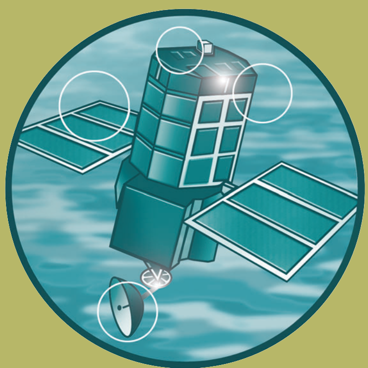
Joint Defra/EA Flood and Coastal Erosion Risk Management R&D Programme

Wash Banks Flood Defence Scheme Freiston Environmental Monitoring 2007

R&D Technical Report FD1911/TR



Environment Agency

defra
Department for Environment Food and Rural Affairs

Joint Defra/EA Flood and Coastal Erosion Risk Management R&D Programme

Wash Banks Flood Defence Scheme Freiston Environmental Monitoring 2007

R&D Technical Report FD1911/TR

Produced: February 2008

Author(s): S. L. Brown

Statement of use
This document provides information to Defra and Environment Agency staff, researchers, coastal partners and consultants about the final year of monitoring at the Freiston Shore Managed Realignment. This report supports the document "Freiston Shore Managed Realignment – Environmental Monitoring 2002 – 2006", which both constitute R&D outputs from the joint Defra/Environment Agency Flood and Coastal Erosion R&D Programme, project FD1911.

These reports and the monitoring datasets regarding the managed realignment site have been supplied by third party sources, namely the Centre of Ecology and Hydrology (CEH) whose standard confidentiality clauses apply.

Dissemination status
Internal: Released internally
External: Released to public domain

Keywords: Freiston Shore, The Wash, Managed Realignment, salt marsh, monitoring

Research contractor:
Philip Staley (philip.staley@environment-agency.gov.uk) acted as Defra support officer and project manager.
Dr Sue Brown (slb@ceh.ac.uk) undertook the majority of monitoring and coordinated third party work.

Defra project officer:
Paul Murby (paul.murby@defra.gsi.gov.uk)

Publishing organisation
Department for Environment, Food and Rural Affairs
Flood Management Division,
Ergon House,
Horseferry Road
London SW1P 2AL

Tel: 020 7238 3000 Fax: 020 7238 6187

www.defra.gov.uk/environ/fcd

Published by the Department for Environment, Food and Rural Affairs (*insert month, year*). Printed on material that contains a minimum of 100% recycled fibre for uncoated paper and 75% recycled fibre for coated paper.

PB No. *xxxxx*

Acknowledgements

Thanks go to Dr S. Brown (the other one!) for help with field work. The monitoring programme was funded by Defra, the Environment Agency, and in part by the NERC Centre for Ecology and Hydrology Science Budget.

Executive summary

The results of four years of monitoring the development of the Freiston realignment site (2002-2006) were reported last year (Brown *et al.* 2007), including a summary overview with lessons learned and recommendations. The monitoring programme comprised measurements of sediment accretion; vegetation establishment and succession; salt marsh invertebrate colonisation; sediment properties; and fish utilisation of the realignment site. Comparisons were made with the salt marsh outside the realignment site to assess the progress of the new site and to ensure that there were no unexpected adverse effects of the realignment site on the existing salt marsh.

In 2007, the monitoring was reduced to an accretion and vegetation survey inside the realignment site only. This report describes the results of the 2007 survey. Summary data on accretion and vegetation outside the realignment (to 2006) are included for comparison.

Sediment Accretion

All sites inside the realignment have accreted sediment since the initial baseline measurements in September 2002, and 25 out of the 30 sites set up in 2002 have built up 6-73mm of sediment over five years, depending upon their positions along the site transects. Sediment accretion has been relatively steady except at two sites which have been under several centimetres of water and showed fluctuating values. Five sites nearest to the central breach showed anomalously high levels of sedimentation (up to 215mm after 5 years). Sediment deposition at these sites was particularly high in the first 1-2 years following the breach and was almost certainly supplemented by sediment deposited from the eroding breach and extensive creek erosion in this area. Total accretion measured at six additional sites set up in 2004 ranged from 12-51mm in three years.

Mean annual accretion rates (September to September) were calculated for the realignment site and the values were adjusted to 52 week intervals. When all sites in the realignment were included in the calculations, the mean annual accretion rate was highest in the first year (2002 to 2003) at 16.7mm, but dropped to between 7.4mm and 10.7mm in the four subsequent years. When the two underwater sites and the five anomalous sites around the central breach were excluded from the calculations, the mean annual accretion rate in the first year was reduced to 8.1mm and in subsequent years the mean annual accretion rate varied between 5.7mm and 8.4mm with no consistent trends. Outside on the salt marsh within the same elevation range as inside the realignment site, the annual accretion rate was 9.9mm in 2002-3 and varied

between 5.6mm and 8.2mm from 2003 to 2006. The rates inside the site (excluding the outliers) were similar to those outside and the inter-annual variations in accretion matched the pattern outside at the equivalent elevation range (2.7-3.3mODN).

We found the expected inverse relationship between accretion and elevation (Brown *et al*. 2007) which was greatly improved when the outliers were removed.
In this report, mean total (cumulative) accretion over time was plotted in three elevation categories and as expected, accretion was highest in the lowest elevation range and lowest in the highest elevation range. The data showed that there was no evidence (to date) that accretion rates have changed in any consistent direction (e.g. they have not slowed down in the realignment site).

Vegetation survey

The entire managed realignment site lies at an elevation suitable for salt marsh vegetation to grow and all monitoring sites contain vegetation except for the two which have been covered with standing water. All mean values given in this summary exclude these two underwater sites.

By 2007, the lowest mean total percentage vegetation ground cover (100 - % bare estimate) was 23% at one site first colonised in 2006 (poor drainage in previous years) up to 97% in one of the highest elevation sites. Vegetation ground cover has increased between 2003 and 2006 at the monitoring sites. Some sites showed a slight decrease in cover this year compared with 2006. Mean total ground cover for all sites in the realignment (excluding the two flooded sites) increased from 40% in 2003 to 84% in 2006 (81% in 2007).

The mean total vegetation cover (calculated from the sum of individual species cover and which can exceed 100% in dense and diverse vegetation, see text for explanation) for all sites in the realignment has increased from 37% in 2003 to 86% in 2006 and 89% in 2007. Mean total cover outside on the salt marsh at the same elevation range varied between 95% and 97%. The continued increase in vegetation cover in the realignment site appears to be on track for cover to reach an equivalent value to that outside at the same elevations by about 2010, as suggested in Brown *et al.* (2007).

As elevation is of key importance for plant establishment and species zonation, mean total vegetation cover was calculated for three different elevation ranges. The outside salt marsh was not surveyed in 2007, so the realignment data were compared with the vegetation surveys between 2002 and 2006.

At elevation range 2.7-2.99mODN mean total vegetation cover had increased to 80% by 2007, compared with 88-93% outside on the salt marsh. At 3.0-3.15mODN mean total vegetation cover had reached 90% in 2007, compared with 97-106% outside. Vegetation spread was most rapid at the highest elevation category (3.16-3.3mODN) inside the realignment site and had reached a mean total cover value of 98% by 2005, which has changed little since (98% in 2006, 97% in 2007) and which was comparable with cover values outside (98-104%) at this elevation range.

Sixteen out of the 17 species found on the salt marsh outside the realignment site had been found in the realignment site by 2006. The exception was *Triglochin maritima*, Sea Arrow-grass, which was only seen occasionally on the outside marsh. All of the common or abundant species outside were also common or abundant in the realignment site.

Up to eleven species in total were recorded overall in the 36 (5 x 1m^2) realignment quadrats between 2003 and 2007, although not all were found in all years (8 to 10 species in a single year, 9 in 2007). A total of 12 species were recorded in the 9 larger (5 x 5m) quadrats over the years of monitoring (8-11 species in different years).

By 2006, the mean species number in the realignment site quadrats was 5.71, equivalent to that in the quadrats outside (5.46-5.77 between 2002 and 2006) at the same elevation range (2.7-3.3mODN). Mean species number was 6.09 inside the realignment quadrats in 2007.

In the lowest elevation category (2.7-2.99mODN, excluding flooded site TFS1), mean species number in the realignment quadrats had increased to 5.09 in 2006. By 2007 mean species number was 5.73, within the range found outside (5.31-6.15) between 2002 and 2006.

At 3.0-3.15mODN (excluding underwater site TBS1) mean species number increased to 5.83 in 2006, comparable with the mean number for the salt marsh outside (5.50-5.83). Mean species number increased further in this elevation range in the realignment site by 2007 to 6.17.

At the highest elevation category (3.16-3.3mODN), mean species number varied between 5.46 and 6.27 from 2003 to 2006, and was 6.36 in 2007. These mean values were higher than the range outside the realignment on upper sites (5.29-5.43).

The pioneer annuals were the first to colonise the realignment site and *Salicornia europaea* and *Suaeda maritima* were the dominant species throughout the site in 2003, at all elevations. Between 2003 and 2006, these pioneer annuals remained the most abundant species at lower elevations in the realignment, although by 2007 *Puccinellia maritima* had spread to become the second most abundant species after *Salicornia europaea* (overtaking *Suaeda maritima*) in the lowest elevation range category. Perennial species have established and spread, particularly at the higher elevations, where the annuals have been replaced by *Puccinellia maritima* as the dominant species. *Atriplex portulacoides*, extremely abundant outside on the salt marsh at higher elevations has shown a steady increase at higher elevations in the realignment site, and by 2006 was the second most important cover species after *Puccinellia* in the highest elevation range category (3.16-3.3mODN).

The species mix in each elevation range was similar inside and outside, although the relative species abundances were still different by 2007, particularly for the dominant species in the two upper elevation categories. At the lowest elevation range (2.7-2.99mODN) the two annual pioneer species, *Salicornia europaea* and *Suaeda maritima*, were the most important cover species both outside and inside the realignment to 2006 (*Puccinellia maritima* had just overtaken *Suaeda maritima* in cover abundance in the realignment in 2007). The main difference between the realignment site and the salt marsh outside at the lower elevation range was that *Salicornia europaea* and *Puccinellia maritima* cover have decreased outside (*Salicornia* since 2002, *Puccinellia* since 2004). In the realignment site *Puccinellia maritima* was still increasing in cover by 2007, although *Salicornia europaea* was at a similar cover value to that in 2006. *Aster tripolium* and *Spartina maritima* were found at greater mean cover outside than inside, but they have both been increasing in cover inside the realignment each year. *Atriplex portulacoides* has increased in cover both outside and inside the realignment site in this elevation range.

