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Northey Island managed retreat scheme

Results of botanical monitoring 1991 to 1994

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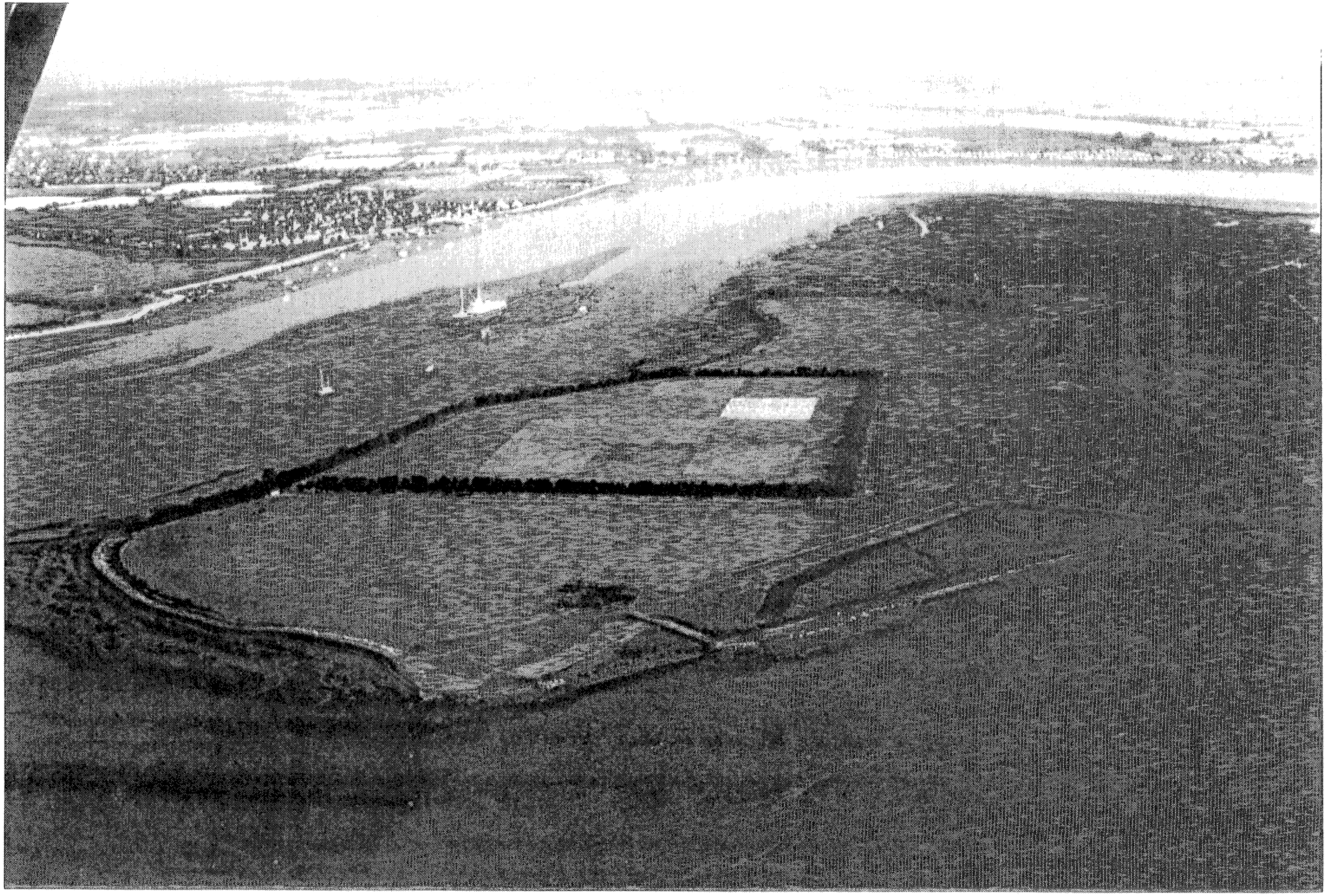

NORTHEY ISLAND

A view from the south showing the managed retreat site in the south east corner (Autumn 1991)

ENGLISH NATURE RESEARCH REPORT

No. 128

NORTHEY ISLAND: MANAGED RETREAT SCHEME

Results of botanical monitoring 1991 to 1994

J R Dagley

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obtained from the Essex, Hertfordshire
and London Team, English Nature,
Harbour House, Hythe Quay,
Colchester, Essex, CO2 8JF.

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EXECUTIVE SUMMARY

1. A collaborative managed retreat experiment, involving The National Trust, the National Rivers Authority and English Nature, was set up on Northey Island in the Blackwater Estuary, Essex in 1991.

2. The aim of the experiment is to create about 0.8 hectares (2 acres) of saltmarsh to provide replacement habitat for eroded saltings and a longer-lasting coastal defence for the island's farmland.

3. English Nature is carrying out botanical monitoring of the colonising vegetation on the site using random nested quadrats as the recording method.

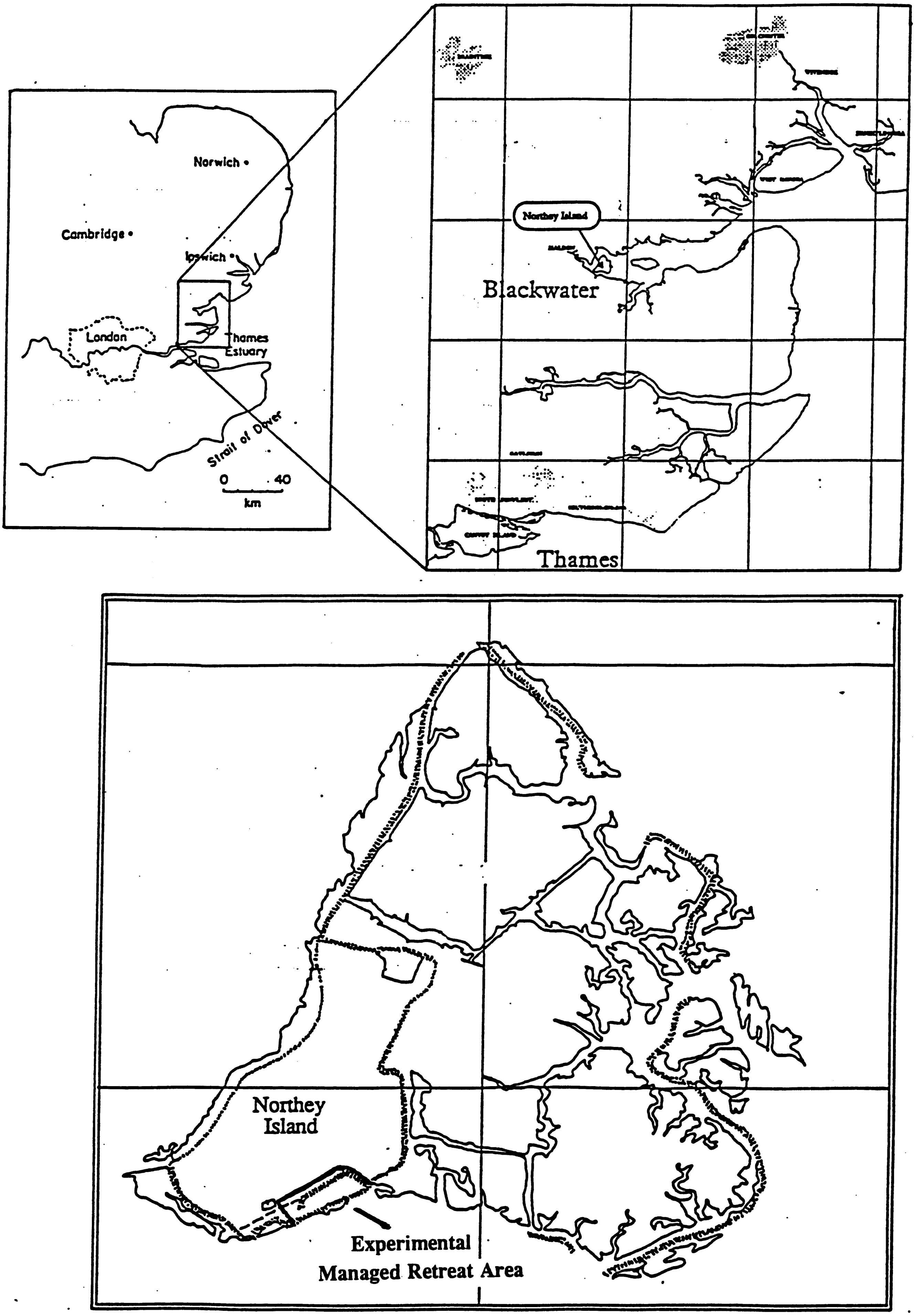
4. The first botanical survey was carried out before the sea wall was taken down in June 1991 and revealed that the site was a typical coastal grassland community dominated by Red Fescue and Creeping Bent with a deep litter layer.

