeum marinum*, *Seriphidium maritimum* (=*Artemisia maritima*) and *Limonium procerum* (=segregate within *L.binervosum* agg.) were noted.

SECTION 3 – PASTURE

This field, comprising the central third of the study area, supported low-lying, poorly drained coastal grazing marsh. Quadrat data are given in Table 2. The grassland was referable to MG11a

[2] In the vegetation descriptions, community names and code-numbers are those given in the relevant sections of the National Vegetation Classification (NVC) (Rodwell 1992 and in press).

Table 2 Two by 2m quadrats recorded from grassland within Section 3

	1	2	3	4	5	6	7	8	9	10	Constancy & Domin range
Agrostis stolonifera	8	6	7	7	9	7	8	8	8	5	V (5-9)
Lolium perenne	5	6	5	5	3	7	4	4	4	8	V (3-8)
Festuca rubra	4	4	5	4	2	2	5	3	3		V (2-5)
Hordeum secalinum		3	1	3	4	3	2	4	2	2	V (1-4)
Dactylis glomerata	2	2	3	1				1	4	2	IV (1-4)
Holcus lanatus	3		5	4			4	2	3		III (2-5)
Cynosurus cristatus	2		2	4		3	3		2		III (2-4)
Bellis perennis					1	3		1		1	II (1-3)
Taraxacum officinale agg.						2	1		1	1	II (1-2)
Medicago arabica		1				1				1	II (1)
Elytrigia atherica		5								3	I (3-5)
Trifolium repens				3			2				I (2-3)
Ranunculus bulbosus			1	2							I (1-2)
Sonchus asper		1								1	I (1)
Torilis nodosa		1								1	I (1)
Alopecurus geniculatus								4			I (4)
Cerastium fontanum							1				I (1)
Cirsium arvense	1										I (1)
Cirsium vulgare		1									I (1)
Phleum bertolonii						1					I (1)
Rumex pulcher						1					I (1)
Trifolium pratense							1				I (1)

(*Festuca rubra-Agrostis stolonifera-Potentilla anserina* grassland, *Lolium perenne* sub-community). In places, however, it showed a degree of intermediacy with other mesotrophic grassland communities, in particular with MG13 (*Agrostis stolonifera-Alopecurus geniculatus* grassland) along drainage gutters, and with MG6 (*Lolium perenne-Cynosurus cristatus* grassland) on the sea-wall and close to the gateway at the north-eastern corner of the field. Notable species occurring in Section 3 included *Rumex pulcher* and *Trifolium fragiferum* in the grassland and extensive patches of *Torilis nodosa* on the (heavily grazed) sea-wall. On the seaward face of the sea-wall there were several plants of *Seriphidium maritimum*.

Section 4 – Arable

Comprising the eastern third of the study area, this was a beet field in 1993, with the sea-wall ungrazed and apparently of little botanical interest. The rock armouring along its seaward face held numerous patches of *Seriphidium maritimum*. Saltmarsh adjoining the eastern end of Section 4 was dominated by species-poor stands of SM6 (*Spartina anglica* saltmarsh) (Table 1), lying at 4.5–5.5m AOD.

BOTANICAL MONITORING OF THE REALIGNMENT LAND, 1994 TO 1997

General Observations

Results of the botanical monitoring are summarised in Table 3. After the new sea-wall had been constructed the area was largely devoid of vegetation. Three small blocks of grassland were retained in Section 3, but these were soon killed off following tidal immersion. Even ex- grassland and sea-wall species known to occur in adjoining saltmarsh – such as *Agrostis stolonifera, Elytrigia atherica* and *Festuca rubra* – quickly succumbed.