The main difference between the salt marsh and realignment site at elevation range 3.0-3.15mODN was that *Puccinellia maritima* was dominant in 2002 outside on the salt marsh but subsequently decreased in mean cover along with *Salicornia europaea*, while *Atriplex portulacoides* increased its cover to become the most abundant species by 2005 and increased its cover further by 2006. In the realignment quadrats, *Puccinellia maritima* spread very rapidly between 2003 and 2005 to become the most abundant species and has continued to expand its cover. *Atriplex portulacoides* has also increased its mean cover steadily each year but was still at a much lower cover value than outside in 2007 at this elevation range.

The main difference between outside and inside the realignment in the upper elevation range category (3.16-3.3mODN) was that *Atriplex portulacoides* was the most abundant species from 2002 on the salt marsh outside and has increased its mean cover steadily while *Puccinellia maritima* has decreased in cover. Inside the Freiston realignment, *Suaeda maritima*, followed by *Salicornia europaea* were the dominant species in 2003, but both have decreased in cover since to values similar to outside the site by 2007. *Puccinellia maritima* spread rapidly to become the most abundant species by 2005 although its cover has changed little since, and it may have reached its peak cover abundance. *Atriplex portulacoides* has spread steadily to become the second most important cover species by 2006, and may replace *Puccinellia maritima* as the dominant cover type in future.

The overall impression to date is that succession of perennial species in the upper half of the elevation range of the site is now occurring rapidly and to a rough approximation is one ‘elevation category’ behind the community composition outside the realignment site. Last year (in Brown *et al.* 2007), I estimated that that if the major perennials continued to spread at the rates observed in the realignment site over the four year survey, the communities (and relative species abundances) could be equivalent to those outside at the same elevations within (approximately) a further five years. The results from this year's survey indicate that community trends have continued to progress towards a closer match with the adjacent salt marsh.

The composition of species and succession in the larger 5 x 5m quadrats is described in the report and the trends observed in these quadrats were similar to those reported for the smaller quadrats.

In conclusion, the results this year showed that accretion has continued at rates similar to those observed previously (which were in general comparable with rates on the salt marsh outside, although slightly higher inside the sheltered realignment site at lower elevations). Vegetation cover and diversity have increased overall and changes in relative species abundances indicated that the plant community compositions are likely to converge with those outside at equivalent elevations (although these have also been changing in time), possibly within a further five years as suggested in Brown *et al.* (2007).

The overall conclusions therefore remain the same as last year. Vegetation establishment and spread within the Freiston realignment site has been highly successful. All common species found outside the site have been found inside, and were present at their expected elevations. By 2006/2007 mean species number was comparable between the realignment site and the salt marsh, and even greater inside the site at the highest elevation sites. Perennial species have been increasing their cover year on year and replacing the annual pioneer species as the dominant plants, particularly in the upper half of the elevation range, and some sites are now approaching similar community compositions (and relative species abundance) to the adjacent salt marsh at the same elevations. It remains to be seen how long it will take for the realignment site be equivalent to the outside marsh in these respects, but it looks possible that this could be achieved by about 2012.

Contents

Figures

Tables

Appendices

1. Introduction

The Freiston Shore Managed Realignment Site, near Boston in Lincolnshire is a 66ha intertidal site which has developed salt marsh vegetation since the site was breached in three places in August 2002 (see Image 1). The southern end of the intertidal realignment site is backed by a 15ha saline/brackish lagoon landward of the sea defences.

This report presents the final year of monitoring accretion and vegetation in 2007 inside the realignment site. The results of four years of monitoring from 2002 to 2006 were reported to the Environment Agency in 2007 (Brown *et al.* 2007). The four year report includes a more detailed introduction, description of methods used for the different ecological components surveyed, results, conclusions, and an overview with lessons learned and recommendations. Surveys were carried out on sediment accretion, vegetation, salt marsh invertebrates, sediment properties, and fish use of the realignment site.

In the final year of the monitoring programme, the surveys were reduced to one accretion survey and a vegetation survey, in September 2007, inside the realignment site only. In previous years the accretion and vegetation surveys were also undertaken on the adjacent and fronting salt marsh for comparison of accretion rates and vegetation community composition, and to check that the realignment site had no adverse effects on the adjacent and fronting salt marsh. Other surveys were also undertaken outside the realignment (as far as possible) to enable comparisons, although there were some time constraints with the tide for the fish surveys (duration of high spring tides) and for the salt marsh invertebrates associated with vegetation (e.g. pitfall traps had to be undertaken during neap tides at sites which would not be covered by water during the annual survey).

A short introduction and a brief description of the methods used in the 2007 survey are given here. For more details see Brown *et al*. (2007).

The aims of the Freiston Shore managed realignment scheme (part of the Wash Banks flood defence scheme) were:

- To create a sustainable flood defence scheme through the establishment of salt marsh
- To establish a salt marsh community of botanical value, and to provide a suitable habitat for invertebrates and birds
- To avoid adverse impacts to existing habitat and adjacent salt marsh and mudflat
- To establish new brackish habitat through the excavation of a borrow pit landward of the new sea defence embankment (monitored by RSPB)

The objectives of the Wash Banks environmental monitoring programme for the salt marsh component carried out by the Centre for Ecology and Hydrology (CEH) and the Cambridge Coastal Research Unit (CCRU) were to monitor the development of the salt marsh within the realignment site (sediment accretion and establishment of flora and fauna) and to check that there were no adverse impacts of the scheme to the existing adjacent salt marsh habitat.

The ecological monitoring requirements of the programme were set out by Halcrow Ltd. for the Environment Agency and comprised the following post-breach surveys to be undertaken inside and outside the site:

- Accretion/erosion surveys (2 per year, for 5 years)
- Vegetation surveys (1 per year, for 5 years)
- Invertebrate surveys (1 per year, for 4 years)
- Fish surveys (1 per year, for 4 years)

Figure 1. 1

Location of the Freiston Shore Managed Realignment

Figure 1. 2

Aerial photograph of the Freiston managed realignment site and lagoon (looking North)

Figure 1.1 Location of Freiston Shore

Figure 1.2 Freiston realignment site and lagoon. Photo: Environment Agency (≈ 2005)

2. Methods

An integrated approach to monitoring the ecological and physical components, relating vegetation surveys and accretion/erosion measurements to elevation, is the best way to gain the most insights into the development of the new salt marsh, and to interpret any changes in the salt marsh vegetation outside the realignment site.

To achieve this, permanent transects and sampling sites were set up inside and outside the realignment site to measure accretion/erosion, vegetation development (inside the site) and vegetation changes (outside the site). Each site was surveyed for its elevation in 2005. In 2007, accretion measurements and the vegetation survey were only carried out inside the realignment site, but the results for the vegetation survey have been compared with the data from outside on the salt marsh (up to 2006).

2.1 Transect establishment

Six transects perpendicular to the shore (i.e. down the marsh profile) were set up outside the managed realignment site in early autumn 2001, approximately one year before the site was breached, extending between a few hundred metres north and south of the realignment site. The transects were labelled Transects 1-6, running north to south, with two north of the realignment site (T1 and T2), two in front of the site (T3 and T4), and two south of the Freiston site (T5 and T6), of which the last (T6) was originally set up in 1995 by S.L. Brown (CEH), under the Land Ocean Interaction Studies (LOIS) programme.

Sites were selected along the marsh profile transects for ecological measurements, including accretion monitoring and surveys of vegetation cover and type. The number of sites along each transect varied between 5 and 8, according to the extent of the marsh, and were as follows: Transect 1: 6 sites (initially 7 were set up but the site closest to the shore was subsequently trampled heavily by cattle, making accretion measurements impossible); Transect 2: 8 sites; Transects 3 and 4: 5 sites each; Transects 5 and 6: 7 sites each. Therefore a total of 38 permanent monitoring sites were established on the natural marsh outside the realignment area.

We were unable to establish transects inside the site at the same time as those outside, because contractors with earth-moving equipment were due to come on site to make initial preparations for the breaches. In spring 2002, 5 transects TA to TE (labelled with letters for easy distinction between inside and outside the realignment site), running from north to south were set up across the site perpendicular to the new defence embankment (i.e. downshore), avoiding areas designated for the contractors to create some artificial starter creeks. Six sites were set up for accretion and vegetation monitoring along each of the 5 transects (30 sites in total) and the initial baseline measurements for sediment accretion were taken in autumn 2002. Initially, the largest gap between transects was between Transect D and Transect E. This area was left because it was a zone where contractors would be creating a twin-branched creek. However, to achieve a more evenly distributed cover of monitoring sites, we set up an additional transect with 6 monitoring sites in this zone in 2004 and initial baseline measurements were taken in September/October 2004. This new transect was labelled Transect E and the previous Transect E (further south) was re-named Transect F. Therefore there were 30 sites inside the realignment in 2002-2003, increasing to 36 sites from summer 2004. Site positions in the report are referred to by the Transect (T) number, followed by the Site (S) number down each transect, for example TDS4 is Site 4 along Transect D.