5. After the sea wall was lowered about 100 tides a year could inundate the lower parts of the site. The sea-water killed off all but a small section of the meadow vegetation.

6. Botanical surveys in 1992 and 1993 showed that there had been rapid colonisation of the area by saltmarsh plants. By 1993, two years after the experiment started, a recognisable pioneer saltmarsh community had become established across the whole area of survey.

7. By 1994 twenty-five species of plant had colonised the site, including the nationally-scarce Shrubby Sea-blite (*Suaeda vera*). In addition, other recognisable saltmarsh communities were developing and intergrading with the first.

MAP 1 - LOCATION OF NORTHEY ISLAND MANAGED RETREAT AREA



NORTHEY ISLAND: MANAGED RETREAT SCHEME

RESULTS OF BOTANICAL MONITORING 1991 TO 1994

1. INTRODUCTION

1.1 In 1991 an experiment aimed at creating an area of saltmarsh habitat was started on Northey Island in the Blackwater Estuary in Essex (Map 1). The experiment was the result of discussions between The National Trust (NT), the National Rivers Authority (NRA) and English Nature (EN). These three bodies jointly funded the experiment (NRA 50%; NT 25%; EN 25%) with English Nature concentrating on the survey and monitoring (Turner and Dagley 1993).

1.2 The experimental site subject to monitoring covers an area of 0.8 ha (2 acres approx.) (Map 1).

1.3 Survey and monitoring was carried out before and after the construction of the experimental area. The work included topographical surveys, measurements of tides, examination of sediment characteristics, design of a sluice and sea wall system, measurements of sediment accretion and monitoring of vegetation changes. All of these items of work apart from the last one were carried out by the Institute of Estuarine and Coastal Studies, University of Hull (IECS) and the results of the studies have been presented in a series of reports (IECS 1991a, 1991b, 1992, 1994a). These reports also contain a rationale for managed retreat and a background to the Northey Island situation (see also Turner and Dagley 1993).

1.4 The monitoring of vegetational changes was carried out by English Nature staff and the results from the monitoring in the years 1991 to 1994 are the subject of this report. A chronological summary of all the main survey and monitoring events appears in Appendix 1.

1.5 The site was first inundated by tides in July 1991.

2. METHODS

2.1 A monitoring technique using randomly-located "mini quadrats" within a fixed grid was chosen as the most suitable to record the changes in vegetation (Leach and Doarks 1991). The site was considered too small for stratified random samples to be taken. Randomly- placed permanent quadrats and permanent quadrats along a permanent transect line were both considered but these techniques were rejected because of a number of serious drawbacks, in particular the difficulty of marking them. These drawbacks and a rationale for the chosen technique of random quadrats are discussed in a short background note which forms Appendix 2 of this report.

2.2 Two axes of the fixed grid were marked out on the ground using ranging poles. Two permanent concrete marker posts were placed at either end of the x-axis to enable its relocation. The concrete posts had to be placed close to existing fence lines to ensure they were not damaged by agricultural activities (eg silage making) or by the sea-wall construction work; they also had to be placed outside the area that was to become tidal. For these reasons the distance between the two marker posts (200.23m) is not an exact number of metres.

2.3 Pairs of coordinates were then chosen using random numbers tables (Lindley and Miller 1970) with the x-axis coordinates being chosen first, to the nearest metre, while the y-axis coordinates were chosen to the nearest 10 centimetres. In the case of the x-axis random numbers were chosen between 000 and 150 and in the case of the y-axis between 00.0 and 50.0; three digit numbers in both cases. The first 50 pairs of coordinates that fell inside the experimental area were used as the quadrat positions. New coordinates would be selected by this method in each year. The x-axis was then marked out on site, landward of the new sea wall, using ranging poles. The origin of the x-axis was taken from the concrete post at the eastern end of the site.

2.4 The 50 quadrat positions were located in 1991 and 1992 using two 50m tape measures and measuring out at a right angle from the x-axis. To achieve a right angle with the x-axis a 3 x 4 x 5 (or 6 x 8 x 10) triangle was measured to define a vertical grid line. From 1993 onwards the right angle has been estimated using compass bearings from the x-axis. Ranging poles and a sighting compass were then used to maintain a straight line to the position of each quadrat. The grid lines arising from the x-axis had to cross over the sea wall and this undoubtedly introduced errors into the measurement of lengths. However, it is not considered that this introduced any significant bias into the positioning of the quadrats.

2.5 Once a grid line had been defined other quadrat locations within 3 metres of either side were positioned using this line. The edge of the metal 1 x 1 m quadrat was used to define a right angle with the grid line and from there the metal quadrat was carefully moved to the location.

2.6 The quadrats used were nested so that in 1991 records were taken for 50 x 50 cm, 25 x 25 cm and 10 x 10 cm areas. In 1992, with sparser saltmarsh vegetation cover, a 1 x 1 metre quadrat was used in addition to the other three sizes. When the quadrat was placed on the ground the smaller quadrats were always in the bottom left hand corner (as defined by the permanent grid's point of origin) of the larger quadrats. From 1993 onwards the 10 x 10 cm quadrat was not used as it did not yield any additional useful information.

2.7 All vegetation <u>rooted within</u> a quadrat was recorded and species were marked as present or absent. Species with the greatest cover were also noted, although in some 1992 quadrats on the saltmarsh, where only one plant of each species was present, this was not done. Bare ground, litter and areas of open water were also recorded as percentage cover to the nearest 5%. The recording forms used (see Appendix 3) were those designed by the England Field Unit of the Nature Conservancy Council for grassland monitoring (Byrne 1991).

2.8 Plant species were recorded using the new nomenclature and classification of Stace (1991).

2.9 Monitoring of 50 nested quadrats was completed in two days each year in 1991 and 1992 and one day in both 1993 and 1994.. The work was carried out on 13th and 14th June 1991, 24th June and 2nd July 1992, 21st June 1993 and 29th July 1994. The data collected from the 1992 to 1994 monitoring days are presented in Appendix 3; the original recording forms are kept at English Nature's Colchester office with copies at Peterborough HQ.

3. RESULTS

3.1 1991 results

The data collected from the survey of the hay meadow showed a typical semi-improved Essex coastal grassland community in which grasses were the dominant component of the vegetation, with relatively few other flowering plants present (see Photograph 1, Appendix 4). Red Fescue (*Festuca rubra*) and Creeping Bent (*Agrostis stolonifera*) were co-dominant in the sward. Meadow Barley (*Hordeum secalinum*) was widespread across the meadow but was overlooked during the quadrat survey and was only noticed when in flower in early July. Smooth Meadow Grass (*Poa pratensis*) and Perennial Rye Grass (*Lolium perenne*) were also common. In total 14 species of higher plant were recorded in the meadow (see Tables 1 and 2 below).

Also notable was the thick litter layer across the whole grassland which suggested that the grassland hadn't been managed particularly tightly for several years prior to the experiment. Hay crops may have been left and grazing had probably been concentrated on the more nutritious swards in the neighbouring fields.