Previous land use (arable/pasture) and initial substrate (bare/vegetated) did not appear to influence saltmarsh development. The earliest colonists, arriving within weeks of the first

Table 3 Frequency of occurrence (no. of quadrats) of vascular plant species, and bare ground estimates, within 120 random 1 x 1m quadrats (all cell-sizes combined)

	Year 1994	1995	1996	1997
1. Ex-pasture/sea-wall species				
Agrostis stolonifera	12	0	0	0
Alopecurus geniculatus	1	0	0	0
Beta vulgaris ssp maritima	8	1	0	0
Cynosurus cristatus	4	0	0	0
Elytrigia atherica	9	2	1	1
Festuca rubra	7	1	2	1
Hordeum secalinum	4	0	1	0
Lolium perenne	13	0	3	0
Polygonum aviculare	0	0	1	0
Sonchus asper	1	0	0	0
2. Colonising saltmarsh species				
Aster tripolium	0	0	3	8
Atriplex prostrata	2	0	7	8
Cochlearia anglica	3	0	5	3
Hordeum marinum	0	0	2	2
Parapholis strigosa	0	5	18	15
Plantago maritima	0	0	0	1
Puccinellia distans	0	0	1	0
Puccinellia maritima	6	28	62	79
Salicornia agg.	0	0	8	46
Spartina anglica	0	0	0	1
Spergularia marina	0	0	59	62
Spergularia media	6	18	19	22
Suaeda maritima	0	47	38	93
Triglochin maritima	0	0	1	1
3. Bare ground (mean %)				
Section 1	100	98	77	55
Section 2	100	99	73	64
Section 3	99	99	82	75
Section 4	100	98	94	88

inundation by seawater, were located chiefly in the drift-line along the toe of the new sea-wall, presumably establishing there from seed carried in by the tide. More widespread colonisation began in 1995, the main colonists that year being *Suaeda maritima* and *Puccinellia maritima*, while in 1996 there was, in addition, a sudden appearance of *Salicornia europaea* agg. and *Spergularia marina*. By 1997 (three years post-realignment) *Puccinellia* and *Suaeda* were well-established throughout the area, along with *Spergularia media*, *S.marina* and *Parapholis strigosa* at higher elevations (6.2–6.7m AOD) and *Salicornia* mainly at lower elevations (5.7–6m AOD).

In 1994 several rooted plants of *Spartina anglica* were noted growing close to the drift-line and in former drainage gutters within the blocks of retained grassland. None of these plants survived, but observations in subsequent years have indicated that *Spartina* may be able to colonise the low-marsh if uprooted fragments get 'trapped' amongst shoots of other saltmarsh plants. *Spartina* is currently very rare on the realignment land – but large stands of it occur immediately downstream, and opportunities for 'entrapment' may increase as the new saltmarsh becomes established.

Many of the species spreading most rapidly on the new intertidal area were annuals (*Salicornia, Suaeda, Spergularia marina, Parapholis*). On the other hand, species slow to colonise – or absent altogether – were mainly perennials, for example *Aster tripolium*, *Triglochin maritima*, *Agrostis stolonifera, Cochlearia anglica, Festuca rubra, Juncus gerardii* and *Plantago maritima.* These species are all prominent in neighbouring areas of long-established saltmarsh (Table 1); which suggests, not surprisingly, that development of saltmarsh on the realignment land is at an early stage, with a number of mid and late-successional species yet to become established there.

Colonisation Rates and Distribution of Species

Relationships between saltmarsh colonisation and elevation were not studied in detail. However, bare ground estimates (Table 3) indicated that colonisation was more rapid at high elevations (>6.3m AOD) in Sections 1 and 2, than at lower elevations (<6.3m AOD) in Sections 3 and 4. It was also noted that in all years, and in all monitoring sections, vegetation cover was greatest at the top of the shoreline, adjoining the new sea-wall (>6.1m AOD).

The distribution of several species appeared to be strongly influenced by elevation. This is reflected, in a general way, in Table 4, which gives 1997 frequency data for the six commonest species across the four monitoring sections. *Salicornia* was most frequent in Section 4, which has the largest expanse of low-elevation substrate (<6m AOD). *Puccinellia* and *Spergularia marina*, on the other hand, occurred at highest frequency in Section 2, much of which, lying as it does at 6.3–6.4m AOD, is at a similar elevation to neighbouring areas of long-established SM13 (*Puccinellia maritima* saltmarsh). *Spergularia media* and *Parapholis strigosa* were found widely only within Section 1 (at >6.5m AOD), their presence in other monitoring sections being largely restricted to patches of upper-marsh close to the sea-wall (6.2–6.7m AOD).