The positions of the monitoring sites inside and outside the Freiston realignment are shown in Figure 2.1

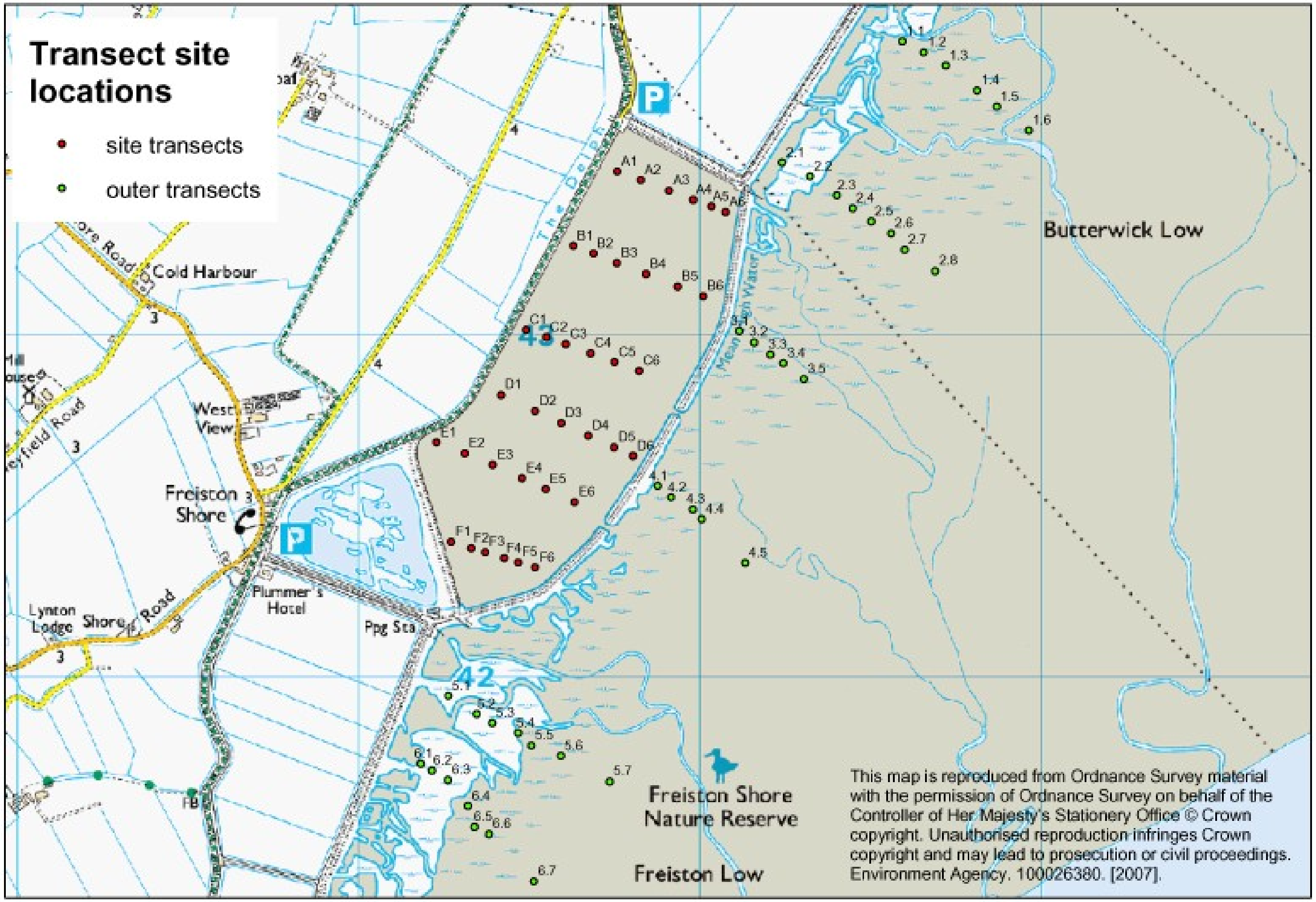


Figure 2.1 Map of Accretion monitoring and vegetation survey (5 x 1m^2 quadrats) site locations

2.2 Accretion/erosion measurements

Accretion varies considerably between upper marsh elevations and the low pioneer zone due to different inundation frequencies and duration, and there can also be considerable lateral and local variation. Relatively inexpensive methods of monitoring accretion were used (buried expanded metal plates or levelled pairs of canes, depending on ground conditions) which the author has used successfully elsewhere (e.g. Brown 1998). We could therefore set up a lot of sites to provide good spatial cover of sediment accretion estimates across the large area of the realignment site and adjacent marsh. In most cases at Freiston (except for on the mudflat in front of the salt marsh outside the realignment site) we used the plate method to measure sediment accretion. The method integrates surface deposition and near-surface below-ground productivity over short to medium timescales (e.g. annual / biennial re-measurements). The numerous plate sites were supplemented by 11 additional sites in which accretion was measured using a Sediment Erosion Table (SET, undertaken by CCRU and reported in Brown *et al.* 2007) that measures the surface elevation change and accounts for the influence of subsurface processes (e.g. compaction) on elevation change.

Five expanded stainless steel plates, each 15cm x 15cm, were buried at each site, generally at approximately 8-10cm depth, by digging up a small 'turf', setting in the plate and replacing the turf. Plate positions were selected randomly along a 5m strip perpendicular to the transect line. After installation the plates were left for a few months to allow regrowth of vegetation around the edges of the turves. Initial baseline measurements were taken outside the realignment in April 2002, and inside the realignment area in September 2002, just after the site was breached. At each survey interval, 5 measurements were taken down to each plate, accurate to approximately 1mm (except where sites were underwater and the very high water content of the mud makes it difficult to determine the surface), to give an average value for each of the five plates. The site means for sediment accretion and the standard errors were calculated from the average values of the 5 sets of plates at each site.

2.3 Vegetation survey

The percentage cover of plant species was surveyed in 5 x 1m^2 quadrats positioned over the accretion monitoring sites outside and inside the realignment area (Figure 2.2). A 5m x 1m^2 rope quadrat was laid out and the percentage cover of all vascular plant species was recorded in each of the 1m^2 quadrats. Species found at a cover of much less than 1% were recorded as present (+) and given a value of 0.2% in the data base for analysis and plotting graphs. The percentage cover of bare ground, algae, permanent water, and litter was also noted. The vegetation was recorded by two people until agreement was reached on our estimations of cover. In dense vegetation the total percentage cover can exceed 100% where different species overlap in cover.

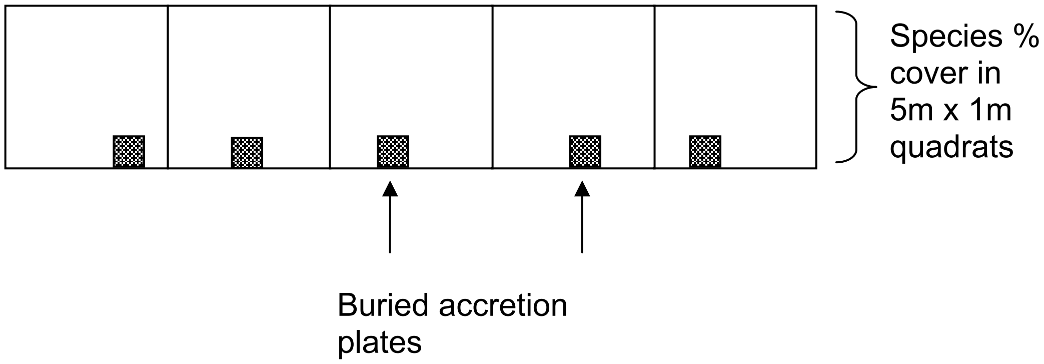


Figure 2.2 Quadrat design for vegetation monitoring (5m x 1m^2)

Larger quadrats (5m x5m) were also set up to provide ground reference data for remote sensing images. These quadrats were positioned in different vegetation types along the transects on the salt marsh outside the realignment. Nine quadrats were also set up inside the realignment in 2003 (one was not found subsequently), and one was added in 2005 to provide a good example of an area with *Atriplex portulacoides* as the predominant species. The position of these is shown in Figure 2.3. A 5m x 5m rope quadrat, divided into a grid of 25 x 1m^2 cells was set between corner markers. The presence of each plant species within each of the 25 cells (frequency) was recorded, together with the occurrence of algal mats, bare mud or litter with a cover value greater than 10%. The total percentage cover of each vascular plant species, algae, bare mud and water was estimated for the entire quadrat.

As well as providing ground reference data for classification of remote sensing images, the macro scale vegetation data was considered useful to provide additional information (i.e. as well as the 5m x 1m^2 quadrats) to assess any possible large scale changes in vegetation communities, cover and condition, on the salt marsh outside the realignment site during the monitoring programme. In the realignment site, their larger size also improves the chances of recording early colonisers which may be patchy initially. For example, vegetation colonisation at Paull Holme Strays in the Humber Estuary was sparse at many sites in the first year after the breach. Plant establishment at Freiston has been more rapid and even.

We also surveyed the large quadrats inside the realignment site in 2007 to provide additional information on the site vegetation. The percentage cover of each species in the entire quadrat was estimated by two people until agreement was reached.

2.4 Site Positions and Elevation

Site positions and elevations were measured in 2005 using a Trimble RTK GPS. The mean values of 3 readings for each of the buried plate sites (plates 1, 3, and 5) are given in Table 1 in the results. The positions and elevations of the nine 5m x 5m vegetation quadrats inside the realignment were also measured using the RTK GPS.

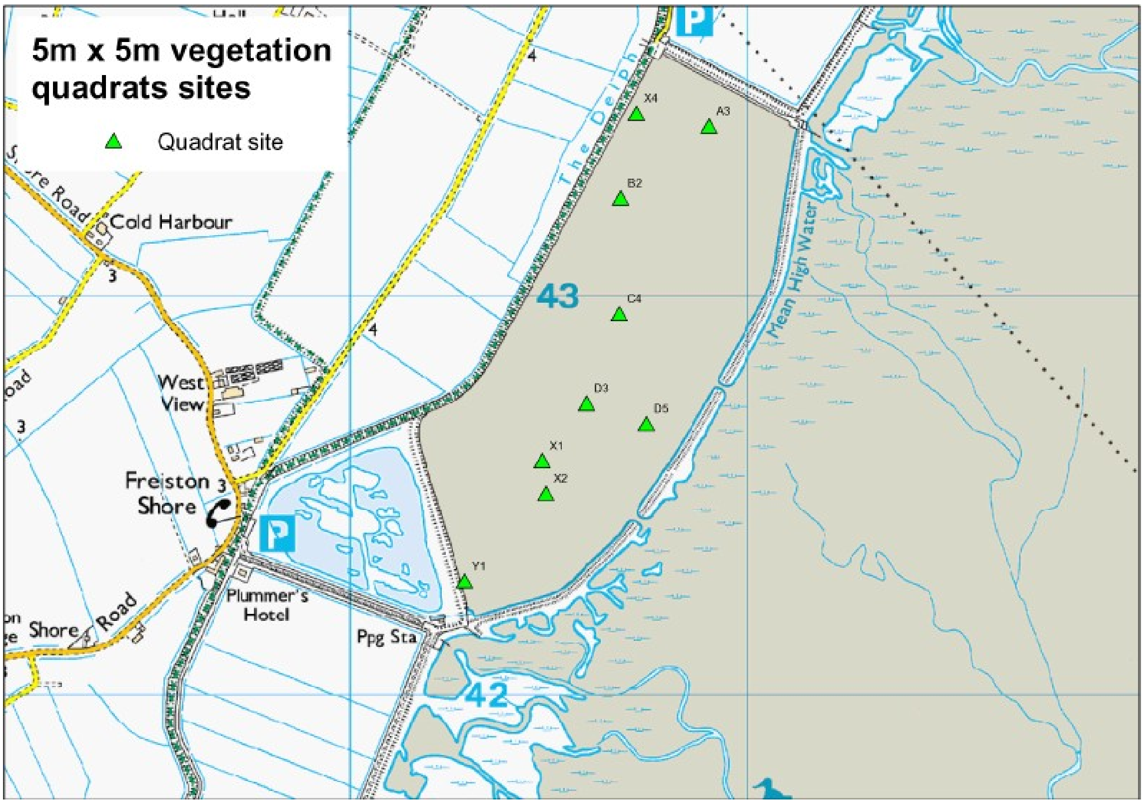


Figure 2.3. Map of 5m x 5m vegetation quadrats inside the realignment site

3. Results: Accretion

Measurements of total sediment accumulated at the sites inside the realignment site, up to September 2007 are plotted in Figures 3.1 and 3.2. Cumulative sediment accretion at each sampling interval at each site along each transect is shown in Figures 3.3 to 3.8. This year's survey was for September only but CEH data taken in April are included in the graphs. Elevations of the sites (measured in 2005) are shown in Table 3.1.