Table 1 **QUADRAT RESULTS FOR HAY MEADOW PLANTS**

Summary of 1991 50 x 50 cm quadrat data from a sample of 50 quadrats

Species	Frequency - no. of quadrats in which species present	No of quadrats in which species formed greatest cover
Festuca rubra	48	23
Agrostis stolonifera	50	25
Poa pratensis	37	-
Lolium perenne	28	1
Phleum pratense	2	-
Holcus lanatus	7	-
Hordeum secalinum	OVERLOOKED	OVERLOOKED
Vicia sativa	23	1
Vicia tetrasperma	3	-
Trifolium pratense	3	-
Lotus corniculatus	1	-
Cerastium fontanum	14	-

Table 2 **OTHER HAY MEADOW PLANTS**

Other species within the managed retreat area NOT recorded from the quadrats in 1991

Sea Couch	(*Elytrigia atherica*)
Grass vetchling	(*Lathyrus nissolia*)

3.2 1992 results

The monitoring during 1992 revealed that the hay meadow vegetation recorded in 1991 had been killed off and was lying as a thick mat of litter across most of the site. The only area of the site where this was not the case was the highest area (3.2m OD) in the western corner next to the new sea wall. Here patches of Red Fescue and Sea Couch remained alive.

There had been reasonable, although patchy, colonisation by saltmarsh plant species across most of the area. The densest area of colonisation (the area of least bare ground) was on the highest areas of the site at the western corner around the remnant patches of Sea Couch. Here bushy growth of Annual Sea-blite (*Suaeda maritima*) and numerous rosettes of Sea-spurrey (*Spergularia* spp.) were present.

From observations of the general distribution of higher plants across the site colonisation appeared to have been better where there was less of the old litter layer and more bare ground. The results from the quadrats, however, did not confirm the significance of these observations (see Table 3 below): the litter layer did not significantly affect the rate of colonisation.

On the other hand, on the bare ground around the edges of the site, where clay infill had been placed in May 1992 during remedial works on the old borrowdyke by the NRA, colonisation was poorer, possibly because of the recent compaction.

Table 3 **EFFECTS OF BARE GROUND AND LITTER**

Chi-square (χ^2) test for differences in colonisation by higher plants of 1 x 1m quadrats locations containing greater than 50% bare ground and those containing greater than 50% litter cover (1992 survey)

		No. of quadrats with Higher Plants		
		Absent	Present	TOTAL
1 x 1 metre quadrats	Bare ground > 50%	6	9	15
	Litter cover >50%	19	10	29
	TOTAL	25	19	44

χ^2 = 1.69 (1 degree of freedom)
NOT SIGNIFICANT

The two most common higher plant colonisers were Annual Sea-blite and species of Glasswort (*Salicornia* spp.), the main one of which was probably *Salicornia europaea* agg. Filamentous algae (*Enteromorpha* spp) provided the greatest area of plant cover over the site. A dense mat of the algae had formed over the grass litter in most areas and the algae appeared to be more abundant on the lower, wetter areas of the site. In quadrats where litter was absent, and where there was little open water, there was usually little or no *Enteromorpha* (see Appendix 3). This could have been due to a combination of drier conditions and lack of any holdfasts, which seem to be a requirement for *Enteromorpha* colonisation (SERG 1992).

3.3 1993 and 1994 results

The survey in 1993 showed a large increase in plant cover across the whole site. There were few areas in which a 50 x 50cm quadrat would have encompassed no higher plants. In addition, the total number of plant species present on the site had increased from 17 in 1992 to 22 in 1993 (Table 4 below). In particular, *Salicornia* spp. and Annual Sea-blite populations had increased dramatically since 1992. The vegetation now clearly constituted a recognisable National Vegetation Classification (NVC) saltmarsh community (SM8) (see Photograph 5, Appendix 4).

Table 4 LIST OF COLONIZING PLANTS

COLONIZING SPECIES		Species present in		
Latin names	(English names)	92	93	94
**Vaucheria* sp.	(algae)	✓	✓	✓
Enteromorpha sp.	(algae)	✓	✓	✓
Cochlearia anglica	(English Scurvy-grass)	-	-	✓
Atriplex prostrata	(Spear-leaved Orache)	✓	✓	✓
**A. littoralis*	(Grass-leaved Orache)	✓	✓	✓
**A. patula*	(Common Orache)	✓	✓	✓
A. portucaloides	(Sea-purslane)	✓	✓	✓
Sarcocornia perennis	(Perennial Glasswort)	(✓)	✓	✓
Salicornia spp.	(Glasswort spp.)	✓	✓	✓
**Suaeda vera*	(Shrubby Sea-blite)	(✓)	✓	✓
S. maritima	(Annual Sea-blite)	✓	✓	✓
Spergularia media	(Greater Sea-spurrey)	-	✓	✓
S. marina	(Lesser Sea-spurrey)	✓	✓	✓
Limonium vulgare	(Common Sea-lavender)	-	✓	✓
**Armeria maritima*	(Thrift)	-	-	✓
**Plantago maritima*	(Sea Plantain)	-	-	✓
**P. coronopus*	(Buck's-horn Plantain)	-	✓	✓
Aster tripolium	(Sea Aster)	✓	✓	✓
**Juncus maritimus*	(Sea Rush)	-	✓	✓
Festuca rubra subsp. *littoralis*	(Red Fescue)	✓	✓	✓
Puccinellia maritima	(Common Saltmarsh-grass)	✓	✓	✓
**Agrostis stolonifera*	(Creeping Bent)	✓	✓	✓
Elytrigia atherica	(Sea Couch)	✓	✓	✓
Hordeum marinum	(Sea Barley)	-	✓	✓
Spartina anglica	(Common Cord-grass)	✓	✓	✓
	TOTALS:	**17**	**22**	**25**
	MEAN No. OF SPECIES PER 1x1m QUADRAT:	1.56	2.96	3.54

() denotes that species present but not recorded that year

* denotes that the species was **not** recorded in a quadrat

The algae, mostly *Enteromorpha*, had not significantly increased their cover but, nonetheless, they still formed the greatest vegetation cover across the site. Other plant species, such as Sea-purslane (*Atriplex portucaloides*) and Common Saltmarsh-grass (*Puccinellia maritima*), had increased their cover to a small extent as shown by the

The 1994 results revealed a number of interesting changes in plant distribution and abundance. Firstly, an increase in the plant diversity was observed across the whole site. The mean number of plant species per 1 x 1 metre quadrat increased from 1.56 in 1992 to 2.96 in 1993 to 3.54 in 1994. Sea Lavender and Sea Aster both seemed to have finally established themselves but were present in very small numbers. After three summers of tidal inundation there was still no sign of an Aster marsh (NVC type: SM11), typical of low marshes in Essex, developing.

Glasswort species remained the dominant higher plants on the marsh, but the other pioneer species, Annual Sea-blite, showed a decline. Although still widespread (32 quadrats in 1994 as compared to 37 in 1993) Annual Sea-blite plants seemed to be becoming sparser, as judged by the number of 50 x 50 cm quadrats in which they were found (see Table 5 below).

The other main change was the large increase in cover of Common Saltmarsh-grass, which was becoming the dominant species on the higher parts of the marsh nearer to the sea wall.

Sea-purslane continued its steady increase and remained more common than both Sea Lavender and Sea Aster. Shrubby Sea-blite, which had established in the first summer, now formed a substantial colony along a ridge of higher ground (3.2m OD) landward of the western arm of the main drainage channel. On the higher ground behind the Shrubby Sea-blite there was a varied flora and Greater Sea-spurrey had increased its cover dramatically (see Photograph 6, Appendix 4).

The areas of compacted clay infill (May 1992), around the perimeter of the site, had been colonised by *Salicornia* spp.and *Suaeda maritima*, but the colonisation was still occurring at a noticeably slower rate than over the rest of the marsh (see also IECS 1994a).

Table 5 QUADRAT RESULTS FOR COLONIZING PLANTS

Summary of 1992, 1993 and 1994 **1 x 1 m** [and 50 x 50 cm] quadrat data from a sample of 50 random quadrats in each year.