Several other saltmarsh colonists, including *Hordeum marinum, Limonium procerum, Seriphidium maritimum* and *Trifolium squamosum,* occurred mainly in high elevation areas adjoining the sea-wall. *H.marinum* has spread rapidly, in places forming a distinct band along the seaward face of the sea-wall (6.5–7.0m AOD), as well as being found sparsely in the drier parts of Section 2. *T.squamosum* occurs chiefly in (artificially seeded) grassland on and to the landward side of the new sea-wall, but in 1997 a few plants were found with *H.marinum,* in saltmarsh fringing the sea-wall in Section 2 (at about 6.7–6.9m AOD).

Table 4 Frequency of occurrence (no. of quadrats) of the main colonising saltmarsh species within the four monitoring sections (1997 1 x 1m quadrat data, 30 quadrats in each section)

	Monitoring section			
	1	2	3	4
Salicornia agg.	9	11	9	**17**
Suaeda maritima	18	24	**26**	25
Puccinellia maritima	25	**27**	17	10
Spergularia marina	21	**24**	6	11
Spergularia media	**10**	8	3	1
Parapholis strigosa	**9**	4	2	0
Elevation range (metres AOD)	6.3-6.7	6.3-6.5	5.7-6.1	5.7-6.2

NVC Communities

By 1997 it had become possible to recognise an assortment of species-assemblages on the realignment land, and these can be tentatively assigned to NVC communities.

Throughout the area the main communities were SM9 (*Suaeda maritima* saltmarsh) and SM10 (transitional low-marsh vegetation with annual *Salicornia, Suaeda maritima* and *Puccinellia maritima*). At lowest levels (<6m AOD), and locally in depressions (incipient pans) at higher elevations, there were patches of SM8 (annual *Salicornia* saltmarsh). At moderate to high elevations SM9 and SM10 formed a mosaic with extensive 'carpets' of *Spergularia marina* (putative SM23, *Spergularia marina-Puccinellia distans* saltmarsh). Close to the toe of the sea-wall there was a well vegetated 3–6m strip dominated by *Puccinellia maritima* (SM13, *Puccinellia maritima* saltmarsh) and patches of *S.marina* (SM23). On the sea-wall itself, within the artificially seeded grassland, there were open areas with *Parapholis strigosa, Trifolium squamosum* and *Hordeum marinum* (occasionally also *Puccinellia distans*), probably also referable to SM23.

DISCUSSION

Is Saltmarsh Colonisation Proceeding as Expected?

There is little doubt that, to date, the Pawlett Hams managed retreat has been successful. Since construction, the sea-wall has been subjected to several storm events and has performed well, while the new strip of intertidal land is rapidly being colonised by saltmarsh, particularly at higher elevations.

Gray and Warman (1993) visited the proposed realignment site in 1993, and made a number of predictions about the way in which the area would become colonised by saltmarsh. They expected that the earliest colonists would be nitrophilous and easily dispersed species such as *Aster tripolium* and *Atriplex prostrata* (Gray and Warman 1993). Perhaps surprisingly, both these species were poorly represented in the first 'wave' of colonisers, the pioneers instead being mainly other nitrophilous or ruderal species such as *Suaeda*, *Salicornia* and *Spergularia marina*. *Puccinellia maritima* was also an important early colonist, particularly at higher elevations, and appears to be establishing itself rather more quickly than originally envisaged.

In the longer term, Gray and Warman (1993) predicted that the new saltings would be dominated by *Festuca rubra* (SM16) – possibly with *Agrostis stolonifera* – at higher elevations, and by *Puccinellia maritima* (SM13) at lower elevations. They noted that the elevation of the new intertidal area would generally be above the *Spartina anglica* (SM6) zone and below the *Elytrigia atherica* (SM24) zone, making it likely that both these species/communities would be absent or, if present, then restricted to the extreme lower and upper fringes respectively.

On the realignment land, many stands of SM8, SM9 and SM10 are at higher elevations (6.2–6.5m AOD) than SM10 in neighbouring long-established saltmarshes (<6.2m AOD). Thus, it is hard to imagine that these 'low-marsh' communities on the realignment land are anything other than transitory. That being the case, one would anticipate a shift towards SM13 – the 'appropriate' community at that elevation – as *Suaeda* and *Salicornia* decline and *Puccinellia* increases. SM8, SM9 and SM10 would then become increasingly restricted to the lowest elevations (perhaps also, locally, in pans at higher levels) with the rest of the area dominated by SM13. Such developments lie firmly in the future, though there are already stands of *Suaeda* at higher elevations being colonised by sprawling patches of *Puccinellia*, producing SM10 which, in turn, may be a transitory community *en route* to SM13.