In general, there was an increase in accumulated sediment going down each transect from the back of the site towards the old (breached) sea wall (Figures 3.1 and 3.2). Five sites showed much higher accretion than the rest, notably TCS5 and TCS6 which have built up 127mm and 215mm of sediment, respectively, during the 5 years of monitoring, and TDS6 which has accreted 175mm of sediment during this time. The other two lower sites on Transect D (TDS4 and TDS5) have accreted 99mm and 108mm respectively. These sites are close to the middle breach, and we suggested in our 4 year report that the high accretion here was due to material washed in from the eroding breach and widening creeks inside the breach area.

The remaining 25 sites on Transects A, B, C, D and F have accreted between 6.04mm and 73.3mm, depending upon their positions along the transect lines. Transect E was set up in 2004, and total accretion on this transect in three years ranged from 12.2mm at the top of the transect line (Site 1) to 50.8mm at the seaward end (Site 6).

The cumulative change in sediment level at each sampling interval is shown in Figures 3.3 to 3.8. Most sites have shown continued accretion each year, except for two underwater sites, and a few of the higher elevation sites such as Transect A, sites 2 and 3, which levelled off during the second year but which have subsequently continued to accrete sediment.

All sites have accreted sediment since the initial baseline (zero) measurements. There were some initial minor losses during the first winter period at some of the highest elevation sites in the upper half of Transects A-C (TAS1 & 2, TBS1-3, and TCS2). Prior to breaching and tidal flooding the soil on the realignment site was very dry with numerous hard clods on the surface and it is likely that these will have been rolled around during the first few tidal inundations before the clods were fully wetted and broken down. Also it was difficult to take accurate first measurements on the site because of air spaces trapped in the matrix of dead terrestrial vegetation (before it had decayed) and clods of earth.

Some sites were underwater for the first year (TAS6 and TDS6) and could not be measured accurately (very fluid mud surface). Sites TBS1 and TFS1 have been under several centimetres of water more or less since the site was breached (TBS1 had just dried out by the end of the neap tide period in September 2005, but was flooded during other surveys; TFS1 has been underwater at all sampling periods). These two sites have shown fluctuating surface levels, probably because the fluid mud is easily re-suspended on ebb tides so there has been no consistent build up of sediment at these sites (and no vegetation establishment to stabilise the sediment

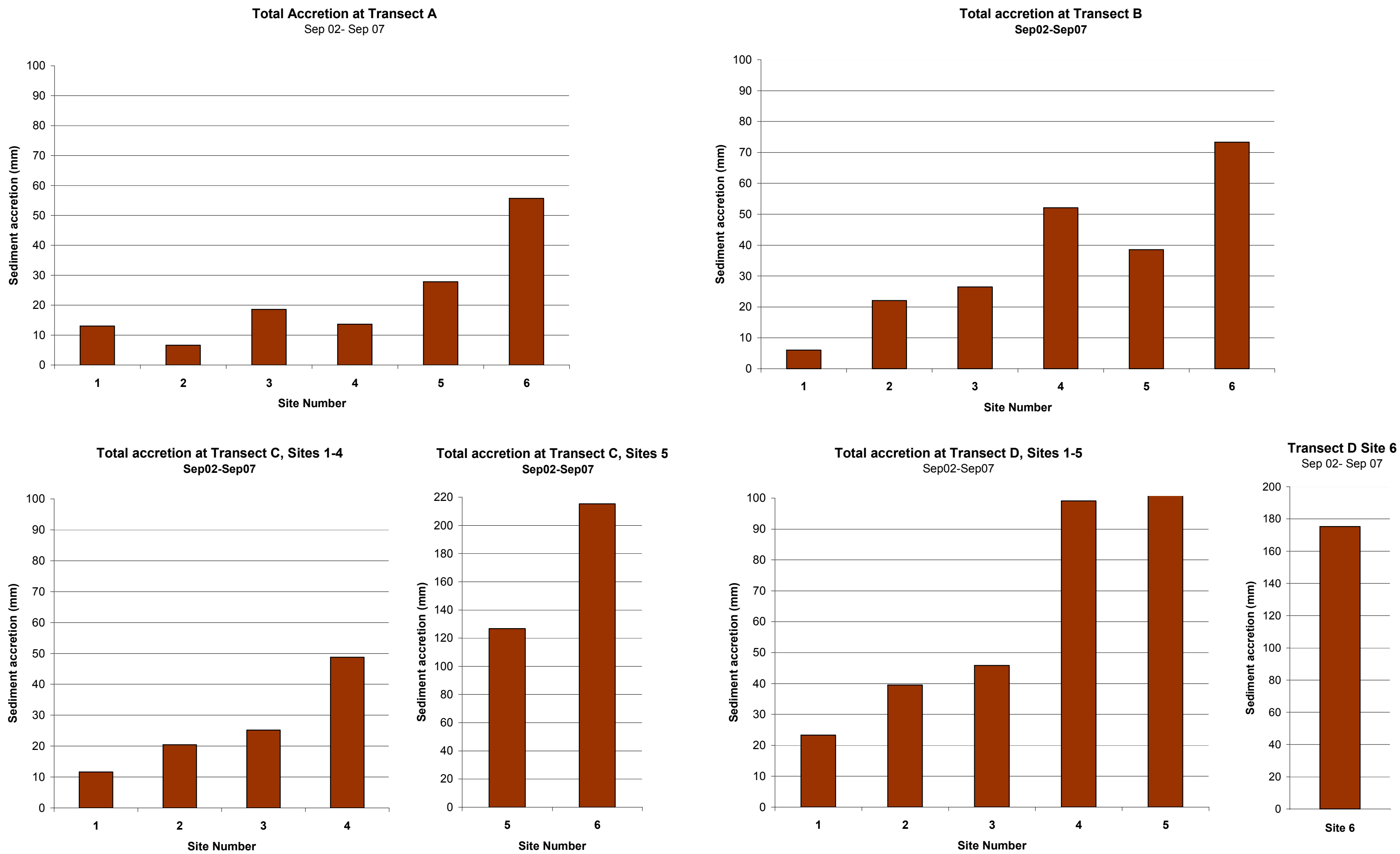
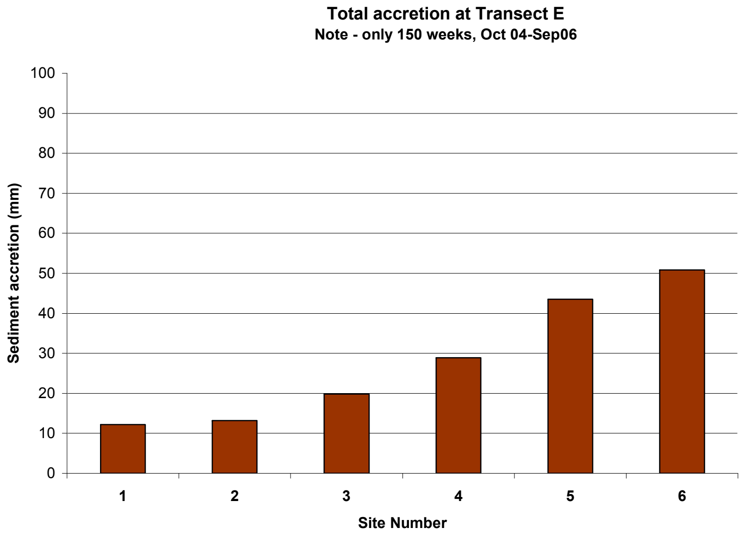


Figure 3.1. Total accretion from September 2002 to September 2007 on Transects A-D inside the realignment site



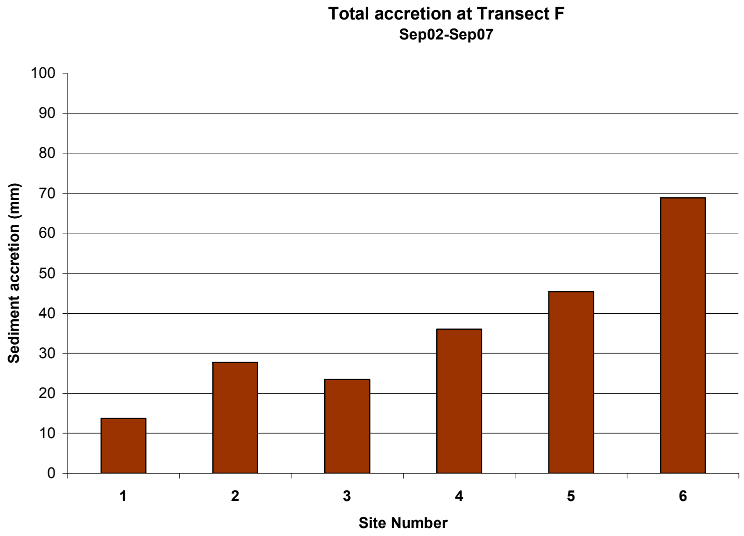


Figure 3.2. Total accretion to September 2007 on Transects E and F inside the realignment site. From September 2002 for Transect F; from October 2004 for Transect E (additional site set up after the initial sites)