Species	Frequency of occurence (no. of quadrats)		
	1992	1993	1994
Algae (*Enteromorpha*)	**44** [34]	**48** [48]	**44** [34]
Cochlearia anglica	**0** [0]	**0** [0]	**1** [1]
Atriplex prostrata	**0** [0]	**0** [0]	**1** [1]
A. portucaloides	**4** [1]	**4** [3]	**8** [2]
Sarcocornia perennis	**0** [0]	**0** [0]	**3** [2]
Salicornia spp.	**12** [6]	**47** [37]	**44** [44]
Suaeda maritima	**10** [4]	**37** [33]	**32** [25]
Spergularia media	**0** [0]	**3** [2]	**9** [5]
S. marina	**2** [1]	**2** [2]	**7** [3]
Limonium vulgare	**0** [0]	**0** [0]	**2** [0]
Aster tripolium	**1** [1]	**0** [0]	**4** [1]
Festuca rubra	**0** [0]	**0** [0]	**1** [1]
Puccinellia maritima	**5** [2]	**6** [5]	**19** [12]
Elytrigia atherica	**1** [0]	**0** [0]	**1** [1]
Hordeum marinum	**0** [0]	**1** [1]	**0** [0]
Spartina anglica	**0** [0]	**1** [0]	**2** [0]

3.4 Sea wall flora

The old sea wall that was lowered in July 1991 supported two scarce plant species, *Lepidium perfoliatum* and the nationally scarce (NCC 1989) Mousetail (*Myosurus minimus*). For *L. perfoliatum* Northey Island appears to be one of only about 12 sites in Britain where this alien species has become naturalised (Rich 1991). The NRA, therefore, undertook to seed the new sea wall outside the experimental area with seeds collected from populations of both plants from the old wall. The seeding of *Lepidium perfoliatum* worked very well and hundreds of plants germinated there in 1992 and again in 1993. Similarly, Mousetail successfully colonised the landward facing slopes of the new sea wall.

4. DISCUSSION

Methodological considerations

4.1 The random mini-quadrat method appeared to be picking up the general extent of colonisation reasonably well. It certainly proved a rapid and convenient way of collecting data. What is clear from the nested quadrat modification used in this case is that the 1 x 1 metre quadrat size is required to monitor the early colonisation.

4.2 The fixed grid (y = 50m; x = 150m) does not cover the westernmost corner of the site which is inundated less frequently by the tides. This area contains the remnants of the old grassland and the greatest density and diversity of colonisation. A grid with an x-axis of 175 metres would have covered some of this area and perhaps given a more complete picture of the vegetation of the experimental site. At present there are no plans to monitor this area but if there was more time available a permanent transect from this corner to the spillway might prove interesting to monitor. Such a transect would also provide a useful comparison with the random mini-quadrat method.

4.3 In addition to the limits of coverage, the sampling method itself is not good at revealing the within-site variation apparent from visual inspection. For example, there is a greater diversity of species towards the toe of the new sea wall which is not easily revealed by the data from the quadrats. Some form of vegetation mapping would provide extra information and this may be carried out in future surveys.

Observations and results

4.4 Initially, the presence of a deep litter layer, as a result of leaving the grass unmown prior to the lowering of the sea wall, was a cause of concern. There were two main reasons for this. Firstly, there were fears that the litter layer might be lifted off and washed out of the area. This fear proved to be unfounded. Secondly, it was considered that the mulching or smothering effect of the saturated litter layer might inhibit the establishment of seedlings. Although in 1992 colonisation did look better in the areas of bare ground, the analysis in Table 3 suggested that this was not significant. By the second year, 1993, a lot of the litter had gone or was itself covered by algae and sediment and plants had colonised most areas (see Appendix 3).

4.5 In managed retreat experiments in the USA litter has actually been deliberately introduced to improve the organic content of the surface layer; the absence of litter has been seen as a problem (Phil Williams pers. comm.). However, it may still be a good idea to mow a grass sward before allowing inundation. What cannot be answered by this experiment is whether a closed grassland sward is more suitable than a cultivated field for saltmarsh creation. This would be interesting to experiment with in any future studies.

4.6 Another possible advantage of the litter layer may be that it acts as a good holdfast substrate for *Enteromorpha* colonisation and this may have significant consequences in terms of nitrogen fixation on the embryonic marsh. However, *Enteromorpha* survives on mudflats elsewhere in the Blackwater Estuary and so holdfasts may not be a significant limiting factor here. It certainly is unlikely that more *Enteromorpha* has colonised this deep grass mat than would have colonised a mown grass sward.

4.7 The botanical monitoring reported here is mainly concerned with the colonisation of the site by higher plants. The role of algae, especially microalgae (eg diatoms), is not being examined closely, although it is argued that they play an important role in the turnover and binding of sediments (Underwood and Paterson 1993). However, an initial inspection was made in 1993 by Essex University and it is planned that monitoring of algae, particularly the distribution of diatoms within the sediments, may be studied in detail at this or another managed retreat site in future.

4.8 One other concern remains the pattern of sediment deposition. Lower down the slope of the site there was more sediment deposited on the litter surface and sediment was apparently most abundant towards the mouth of the spillway (John Pethick pers. comm). It was certainly apparent that there was little sedimentation, in the first year, alongside the new sea wall. Early indications seem to suggest that sediment may build up near to the tidal entrance of the site. If this proves to be the case, and the sediment stabilises there, this may provide a sill which will tend to pond-back the water over the rest of the site. Any ponding-back of sea-water may cause problems with higher plant colonisation because where water lies there is no plant colonisation.

4.9 A channel system has gradually developed on the site with the already-existing low-way acting still as the main drainage channel. A new channel has cut its way through to join this low-way, but there are still problems with poor drainage in parts of the site (IECS 1994a). The early development of an efficient drainage pattern is probably critical to ensure success for two reasons. Firstly a channel system allows sediment to be deposited further into the marsh (IECS 1993) and, secondly, it allows water to drain off exposing the area to plant colonisation. The bigger the site the more important this is likely to be. It would be interesting to experiment with this in future on other sites.

4.10 The saltmarsh established by 1993 was almost entirely a pioneer *Salicornia* community: National Vegetation Classification (NVC) type SM8 (Burd 1989; NCC unpub.). By 1994 some differentiation was visible, with a thin strip of transitional low saltmarsh (NVC type SM10), made up of *Puccinellia*, *Salicornia* and *Suaeda* mainly, beginning to develop on higher ground. Higher still (3.2m OD) a more diverse community of *Suaeda vera* and *Elytrigia atherica*, with abundant Greater Sea-spurrey (*Spergularia media*) and *Atriplex* spp., had developed. This community was very mixed and seemed to include elements of NVC communities SM13, SM24 and SM25. The change from an agricultural mesotrophic grassland community, something akin to MG11 (Rodwell (ed.) 1992), to completely different NVC communities has been rapid compared with development of terrestrial communities.

4.11 Work on historical retreat sites in Essex (eg where sea walls were breached and were not repaired after the 1953 floods) shows that old enclosed marshes, inundated in the last 100 years, have developed into a mixture of NVC community types SM11, *Aster tripolium* var. *discoideus* saltmarsh, and SM10, transitional low saltmarsh, with *A. tripolium* as the most conspicuous species throughout (IECS 1994b; see also Burd 1995). The monitoring reported here, however, has confirmed that Sea Aster is not a successful primary coloniser (NCC unpub.) and has been slow to establish. Along with Sea Lavender, it still has a very small presence on the site (see Table 5 above).

4.12 Future monitoring on Northey Island should determine how persistent the present *Salicornia* pioneer community is and whether or not it is just a stage towards the gradual development of an *Aster* pioneer marsh or another more complex saltmarsh community. If the latter is the case, then it will be important to understand the differences between Northey and other historical retreat sites in Essex and to examine the importance of elevations and slope in determining any differences.

4.13 The relative height and slope of Northey should allow the development of diverse and transitional plant communities (Burd 1995) and so future monitoring will also provide an excellent opportunity to record the rate of change from one plant community to another. Chapman (1959) suggested that Aster marsh took about 25 years to develop from *Salicornia* pioneer marsh on naturally-forming saltmarshes at Scolt Head Island, Norfolk. He also postulated that there might be a reasonably predictable succession of plant communities with time. It will be interesting to see whether there is any such succession on Northey and how the rate and sequence compare to naturally-formed systems.