At high elevations, the eventual balance between *Puccinellia*-dominated SM13 and *Festuca*-dominated SM16 is hard to predict. In Section 1, parts of the upper-marsh are prone to waterlogging, conditions known to give *Puccinellia* a competitive advantage over *Festuca* (Gray and Scott 1977). Furthermore, the sea-wall grassland and new saltmarsh is to be grazed by livestock, with the aim of producing a tight close-cropped sward suitable for grazing wildfowl. Such a management regime may also favour *Puccinellia*, allowing it to persist even at elevations where one would normally expect *Festuca* to be the dominant grass (Ranwell 1968, fig. 1.26, in Adam 1990). Thus, we anticipate that SM16 will be absent from all but the extreme upper-marsh at the south-western end of the site (Sections 1 and 2). SM23 (*Spergularia marina-Puccinellia distans* saltmarsh), on the other hand, will probably benefit from such a management regime. Elsewhere in Bridgwater Bay SM23 is well represented in saltmarshes and on sea-walls which are grazed and trampled by livestock (S. J. Leach pers. obs.).

While grazing would certainly limit opportunities for colonisation by grazing-sensitive species such as *Atriplex portulacoides* (=*Halimione portulacoides*), *Limonium vulgare* and *Seriphidium maritimum*, it would also, importantly, prevent the spread of *Elytrigia atherica* on the sea-wall and fringing upper-marsh. On ungrazed marshes dense stands of *E.atherica* (SM24, *Elymus pycnanthus* saltmarsh) can have a stifling effect on botanical diversity, both of species and communities. Several species of key interest at Pawlett Hams (e.g. *Hordeum marinum, Trifolium squamosum, Limonium procerum*) thrive in open conditions, and would probably be lost if the upper-marsh and sea-wall were left ungrazed. However, D.A. Coombe (in Stewart *et al.* 1994) considered *T.squamosum* to be intolerant of trampling or grazing, so its response to grazing management will need to be monitored.

Comparisons with Other Studies

There are currently few other sites for which monitoring data are available. On realignment land at Northey Island, on the Blackwater Estuary, Essex, *Salicornia* and *Suaeda maritima* were the main colonists in the first two years of tidal inundation, together with *Puccinellia maritima* on higher ground (Turner and Dagley 1993; Dagley 1995). As observed at Pawlett Hams, the most rapid colonisation and greatest species-richness were at relatively high elevations, particularly along the toe of the new sea-wall.

Similar results have emerged from botanical monitoring at two other managed retreat sites on the Blackwater Estuary, at Tollesbury (C. Reid, pers. comm.) and at Orplands (HR Wallingford Ltd 1997). At all three Essex sites, the main colonising communities were 'low-marsh' SM8, SM9 and SM10, although at Orplands – as at Pawlett Hams – carpets of *Spergularia marina* have recently appeared (C. Reid, pers. comm.). It is anticipated that in the longer term these pioneer communities will be replaced by others, such as SM11 (*Aster tripolium* var. *discoideus* saltmarsh) or SM14 (*Halimione portulacoides* saltmarsh) – quite different from those expected to develop at Pawlett Hams, but perhaps this is not surprising given the different tidal regimes, the lack of grazing management and the different 'pool' of available species at the Essex sites.

Future Monitoring

This paper provides an account of the early stages of saltmarsh colonisation at Pawlett Hams. Further monitoring, at less frequent intervals but over a longer time period, is now being undertaken, to document any further shifts in the species composition of these saltmarshes, to investigate in more detail the influence of elevation on saltmarsh development, and to assess the impact of grazing management.

The results of the study will help to inform the planning and implementation of future realignment schemes elsewhere in the Bridgwater Bay area. In the longer term, it is hoped that it will contribute to a more general understanding of the dynamics of saltmarsh development following managed retreat.

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