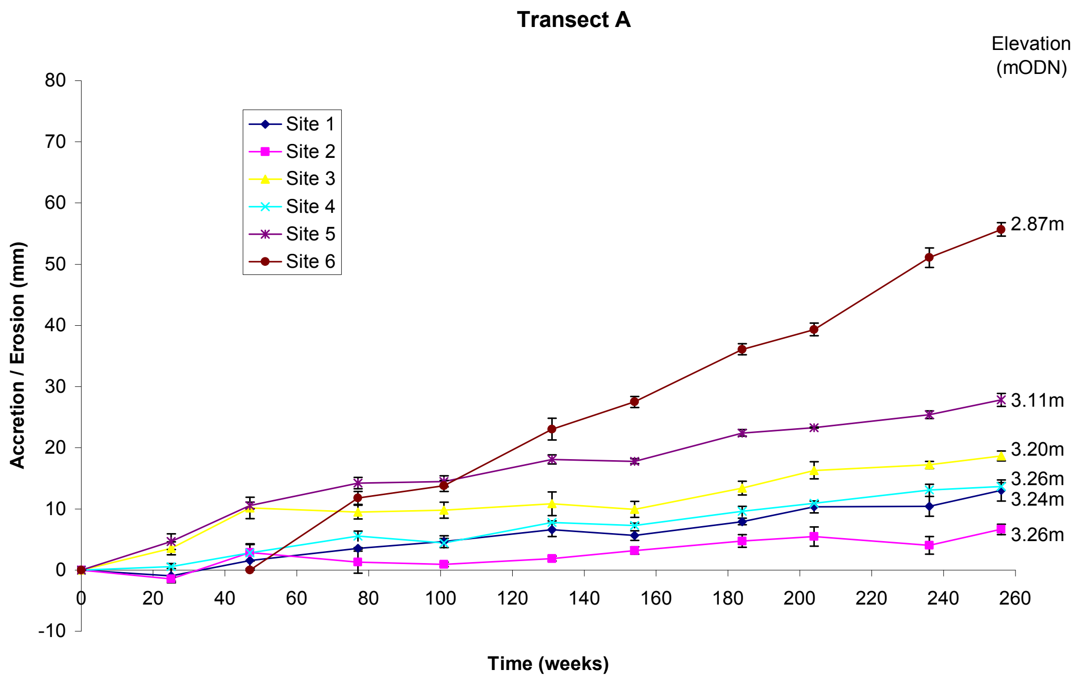


Figure 3.3. Accretion from September 2002 to September 2007 at 6 sites on Transect A (mean site values ± SE)

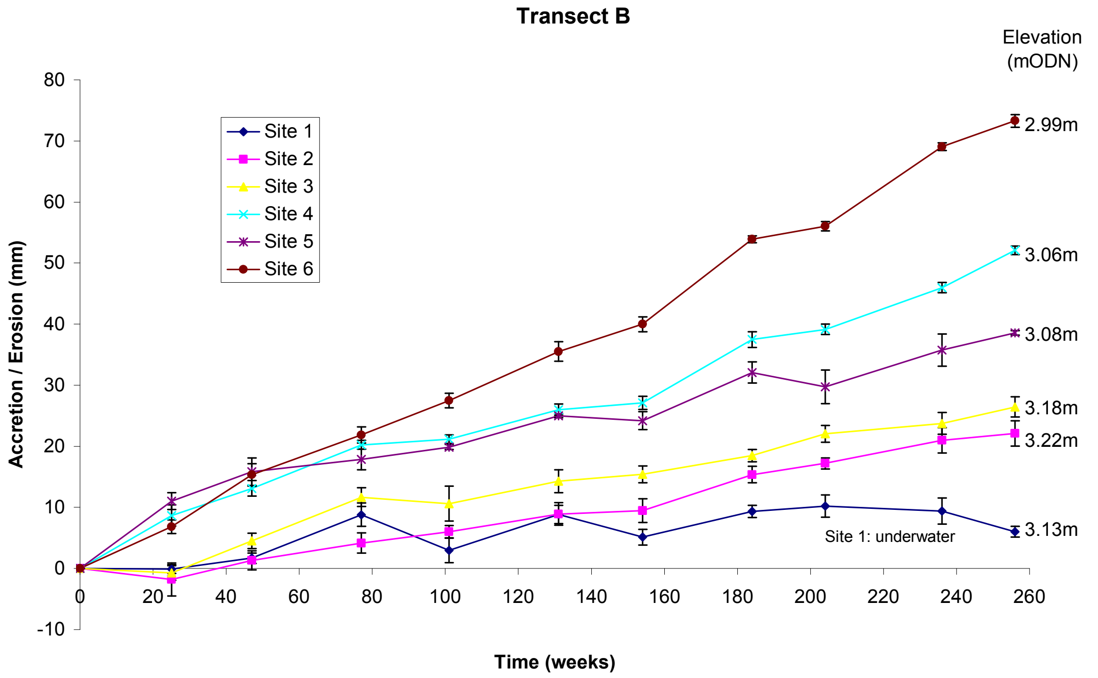


Figure 3.4. Accretion from September 2002 to September 2007 at 6 sites on Transect B (mean site values ± SE)

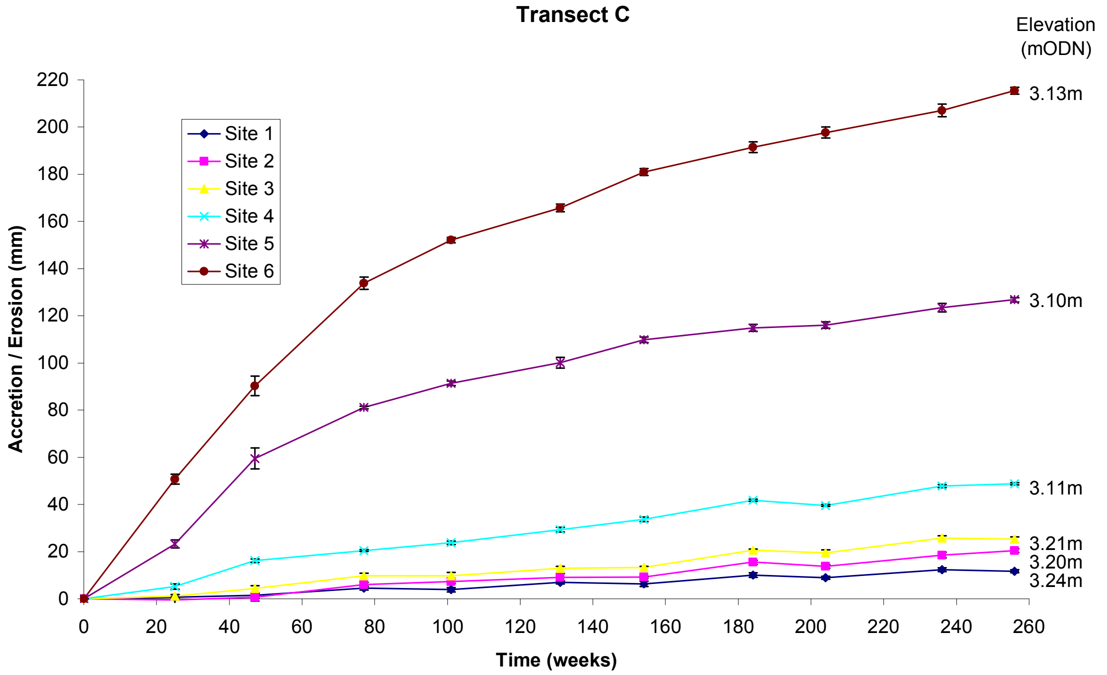


Figure 3.5. Accretion from September 2002 to September 2007 at 6 sites on Transect C (mean site values ± SE)

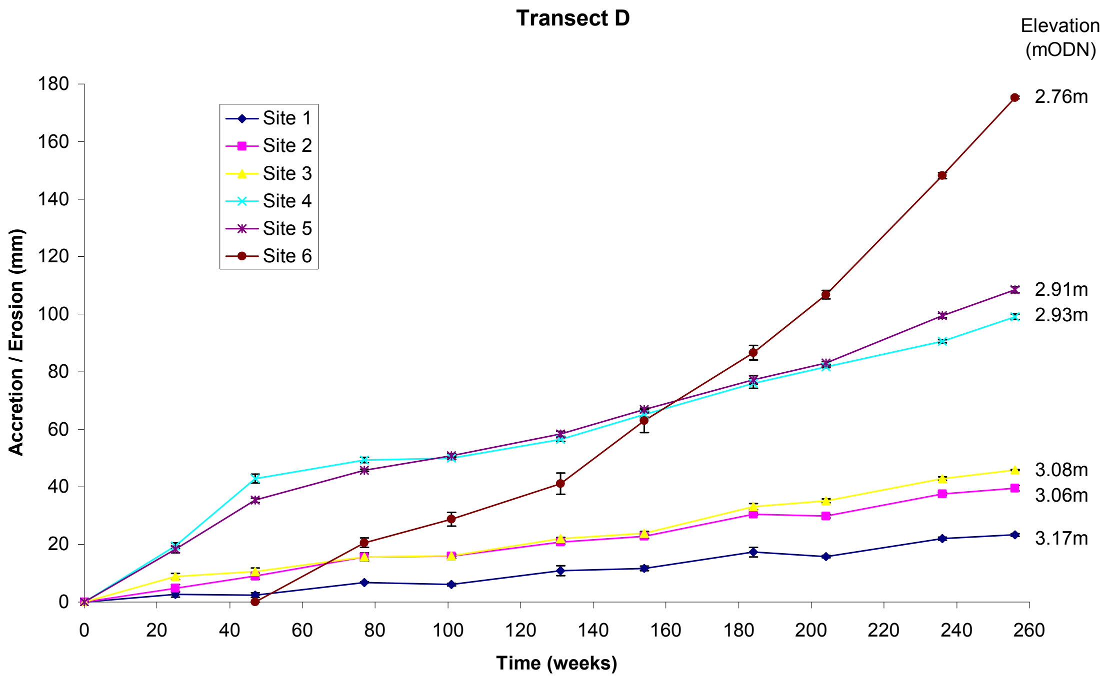


Figure 3.6. Accretion from September 2002 to September 2007 at 6 sites on Transect D (mean site values ± SE)