4.14 The rapid establishment of dense vegetation cover on the Northey Island managed retreat site may have been favoured by the relatively high surface of the inundated land. Burd (1995; see also IECS 1994b) has suggested that on historical retreat sites whenever the surface elevations are above about 2 metres OD marshes lose less of their vegetated surface to erosion; in other words they are more sustainable. The 2m "threshold" is an indicative level above which marshes seem to be able to retain vegetation on more than 60% of their surface area. At Northey the experimental site slopes from about 3.2m OD to 2.6m OD at its lowest point, comfortably above the 2m "threshold". Long-term monitoring will reveal how stable the vegetation cover is at this site and may help us to understand the processes that have taken place on the other inundated sites.

4.15 Outside the saltmarsh experiment, the maintenance of the sea wall populations of *Lepidium perfoliatum* and Mousetail will depend on the amount of bare ground created each year for their seeds to germinate in. At present, the wall is only mown occasionally to maintain a path. Grazing is not allowed, in order to protect the developing saltmarsh. However, if the populations are to be maintained some disturbance, ideally through grazing, will be essential. In the next few years the populations will require close monitoring and managing by hand if necessary.

5. CONCLUSIONS

5.1 The hay meadow sward was almost entirely killed off during the first months of tidal inundation.

5.2 The thick litter layer left on the surface did not prevent establishment of saltmarsh plants.

5.3 Areas of shallow standing water were not colonized by higher plants. The early development of an efficient drainage system seems to be critical to the success of saltmarsh creation, particularly on a site much larger and deeper than the present one.

5.4 *Enteromorpha* algae established across the site covering, in the form of a mat, almost every area of mud and litter.

5.5 Higher plants, mainly *Salicornia spp.* and *Suaeda maritima* established across the whole site. In total 23 species of higher plant have colonised to date. The mean number of species per quadrat doubled from 1.56 in 1992 to 3.54 in 1994. The greatest diversity, and density, of plants has become established near the new sea wall on the highest areas of ground, at about 3.1m OD.

5.6 A new saltmarsh habitat formed within two years of starting the experiment. A recognisable NVC annual *Salicornia* saltmarsh community (SM8) had established itself by 1993 and by 1994 was intergrading with a transitional low-marsh community (SM10). The rapidity of the colonisation process may have been due, in part, to the relatively high surface elevations of the managed retreat site.

5.7 Future monitoring should reveal whether these communities are stable, or are themselves part of a progression towards a different type of saltmarsh, such as an Aster marsh (SM11) or Sea-purslane marsh (SM14) for example. It should also be possible to measure the percentage of the marsh surface on which vegetation cover is retained and thereby make comparisons with other retreat sites and naturally-formed marshes at different elevations and in different conditions.

6. ACKNOWLEDGEMENTS

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The managed retreat scheme at Northey Island is on National Trust property and entry is by permit only. This experiment is jointly funded by the National Rivers Authority, The National Trust and English Nature.

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APPENDIX 1

SITE DESCRIPTION AND CHRONOLOGY OF MONITORING EVENTS

A. SITE DESCRIPTION

NORTHEY ISLAND : 140 ha

EXPERIMENTAL AREA : 0.8 ha

SEA WALLS:

- all the walls around Northey had been constructed by 1774
- the first main breaches of these walls, allowing "natural re-formation" of the saltmarshes, took place in 1900

B. CHRONOLOGY OF MONITORING EVENTS

Nov 1990	Discussions began.
April 1991	Decision made - NRA/NT/English Nature to share costs 50%, 25%, 25% - full length new sea wall to be built.
May 1991	IECS work including: Topographical survey; Tidal data gathered (20th May - 5th June); Sediment analysis; Design of sluice and wall heights.
June 1991	EN Botanical survey (13/14th June); IECS report of initial survey
July 1991	Visit to observe wall-building. Photographs taken of site before inundation (9th July). Experimental area construction completed by NRA and opened to the sea (costs: £22,000).
August 1991	Topographic survey repeated; Accretion plates put in position.
September 1991	Visit to make photographic record of site following inundation (4th September). Observation by IECS of high tide (17th September).
October 1991	Results of IECS monitoring.

January 1992	Accretion plates re-measured.
February 1992	IECS review report.
May 1992	Remedial works on borrowdyke and new sea wall; fencing against cattle
June 1992	EN 2nd Botanical survey (24th June) Review meeting at Peterborough between NRA, NT, EN (25th June)
July 1992	EN 2nd Botanical survey completed (2nd July)
December 1992	Discussions with Dr. Graham Underwood (Essex University) concerning additional survey work on microalgae (eg diatoms) (18th December) First sample of microalgae taken for biomass estimate by Essex University
February 1993	3rd topographical survey carried out by IECS (15-19th February)
March 1993	Second sample of microalgae taken for biomass estimate by Essex University Summary report of preliminary results of investigation of microbial assemblages and microalgal biomass produced by Essex University
June 1993	EN 3rd Botanical survey (21st June)
February 1994	4th topographical survey carried out by IECS
March 1994	IECS Review report
July 1994	EN 4th botanical survey (29th July)

APPENDIX 2

Northey Island
Botanical monitoring strategy

Geoff Radley

APPENDIX 2

NORTHEY ISLAND BOTANICAL MONITORING STRATEGY

Background

A small area that is currently grassland will be inundated by the sea later this year when the earth bank protecting it is allowed to break as part of an experimental setback scheme. It is hoped that saltmarsh will re-establish itself at the site. Monitoring is required to measure the speed and direction of the vegetational changes.

Approaches to monitoring

There are a number of different approaches to this process. The pro's and con's of three of them are set out below:-

1. Permanent quadrats

   These are easy to interpret intuitively but suffer from several serious drawbacks:

   a) Relocation in a rapidly changing environment may be difficult.

   b) Quadrats age. The process of marking and repeatedly monitoring them renders them untypical of the area as a whole.

   c) Because such quadrats take a relatively long time to record only a limited number can be marked. These locations could be destroyed by chance factors such as creek formation, thus wrecking the monitoring scheme.

2. Random mini quadrats

   These offer considerable flexibility and the ability to conduct valid statistical analyses of the results. They also have the advantage of not requiring to be permanently marked.

   A monitoring scheme of this type does however need to be designed around the analysis of the results. There are several possibilities, of which I shall explore two.

   2.1 Analysis of Variance

   Analysis of variance is a sophisticated statistical technique that will show how much of the variation in a set of observations can be related to one or more variables. It has obvious attractions in this case where we want to look at the reaction of a heterogeneous site to changes that will vary in nature and magnitude over that site. The use of this technique is advocated in Byrne (1991).

   It would be possible to design a series of experimental designs with different degrees of sophistication that would help to reflect this complexity. There is however one big snag. It is not possible to treat different species from the same quadrat as independent variables. So it is only really valid to look at one species per set of quadrats. If we are so restricted then it would be nice to look at a saltmarsh species that is coming in, rather than a grassland species that is on the way out. However, for experimental validity this one species really needs to be chosen in advance, and the direction of the succession is so uncertain that this would be impossibly risky.

The validity of any analysis of variance would also be open to question because of the difficulties of randomising samples with respect to time, 1992 must follow 1991!

At a deeper level also this is an inappropriate form of analysis. It may be suitable for detecting the subtle changes that may reflect changes in grassland management but it is not appropriate to describe the complete replacement of one community by another, which is what we expect to occur.

2.2 Multivariate analysis by ordination

Analyses of this type have the advantage of being able to use all the information available on floristic variation. The experimental design can be very simple, unrestricted random sampling, but the analysis will allow major axes of variation to be related to environmental parameters such as position within the site, height relative to sea level, and year of recording. The principal drawback is that the interpretation of the results is essentially qualitive, rather than quantitative. Rowell (1988) discuss the use of ordination to interpret the results of monitoring.

My conclusion from the above is that on balance the best monitoring technique would be to record presence/absence of all species within a series of randomly located mini quadrats distributed throughout the area that is to be inundated. Certain structural parameters such as bare ground, litter and vegetation height should also be recorded from those quadrats. The exercise should be repeated using a fresh set of randomly located mini quadrats in each subsequent year and the results analysed using an ordination technique such as 'Decorana'. As a 'back up' it may be worth recording two or three traditional, permanently marked, quadrats.