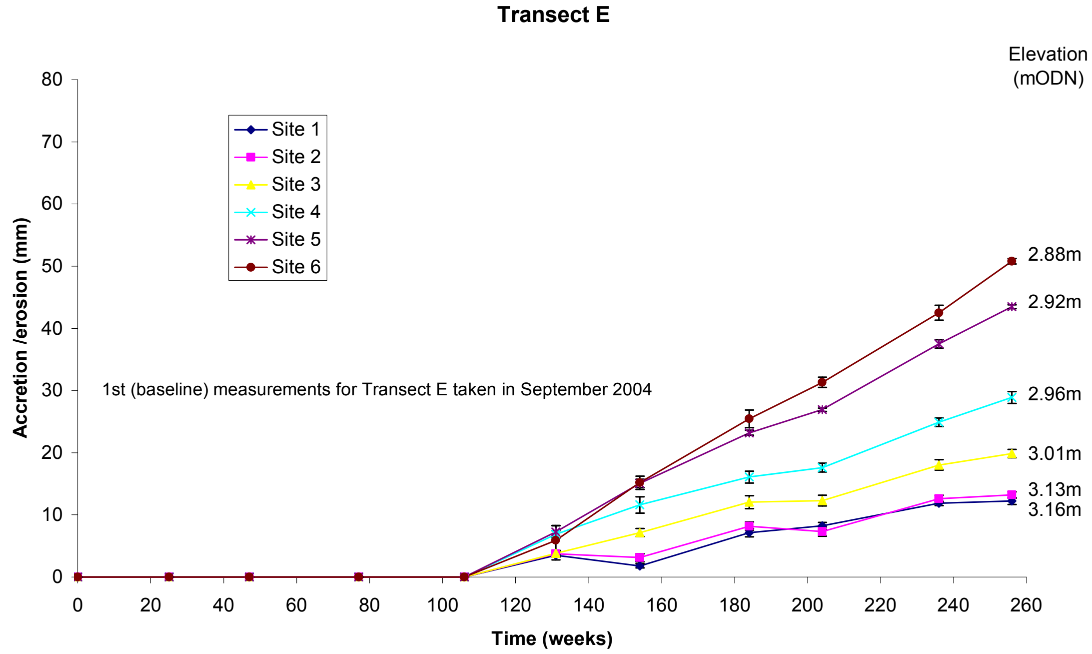


Figure 3.7. Accretion from September 2004 to September 2007 at 6 sites on Transect E (mean site values ± SE)

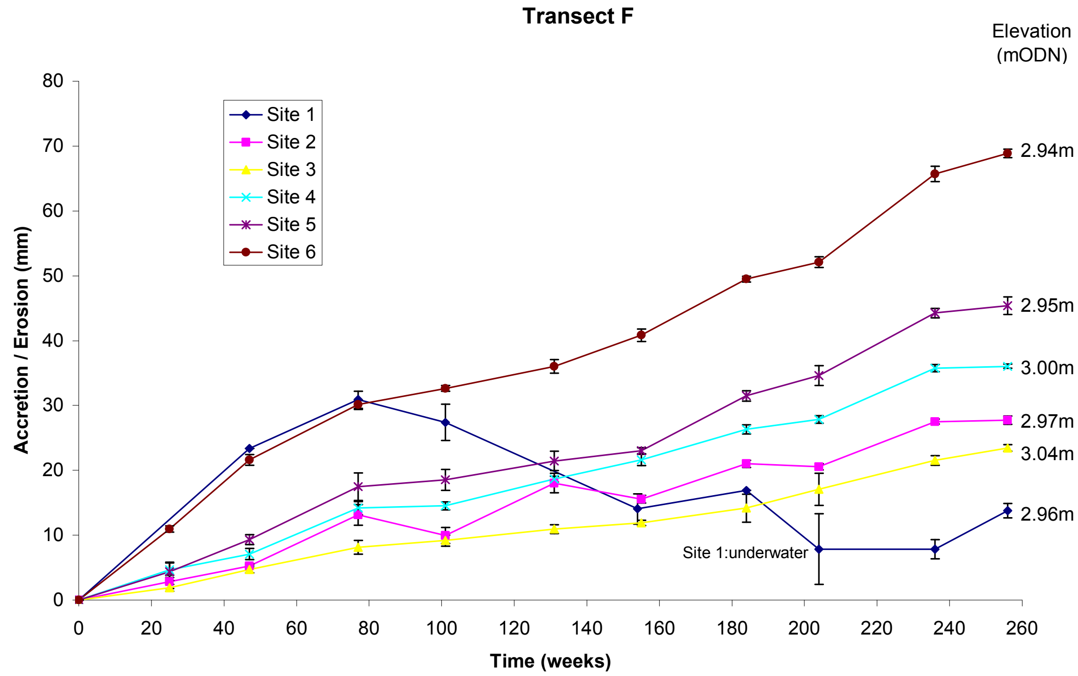


Figure 3.8. Accretion from September 2002 to September 2007 at 6 sites on Transect F (mean site values ± SE)

Table 3.1. Elevations at the Freiston Monitoring Sites
Elevations measured in 2005

T=Transect, S=Site, S.E.=Standard error

OUTSIDE MANAGED REALIGNMENT

Transect & Site	Elevation (mODN)	S.E.
T1S1	3.16	0.014
T1S2	3.01	0.004
T1S3	2.97	0.007
T1S4	2.79	0.008
T1S5	2.57	0.019
T1S6	2.38	0.029
T2S1	3.15	0.003
T2S2	3.28	0.010
T2S3	3.08	0.005
T2S4	2.98	0.005
T2S5	2.90	0.002
T2S6	2.69	0.006
T2S7	2.56	0.000
T2S8	2.33	0.004
T3S1	3.00	0.005
T3S2	2.83	0.010
T3S3	2.82	0.004
T3S4	2.68	0.005
T3S5	2.54	0.010
T4S1	2.91	0.007
T4S2	2.80	0.004
T4S3	2.78	0.001
T4S4	2.69	0.006
T4S5	2.09	0.018
T5S1	3.26	0.010
T5S2	3.26	0.008
T5S3	3.21	0.008
T5S4	3.04	0.004
T5S5	2.96	0.017
T6S6	2.68	0.004
T5S7	2.28	0.008
T6S1	3.29	0.010
T6S2	3.20	0.003
T6S3	3.14	0.004
T6S4	2.92	0.006
T6S5	2.78	0.001
T6S6	2.73	0.027
T6S7	2.30	0.026

INSIDE MANAGED REALIGNMENT

Transect & Site	Elevation (mODN)	S.E.
TAS1	3.24	0.027
TAS2	3.26	0.003
TAS3	3.20	0.004
TAS4	3.26	0.018
TAS5	3.11	0.002
TAS6	2.87	0.008
TBS1	3.13	0.009
TBS2	3.22	0.005
TBS3	3.18	0.012
TBS4	3.06	0.007
TBS5	3.08	0.007
TBS6	2.99	0.002
TCS1	3.24	0.002
TCS2	3.20	0.012
TCS3	3.21	0.018
TCS4	3.11	0.020
TCS5	3.10	0.007
TCS6	3.13	0.008
TDS1	3.17	0.002
TDS2	3.06	0.008
TDS3	3.08	0.010
TDS4	2.93	0.005
TDS5	2.91	0.006
TDS6	2.76	0.008
TES1	3.16	0.005
TES2	3.13	0.004
TES3	3.01	0.005
TES4	2.96	0.004
TES5	2.92	0.005
TES6	2.88	0.021
TFS1	2.96	0.006
TFS2	2.97	0.004
TFS3	3.04	0.009
TFS4	3.00	0.018
TFS5	2.95	0.007
TFS6	2.94	0.004

Mean annual accretion rates were calculated for the realignment site. Transect E was set up in 2004, so the annual data for these 6 extra sites were included in the mean calculations from 2004 onwards. Intervals between autumn measurements (generally September to September) varied from 47 weeks to 54 weeks, so the mean total accretion values for each year were adjusted for a 52 week interval. The adjusted values are shown in Table 3.2, for all sites in the realignment, and also for sites excluding the outliers identified in the four year report (Brown *et. al.* 2007). These were:

(1) One group excluding the two underwater sites (TBS1, TFS1) and three most highly accreting sites (biggest outliers: TCS5, TCS6, and TDS6) which have almost certainly been influenced by deposition of washed-in material eroded from the central breach and significant creek erosion in this area. There was also a lot of loose sandy sediment left around here after the pre-breach earth moving works;

(2) A group excluding the sites in (1) above, and 3 additional sites, which were probably influenced by erosion and sediment movement around the central breach area (TCS4 and TDS4-5). We included an aerial image of the site in our four year report which showed a large fan shaped area of sediment inside the realignment opposite the central breach. The main influence of the breach area seems to have been during the first 12-18 months, judging by the cumulative accretion shown for Transects C and D (Figures 3.5 and 3.6) and by the difference in annual accretion rates between the first year post-breach and subsequent years.

The rates shown in Table 3.2 are plotted in Figure 3.9, alongside calculated annual rates from outside the realignment site (to 2006) at the same elevation range.

Table 3.2. Annual Accretion Rates (mm yr^{-1}) in the Managed Realignment Site for all sites, and for sites excluding outliers waterlogged sites and sites influenced by the central breach

Year	All Sites	Excluding C5, C6, D6, B1, F1	Excluding C4-6, D4-6, B1, F1
2002-3	16.7	11.5	8.14
2003-4	9.00	5.88	6.69
2004-5	7.38	6.39	5.66
2005-6	9.17	8.40	7.83
2006-7	10.7	9.28	8.41

For all sites, the greatest accretion rate was in the first year (Table 3.2, Figure 3.9) at over 16mm, with subsequent rates ranging between 7.4mm and

10.4mm. But when the sites on the lower half of Transects C and D in the vicinity of the central breach, (and the submerged sites) were removed, the mean value for the remaining sites in the first year was close to the rates found in later years (particularly 2005-2007). With the exclusions the annual rate has fluctuated between approximately 5.7mm and 8.4mm yr^{-1}, with no consistent trends.

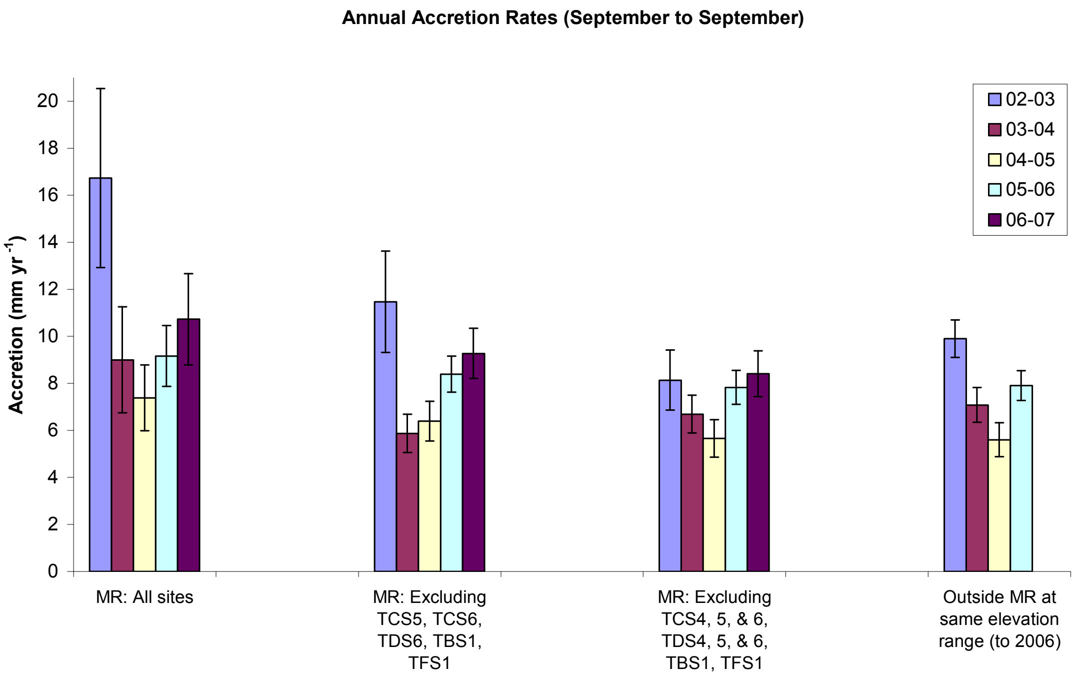


Figure 3.9. Mean annual accretion rates inside the Freiston realignment site, and outside at the same elevation range (to 2006 outside). MR: data from all sites and from sites excluding outliers identified in accretion *vs.* elevation analysis in Brown *et al.* (2007). Outliers include sites underwater and sites influenced by deposition of sediments washed in from the central breach area.

The mean annual accretion rates for the remaining sites inside the realignment were similar to the annual rates outside on the salt marsh at the equivalent elevations (Figure 3.9). The rate outside was approximately 9.9mm in the first year, 7.1mm in the second year, 5.6mm in the third year, and 8.2mm between 2005 and 2006. The trends in annual accretion for the remaining sites in the realignment also matched those on the salt marsh between 2002 and 2006, i.e. mean accretion rates were highest in 2002-3, dropped in the next two years to the lowest value in 2004-5, but increased again in 2005-6. Therefore the inter-annual patterns of accretion observed in the realignment site were consistent with the natural inter-annual variation on the salt marsh in the Freiston area of the Wash.

In last year's report we showed that the accretion measurements inside the site (excluding the outliers) were comparable with those outside on the salt marsh at the equivalent elevation range (2.7-3.3mODN). We also found a significant inverse relationship (as expected) between accretion and elevation, which was improved greatly inside the realignment when the outliers were removed.

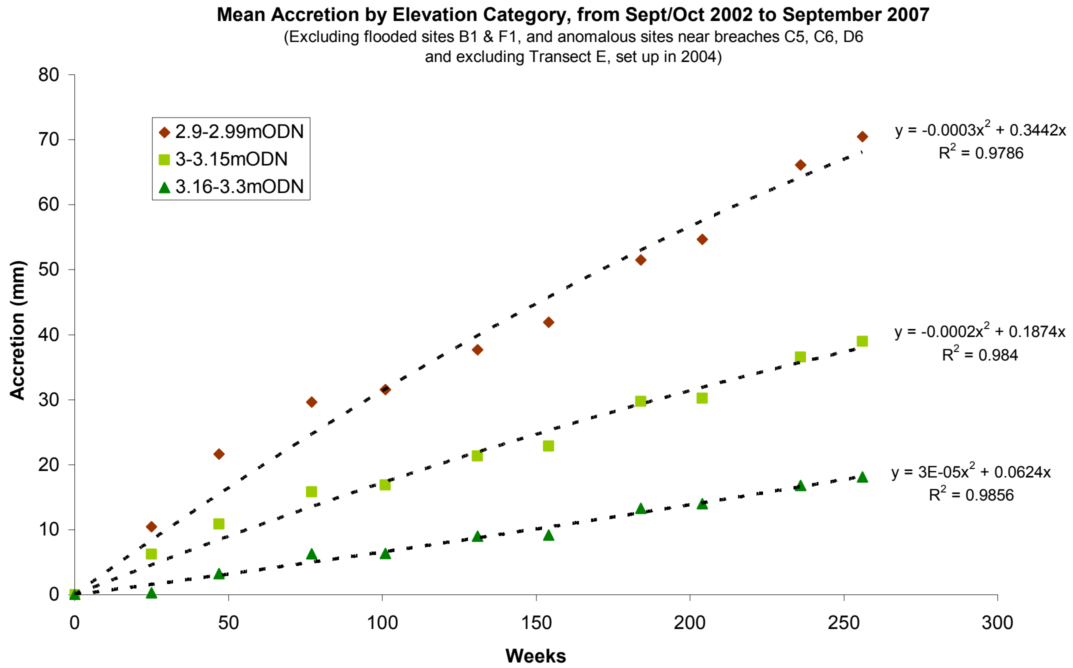


Figure 3.10. Mean accretion according to elevation from September 2002-2007

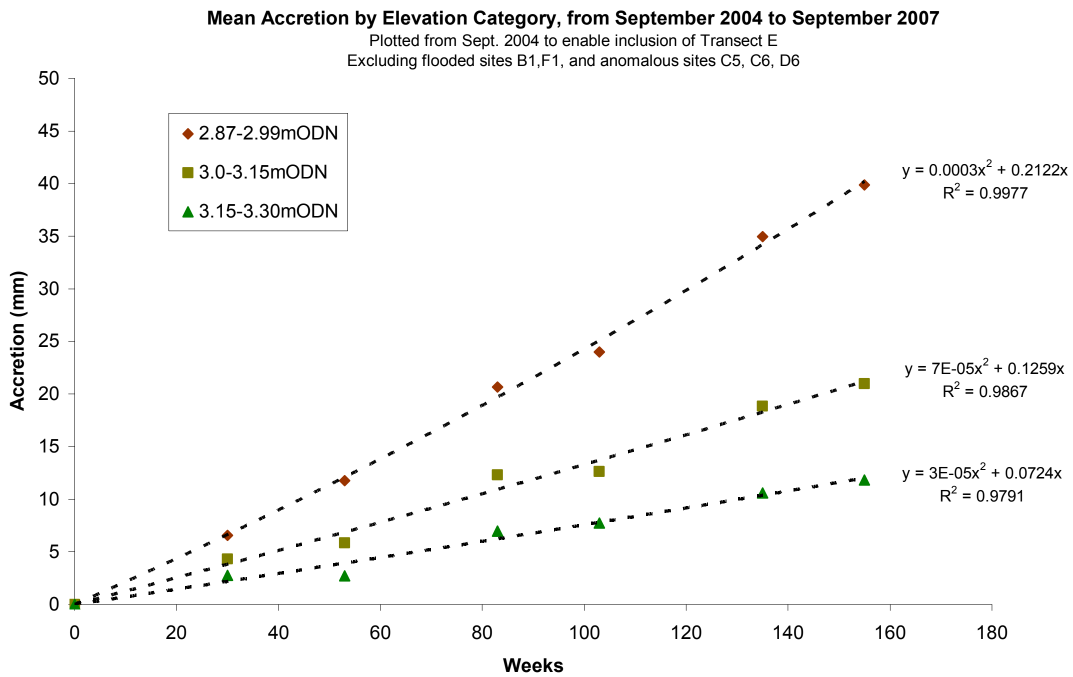


Figure 3.11. Mean accretion according to elevation from September 2004-2007

Mean (cumulative) accretion for realignment sites grouped into elevation categories is shown in Figure 3.10. As expected, the highest accretion was in the lowest elevation category, and the lowest accretion was in the highest elevation category. [Note that the lowest elevation category in this figure is 2.9-2.99mODN, and not 2.7-2.99mODN, because some of the lowest sites were either near the central breach and were excluded, or they were underwater and could not be measured in the first year.] The best-fit trend line was for a polynomial relationship, although the fit (R^2) was almost as good for a linear relationship. The main point in this graph is that it shows no evidence as yet that accretion have changed in any consistent direction (e.g. slowing down) in any of the elevation categories in the realignment site.

The data is also shown from September 2004 to September 2007 (Figure 3.11) so that the results from Transect E could be included. The data for the other sites were re-calculated to start from zero in September 2004. The number of sampling points were more limited (7 compared with 11 in the previous figure) but again, there was no evidence that accretion rates are slowing down to date, and in fact the trend has been towards a very slight increase in accretion since 2004 in the lower elevation category.

4. Results: Vegetation

4.1 5 x 1 m^2 Quadrats Inside the Realignment Site: Summary Observations on Vegetation Cover

Percentage ground cover of vegetation (calculated from 100 - % bare estimate) at sites inside the realignment site in 2007 is shown in Figure 4.1. Excluding the two sites with standing water (TBS1 and TFS1), the lowest mean total cover was 23% at TDS6 (first colonised in 2006 after poor drainage in previous years), followed by 57% cover at TDS4, and the highest cover (94% to 97%) was found at the top of Transect A (TAS1-4) in the northwest corner at the highest elevation sites, and TCS1.