Size of mini quadrat may take some further work to determine. Saltmarsh vegetation tends to be more coarse grained than grassland for which 10 x 10 cm quadrats have been used by EFU. I would suggest trying 25 x 25 cms. If in doubt it may be worth using 'nested' quadrats, at least initially.

Number of quadrats may again require some trials but I would suggest 50 per year as an adequate number that should not be impossibly onerous.

Quadrats should be positioned using a pair of axis along the margins of the sites and random number tables to determine the coordinates. It would be useful to plot the axes and hence the quadrat locations on the topographic base map supplied by Hull University, so that the height of the quadrats can be recorded. A procedure for recording random quadrats is given in Rowell (1988).

A useful refinement, if it were possible, would be to position a second block of random mini quadrats in an adjacent, similar area that was not going to be inundated. This could act as a 'pseudo-control'.

Geoff Radley
Coastal Ecologist
SSD

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APPENDIX 3

Data from 1992, 1993, and 1994 monitoring quadrats

APPENDIX 3 Sheet ① of ⑨

Frequency of species within a sample area 1992 Recorders G.P. RADLEY + J.R. DAGLEY

Site NORTHEY IS. Date 24/06/92 Start time 11-00 Finish time 15-40

Sample area 1 x 1 metre / 50 x 50 cm Date Start time Finish time

Quadrat number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
Species X-axis Random numbers	9	16	18	18	20	20	20	21	26	26	26	27	33	33	33	36	37	38	39	42	
Y-axis	23 ·8	5 -6	12 ·5	34 ·1	22 ·3	27 ·1	32 ·4	23 ·2	21 ·4	23 ·3	44 ·5	45 ·3	30 ·8	33 ·3	40 ·9	21 ·4	34 ·3	23 ·9	50 ·6	42 ·1	
Enteromorpha / algae	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	
Puccinellia maritima	✓								✓												
Elytrigia atherica																					
Suaeda maritima	✓								✓												
Salicornia spp.			✓			✓															
Aster tripolium																					
Halimione portulacoides																					
Spergularia marina			✓																		
OPEN WATER																			100		
LITTER	30	5	100	100	100	100	100	100	95	100			80	85	80	100	95	100		80	
BARE GROUND	70	95							5		60	30	20	15	20		5			20	
TOTAL NO. OF SPECIES	3	1	3	1	1	2	1	1	3	1	1	1	1	1	1	1	1	1	1	1	

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
Enteromorpha / algae									(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	
Puccinellia maritima																					
Elytrigia atherica																					
Suaeda maritima																					
Salicornia spp.																					
Aster tripolium																					
Halimione portulacoides																					
Spergularia marina																					
OPEN WATER																			100		
Litter	30	5	100	100	100	100	100	100	100	100			80	95	90	100	100	10		90	
Bare ground	70	95									80	40	20	5	10					10	
Total number of species	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	
Vegetation height																					

Key	presence of mature plant ✓	presence of mature plant and seedling ✓s	Record bare ground and litter as amounts visible from directly overhead and as '50' if cover 50 % or more
	presence of seedling s	species with greatest cover (✓)	

APPENDIX SHEET of

Frequency of species within a sample area 1992

Recorders GPR + JRD / *JRD + I BLACK

Site NORTHEY IS.

Date 24/06/92 Start time 11-00 Finish time 15-40

Sample area 1 x 1 metre/50x50cm *Date 02/07/92 *Start time 07-30 *Finish time 10-30

*→

Quadrat number	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	Total
Species X-axis Random numbers	49	53	53	56	58	58	68	71	73	77	79	81	87	88	89	90	90	91	105	108	
Y-axis	9 -2	17 -0	34 -2	11 -4	13 -4	24 -1	10 -4	28 -1	11 -2	24 -1	37 -1	22 -2	31 -6	22 -4	14 -1	26 -2	37 -2	13 -4	22 -0	41 -4	
Enteromorpha/algae	✓	✓	✓			✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Puccinellia maritima	✓			✓	✓																
Elytrigia atherica																					
Suaeda maritima	✓				✓		✓						✓								
Salicornia spp.	✓						✓		✓										✓		
Aster tripolium																	✓				
Halimione portulacoides									✓				✓								
Spergularia marina																					
OPEN WATER												100			40			75			
LITTER	20	100	40	10	10	100	5	100	10	90	100		100	100		100	10		85	30	
BARE GROUND	80		5	90	90		95		90	10					60		90	25	15	70	
TOTAL NO. OF SPECIES	4	1	1	1	2	1	2	1	2	1	1	1	3	1	1	1	2	1	2	1	
Enteromorpha/algae	✓	✓	✓			✓		✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	
Puccinellia maritima				✓	✓																
Elytrigia atherica																					
Suaeda maritima					✓																
Salicornia spp.	✓						✓		✓										✓		
Aster tripolium																	✓				
Halimione portulacoides																					
Spergularia marina																					
OPEN WATER												100			60			90			
Litter	20	100	40	10	5	100		100	5	100	100		100	100		100	80		75	25	
Bare ground	80			90	95		100		95						50		20	10	25	75	
Total number of species	2	1	1	1	2	1	1	1	1	1	1	0		1	1	1	2	1	2	1	
Vegetation height																					

Key	presence of mature plant ✓ presence of seedling s	presence of mature plant and seedling ✓s species with greatest cover ◯✓	Record bare ground and litter as amounts visible from directly overhead and as '50' if cover 50 % or more

APPENDIX 3 Sheet ③ of ⑨

Frequency of species within a sample area

1992 Recorders J.R.DAGLEY + I. BLACK

Site NORTHEY ISLAND Date Start time Finish time

Sample area 1x1 metre/50x50cm Date 02/07/92 Start time 07-30 Finish time 10-30

Quadrat number	41	42	43	44	45	46	47	48	49	50											Total
Species X-axis Random numbers	100	111	116	121	134	134	135	140	140	142											
Y-axis	44 ·1	32 ·1	17 -6	15 -2	22 -4	37 -3	36 -5	32 -5	31 -3	46 -5											
Enteromorpha /algae		✓	✓		✓	✓	✓	✓	✓												
Puccinellia maritima																					
Elytrigia atherica				✓																	
Suaeda maritima		✓		✓		✓			✓												
Salicornia spp.		✓	✓	✓		✓	✓	✓													
Aster tripolium																					
Halimione portulacoides			✓			✓															
Spergularia marina				✓																	
OPEN WATER			20	5	100				40												
LITTER		100				100	75	100	60												
BARE GROUND	100		80	95			25			100											
TOTAL NO. OF SPECIES	0	3	3	4	1	4	2	2	2	0											
Enteromorpha /algae		✓	✓		✓	✓	✓	✓	✓												
Puccinellia maritima																					
Elytrigia atherica																					
Suaeda maritima				✓		✓			✓												
Salicornia spp.			✓				✓														
Aster tripolium																					
Halimione portulacoides			✓																		
Spergularia marina				✓																	
OPEN WATER					100				10												
Litter		100				100	75	100	90												
Bare ground	100		100	20			25			100											
Total number of species	0	1	3	2	1	2	2	1	2	0											
Vegetation height																					

Key presence of mature plant ✓ presence of mature plant and seedling ✓s

presence of seedling s species with greatest cover ⓥ

Record bare ground and litter as amounts visible from directly overhead and as '50' if cover 50 % or more

APPENDIX 3 Sheet (4) of (9)

Frequency of species within a sample area 1993 Recorders J.R.DAGLEY + G.P.RADLEY

Site NORTHEY IS. MAN. RETREAT Date 21/06/93 Start time Finish time

Sample area 1x1metre / 50x50cm Date Start time Finish time

1 x 1 metre

Quadrat number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
Species x-axis Random numbers	9	7	11	18	17	17	22	28	32	33	34	34	35	39	39	41	41	45	46	47	
Y-axis	24^{3}	40^{8}	29^{6}	32^{5}	42^{2}	31^{7}	23^{4}	34^{5}	06^{3}	16	10^{9}	14	48^{8}	31^{8}	27^{8}	27	43^{3}	46^{2}	47^{6}	15^{9}	
Enteromorpha / algae	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Puccinellia maritima									✓		✓										
Hordeum marinum									✓												
Spartina anglica												✓									
Suaeda maritima	✓		✓	✓			✓	✓	✓	✓	✓	✓			✓	✓	✓			✓	
Salicornia spp.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Atriplex (Halimione) portulacoides									✓											✓	
Spergularia marina																					
Spergularia media									✓											✓	
OPEN WATER																	2		70		
LITTER									15	5		1								1	
BARE GROUND	90		10	25			40					5									
TOTAL NO. OF SPECIES	3	2	3	3	2	2	3	3	7	3	4	4	2	2	3	3	3	2	2	5	
Enteromorpha / algae	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Puccinellia maritima									✓		✓										
Hordeum marinum									✓												
Spartina (maritima?)																					
Suaeda maritima	✓		✓				✓		✓	✓	✓	✓			✓	✓	✓			✓	
Salicornia spp.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Atriplex (Halimione) portulacoides									✓												
Spergularia marina																					
Spergularia media									✓											✓	
OPEN WATER																			40		
Litter										5		2								2	
Bare ground	95		30	5			50					5									
Total number of species	3	2	3	2	2	2	3	2	7	3	4	3	2	2	3	3	3	2	2	4	
Vegetation height																					

50 x 50 cm

Key	presence of mature plant ✓ presence of seedling s	presence of mature plant and seedling ✓s species with greatest cover (✓)

Record bare ground and litter as amounts visible from directly overhead and as '50' if cover 50 % or more

APPENDIX 3 Sheet ⑤ of ⑨

Frequency of species within a sample area 1993

Recorders J.R. DAGLEY + G.P. RADLEY

Site NORTHEY IS. MAN. RETREAT

Date 21/06/93

Start time

Finish time

Sample area 1x1 metre / 50x50cm

Date

Start time

Finish time

1x1 metre

Quadrat number	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	Total
Species X-axis Random numbers	51	51	52	54	56	56	56	57	60	64	68	70	74	75	81	81	99	106	107	109	
Y-axis	36	26^{8}	30^{3}	28^{3}	45	24^{7}	19^{4}	22^{3}	29	48^{9}	21^{2}	45^{1}	24^{1}	43	31	22^{2}	47^{5}	22	32^{6}	22^{3}	
Enteromorpha / algae	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	
Puccinellia maritima													✓								
Hordeum marinum																					
Spartina anglica																					
Suaeda maritima	✓	✓	✓	✓		✓	✓	✓	✓		✓		✓					✓	✓	✓	
Salicornia spp.	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	
Atriplex (Halimione) portulacoides													✓								
Spergularia marina																					
Spergularia media																					
OPEN WATER					100					30		90			100	95					
BARE GROUND					90					15		30				95					
LITTER							5				30		30					10	1	3	
TOTAL NO. OF SPECIES	3	3	3	3	1	3	3	3	3	2	3	2	5	2	0	1	2	3	3	3	

50x50cm

	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	
Enteromorpha / algae	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	
Puccinellia maritima													✓								
Hordeum marinum																					
Spartina (maritima?)																					
Suaeda maritima	✓		✓	✓		✓	✓	✓	✓		✓		✓					✓	✓	✓	
Salicornia spp.	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	
Atriplex (Halimione) portulacoides													✓								
Spergularia marina																					
Spergularia media																					
OPEN WATER					100					75		80			100	80					
Litter							5			5	40		10					10	3	3	
Bare ground					80											90					
Total number of species	3	2	3	3	1	3	3	3	3	2	3	2	5	2	0	1	2	3	3	3	
Vegetation height																					

Key	presence of mature plant ✓	presence of mature plant and seedling ✓s	Record bare ground and litter as amounts visible from directly overhead and as '50' if cover 50 % or more
	presence of seedling s	species with greatest cover ◯✓	

APPENDIX 3 Sheet (6) of (4)

Frequency of species within a sample area 1993

Recorders: J.R.DAGLEY + G.P.RADLEY

Site: NORTHEY IS. MAN. RETREAT

Date: 21/06/93 Start time: Finish time:

Sample area: 1x1 metre / 50x50cm

Date: Start time: Finish time:

1 x 1 metre

Quadrat number	41	42	43	44	45	46	47	48	49	50	Total
Species x-axis Random numbers	110	112	117	133	134	143	147	148	149	135	
y-axis	36^1	20^4	38^6	24^2	39^4	45^5	46^1	19^3	49^2	11^5	
Enteromorpha / algae	✓	✓	✓	✓	✓	✓	✓	✓		✓	
Puccinellia maritima								✓	✓	✓	
Hordeum marinum											
Spartina anglica											
Suaeda maritima	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Salicornia spp.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Atriplex (Halimione) portulacoides										✓	
Spergularia marina		✓						✓			
Spergularia media								✓			
OPEN WATER											
BARE GROUND		90	1	40	40	75	98	20	98	30	
LITTER				2				5		4	
TOTAL NO. OF SPECIES	3	4	3	3	3	3	3	6	3	5	

50 x 50cm

	41	42	43	44	45	46	47	48	49	50	Total
Enteromorpha / algae	✓	✓	✓	✓	✓	✓	✓	✓		✓	
Puccinellia maritima								✓	✓		
Hordeum marinum											
Spartina (maritima?)											
Suaeda maritima	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Salicornia spp	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Atriplex (Halimione) portulacoides										✓	
Spergularia marina		✓						✓			
Spergularia media											
OPEN WATER											
Litter				5				3			
Bare ground		80		60	10	80	98	30	99	30	
Total number of species	3	4	3	3	3	3	3	5	3	4	
Vegetation height											

Key			
	presence of mature plant ✓	presence of mature plant and seedling ✓s	Record bare ground and litter as amounts visible from directly overhead and as '50' if cover 50 % or more
	presence of seedling s	species with greatest cover (✓)	

APPENDIX 3 Sheet (7) of (9)

Frequency of species within a sample area 1994

Recorders J.R.DAGLEY + M.HOULDEN

Site NORTHEY IS. MAN. RETREAT
Date 29/07/94
Start time 09-00
Finish time 14-00

Sample area 1x1M / 50x50cm
Date
Start time
Finish time

Quadrat number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
Species x-axis Random numbers	4	3	4	7	9	12	13	16	18	19	20	25	28	28	31	32	33	37	51	53	
y-axis	$26^{.9}$	$28^{.2}$	$42^{.2}$	$28^{.6}$	$08^{.8}$	$45^{.3}$	$10^{.3}$	$18^{.2}$	$28^{.8}$	$21^{.8}$	$49^{.5}$	$41^{.0}$	$10^{.5}$	$22^{.7}$	$20^{.3}$	$19^{.2}$	$46^{.8}$	$39^{.4}$	$37^{.8}$	$41^{.7}$	
Enteromorpha / algae	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	(✓)	✓	✓	
Puccinellia maritima	✓			✓	✓			✓	✓				(✓)								
Elytrigia atherica																					
Spartina anglica										✓									✓		
Festuca rubra																					
Suaeda maritima	✓	✓		✓	✓		✓	✓					✓			✓			✓		
Salicornia spp.	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	✓	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	
Sarcocornia perennis				✓												✓					
Atriplex portulacoides					✓								✓								
Atriplex prostrata																					
Aster tripolium																					
Cochlearia anglica					✓																
Spergularia marina					✓								✓								
Spergularia media													✓								
OPEN WATER											50							20		30	
LITTER																				2	
BARE GROUND	75	70	-	-	15	5	70	5	-	-	35	5	-	25	10	-	15	15	5	50	
TOTAL No. OF SPECIES	4	3	2	5	7	2	2	4	3	3	2	2	7	2	2	4	2	2	4	2	
Enteromorpha / algae	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	(✓)	✓	✓	
Puccinellia maritima				✓	(✓)			✓					(✓)								
Elytrigia atherica																					
Spartina anglica																					
Festuca rubra																					
Suaeda maritima	✓	✓		✓	✓		✓	✓					✓								
Salicornia spp.	(✓)	(✓)	(✓)	✓	✓	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	✓	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	
Sarcocornia perennis				✓												?					
Atriplex portulacoides					✓																
Atriplex prostrata																					
Aster tripolium																					
Cochlearia anglica					✓																
Spergularia marina					✓																
Spergularia media																					
OPEN WATER											15		✓					20		5	
Litter																				2	
Bare ground	75	65	-	-	-	10	90	-	-	-	70	-	-	80	5	-	5	-	-	25	
Total number of species	3	3	2	5	7	2	2	4	2	2	2	2	5	2	2	3?	2	2	2	2	
Vegetation height																					

Key	presence of mature plant ✓ presence of seedling s	presence of mature plant and seedling ✓s species with greatest cover (✓) HIGHER PLANT ONLY	Record bare ground and litter as amounts visible from directly overhead and as "50" if cover 50 % or more

Frequency of species within a sample area 1994

Recorders: G.P. RADLEY + T. INGHAM

Site: NORTHEY IS. MAN. RETREAT
Date: 29/07/94
Start time: 09-00
Finish time: 14-00

Sample area: 1x1m/50x50cm
Date:
Start time:
Finish time:

1 x 1 metre

Quadrat number	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	Total
Species x-axis Random numbers	59	66	66	66	69	71	74	78	79	84	85	85	87	87	94	99	100	102	107	111	
y-axis	12.9	11.1	34.2	48.5	23.4	12.1	19.6	23.7	15.9	26.1	27.9	38.2	22.1	34.4	16.8	18.7	38.1	42.5	41.6	29.5	
Enteromorpha / algae	✓	✓	✓	(✓)	✓	✓	✓	✓		✓	✓		✓	✓		✓	✓	✓	✓	✓	
Puccinellia maritima	✓	✓			✓	✓	✓	✓			✓		✓			✓					
Elytrigia atherica																					
Spartina anglica																					
Festuca rubra																					
Suaeda maritima	✓	✓	✓		✓	✓	✓	✓		✓			✓	✓		✓	✓	✓	✓	✓	
Salicornia spp.	(✓)	(✓)	(✓)		(✓)	(✓)	(✓)	(✓)		(✓)	(✓)		(✓)	(✓)		(✓)	(✓)	(✓)	(✓)	(✓)	
Sarcocornia perennis	✓																				
Atriplex portulacoides	✓												✓			✓					
Atriplex prostrata																					
Aster tripolium	✓	✓			✓											✓					
Limonium vulgare																					
Spergularia marina		✓					✓									✓					
Spergularia media	✓				✓								✓								
OPEN WATER				90					70			100			100						
LITTER	10	25	2			5	5	5		2	2		5	5		2	5	2	5	3	
BARE GROUND	—	10	—	10	—	10	—	25	30	75	70	—	—	—	—	—	15	—	—	—	
TOTAL NO. OF SPECIES	8	6	3	1	6	4	5	4	0	3	3	0	6	3	0	7	3	3	3	3	

50 x 50

Enteromorpha / algae	✓	✓	✓		✓	✓	✓	✓		✓	✓		✓	✓		✓	✓	✓	✓	✓	
Puccinellia maritima	(✓)	(✓)				✓	✓						✓			✓					
Elytrigia atherica																					
Spartina anglica																					
Festuca rubra																					
Suaeda maritima	✓	✓			✓	✓	✓	✓					✓	✓		✓	✓	✓			
Salicornia spp.	(✓)	(✓)	(✓)		(✓)	(✓)	(✓)	(✓)		(✓)	(✓)		(✓)	(✓)		(✓)	(✓)	(✓)	(✓)	(✓)	
Sarcocornia perennis	✓																				
Atriplex portulacoides																					
Atriplex prostrata																					
Aster tripolium																✓					
Limonium vulgare																					
Spergularia marina		✓														✓					
Spergularia media																					
OPEN WATER				100					50			100			100						
Litter	5	20	4				5	10					5			5	3	4	3	3	
Bare ground	—	5	—	—	—	10	—	10	50	85	85	—	—	—	—	—	20	—	—	—	
Total number of species	5	5	2	0	3	4	4	3	0	2	2	0	4	3	0	6	3	3	2	2	
Vegetation height																					

Key
presence of mature plant ✓
presence of seedling s
presence of mature plant and seedling ✓s
species with greatest cover (✓) HIGHER PLANT ONLY

Record bare ground and litter as amounts visible from directly overhead and as "50" if cover 50 % or more

APPENDIX 3 Sheet ⑨ of ⑨

Frequency of species within a sample area 1994 **Recorders** J.R. DAGLEY + M. HOULDEN

Site NORTHEY IS. MAN. RETREAT **Date** 29/07/94 **Start time** 09-00 **Finish time** 14-00

Sample area 1x1m / 50x50cm **Date** **Start time** **Finish time**

1 x 1 Metre

Quadrat number	41	42	43	44	45	46	47	48	49	50											Total
Species x-axis Random numbers	113	119	129	130	134	137	142	143	144	146											
y-axis	21.4	49.9	36.6	14.2	30.8	44.6	29.3	30.9	19.3	31.0											
Enteromorpha/algae	✓		✓		✓		✓	✓	✓												
Puccinellia maritima	✓				✓			✓	✓												
Elytrigia atherica				(✓)																	
Spartina anglica							✓														
Festuca rubra				✓																	
Suaeda maritima	✓	✓	✓		✓	✓	✓	✓	✓												
Salicornia spp.	(✓)	(✓)	(✓)		(✓)	(✓)	(✓)	(✓)	✓												
Sarcocornia perennis																					
Atriplex portulacoides	✓			✓			✓														
Atriplex prostrata				✓																	
Aster tripolium																					
Limonium vulgare								✓	✓												
Spergularia marina	✓			✓																	
Spergularia media	✓				✓		✓	✓	(✓)												
OPEN WATER							10			100											
LITTER									10												
BARE GROUND	-	85	-	-	-	60	20	15	-												
TOTAL NO. OF SPECIES	7	2	3	5	5	2	6	6	6	0											

50 x 50cm

Enteromorpha/algae	✓		✓		✓		✓	✓	✓												
Puccinellia maritima					✓				✓												
Elytrigia atherica				(✓)																	
Spartina anglica																					
Festuca rubra																					
Suaeda maritima	✓	✓	✓		✓		✓	✓	✓												
Salicornia spp.	(✓)	(✓)	(✓)		(✓)	(✓)	(✓)	(✓)	✓												
Sarcocornia perennis																					
Atriplex portulacoides				✓																	
Atriplex prostrata				✓																	
Aster tripolium																					
Limonium vulgare																					
Spergularia marina																					
Spergularia media	✓				✓			✓	(✓)												
OPEN WATER										100											
Litter									10												
Bare ground	-	85	-	-	-	60	20	15	-												
Total number of species	4	2	3	3	5	1	3	4	5	0											
Vegetation height																					

Key
presence of mature plant ✓
presence of seedling s
presence of mature plant and seedling $\checkmark_s$
species with greatest cover (✓) HIGHER PLANT ONLY

Record bare ground and litter as amounts visible from directly overhead and as "50" if cover 50 % or more

APPENDIX 4

Photographs of the retreat site

PHOTOGRAPH 1 A view from the eastern end of the site showing the hay meadow vegetation in June 1991 prior to inundation. Note the new sea wall under construction in the background.

PHOTOGRAPH 2 The new sea wall under construction in June 1991. The hay meadow to be inundated is to the left.

PHOTOGRAPH 3 The old sea wall lowered with the blocks pushed to the toe to provide some protection. This picture was taken after inundation in September 1991.

PHOTOGRAPH 4 A view from the eastern end of the site (compare with Photo. 1) taken in February 1993 showing the algal mats of *Enteromorpha* and the sparse vegetation. Note the water lying in places where drainage is still not efficient.

PHOTOGRAPH 5 A view from the western end of the site taken in autumn 1993 showing the bushy growth of annuals and other plants on the high (3.2m OD) ground.

PHOTOGRAPH 6 A view from the western end of the site (compare with Photo. 5) showing the growth of vegetation on 29th July 1994 on the high (3.2m OD) ground.