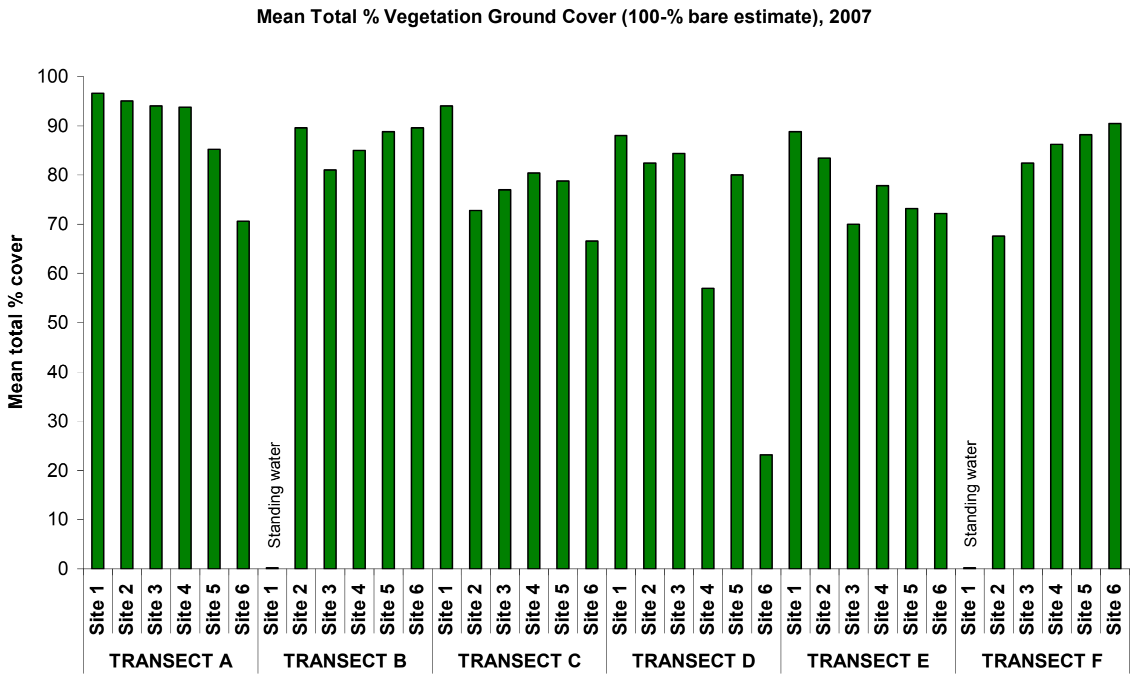


Figure 4.1. Mean total percentage vegetation ground cover (100- % bare ground estimates) at sites in the realignment in 2007

Mean total percentage ground cover for all years at sites inside the realignment is shown in Figures 4.2 to 4.7.

Apart from sites covered in standing water for all or most of the monitoring programme, where conditions were unsuitable for vegetation establishment, vegetation cover increased between 2003 and 2006. By 2006, the lowest mean total percentage ground cover was 7.2% at TDS6, followed by 39% at TDS4. The remaining 32 sites were covered with 60% vegetation or more, of which 25 sites were recorded with more than 80% vegetation ground cover, and 11 sites had exceeded 90% ground cover.

Several sites, particularly on Transects D to F showed a slight decrease in vegetation ground cover between 2004 and 2005. This was due mainly to fluctuations in cover by the early pioneer annuals, particularly *Salicornia europaea* (Common Glasswort) and a reduction in the size of individual annual plants, particularly *Suaeda maritima* (Annual Sea-blite). This was noted in Brown *et al*. (2007) and is shown in a later section on species composition. The declining annual plant cover has been replaced by perennial species which have been spreading, but they had not increased in cover sufficiently by 2005 to offset the drop in cover of annual plants. Some sites on all of the six transects also showed a slight drop in estimated mean ground cover values between 2006 and 2007. Fluctuations in plant cover would not be unexpected during plant succession.

Mean vegetation ground cover on Transect A (Figure 4.2) increased each year in sites 1-5 to over 90% in 2006, and it changed little (or decreased slightly) by 2007. Site 6 was covered in water during the first two years but once the site was drained vegetation ground cover has increased from 13% in 2004 to 71% in 2007.

Sites 2-5 on Transect B (Figure 4.3) developed vegetation cover rapidly, reaching between 78% and 92% ground cover by 2004. Mean ground cover at site 6 was lower than the other sites in 2004 (68%) but cover has increased steadily each year. By 2007, sites 2-6 had between 81% and 90% mean plant cover. Estimated ground cover on sites 2 and 3 was slightly lower in 2007 than in 2006. Site 1 has been underwater most of the time except for occasional drying out during hot weather when not flooded by neap tides, so conditions have not been suitable for plant establishment.

Vegetation has spread steadily year on year up to 2006 at most sites on Transect C (Figure 4.4). Mean ground cover was between 81% and 93% at sites 1-4 in 2006. Cover was somewhat lower in 2007 at sites 2-4 than in 2006, and mean values for sites 1-4 in 2007 ranged from 73% to 94%. Sites 5 and 6 received considerable sediment deposition washed in from the central breach area, particularly in the first year or two following the breach and site 5 was also poorly drained in the first year. These sites had just 0.6%-3% mean vegetation ground cover in 2003 but have increased their plant cover steadily to 67% cover at site 6 and 79% cover at site 5 by 2007.

On Transect D (Figure 4.5) mean vegetation ground cover had increased to between 82% and 94% at sites 1 to 3 and site 5 by 2006. Slightly lower cover values were recorded in 2007 compared with 2006 at sites 1, 3, and 5. Site 4 has shown fluctuating values for mean ground cover, probably due to poor drainage. Although not permanently underwater this site retained water after spring tides had left the realignment site and was slow to dry out. Site 6 was under a film of water during each survey up to 2005, but vegetation has since colonised and spread to reach a mean ground cover value of 23% in 2007.

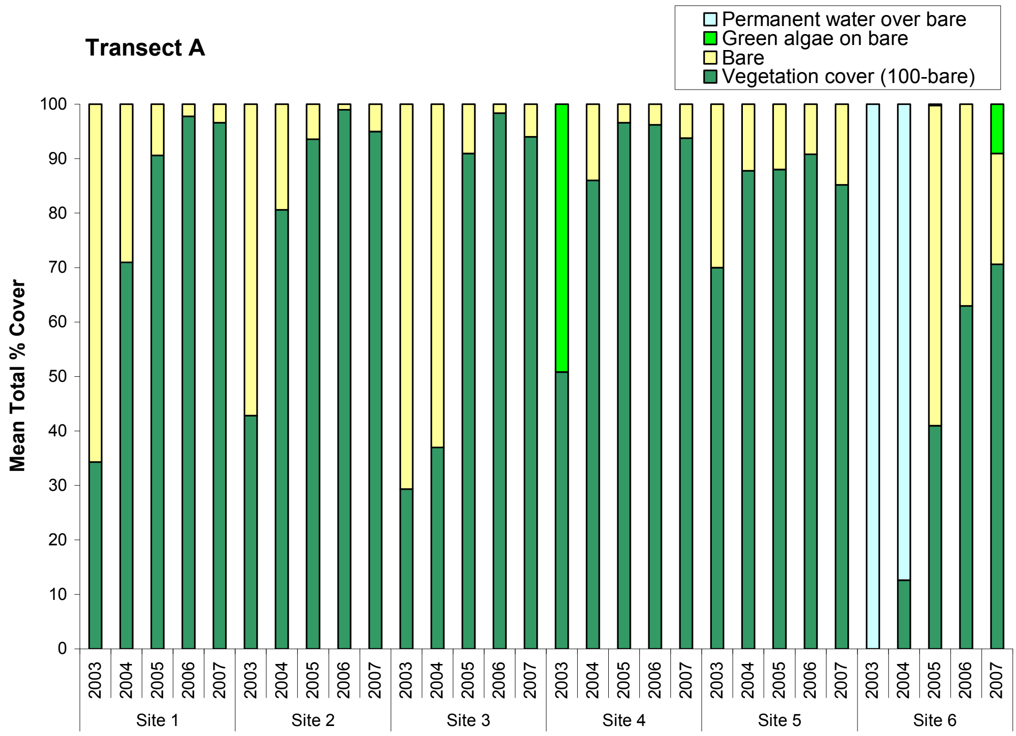


Figure 4.2. Mean total percentage vegetation ground cover (100%-bare estimate) on Transect A

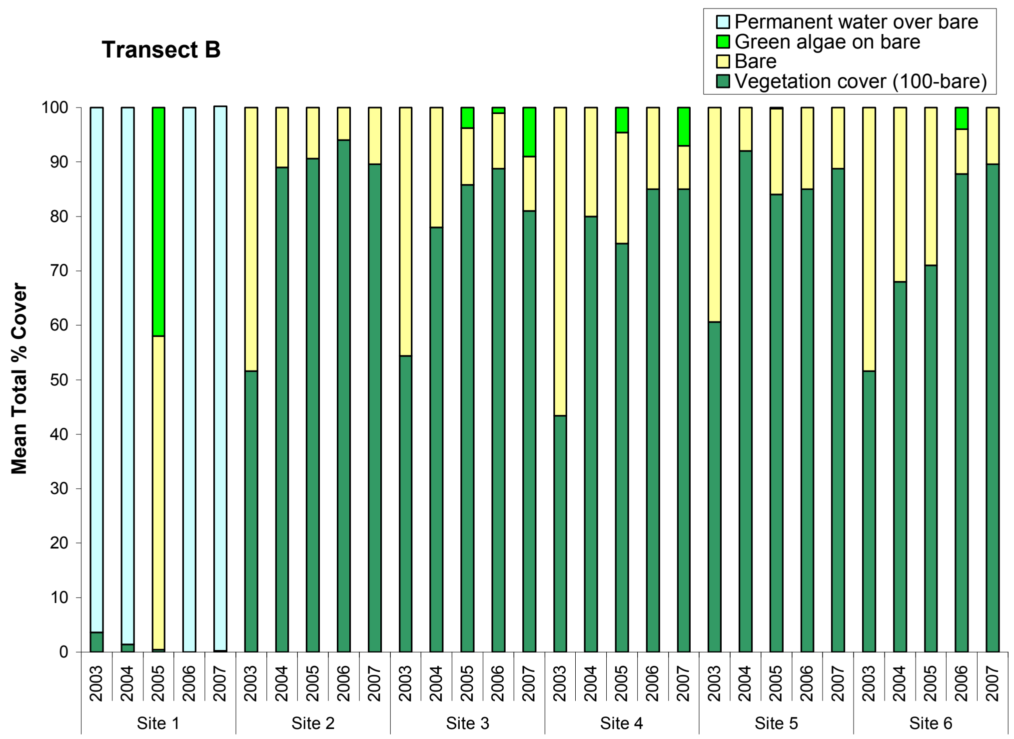


Figure 4.3. Mean total percentage vegetation ground cover (100%-bare estimate) on Transect B

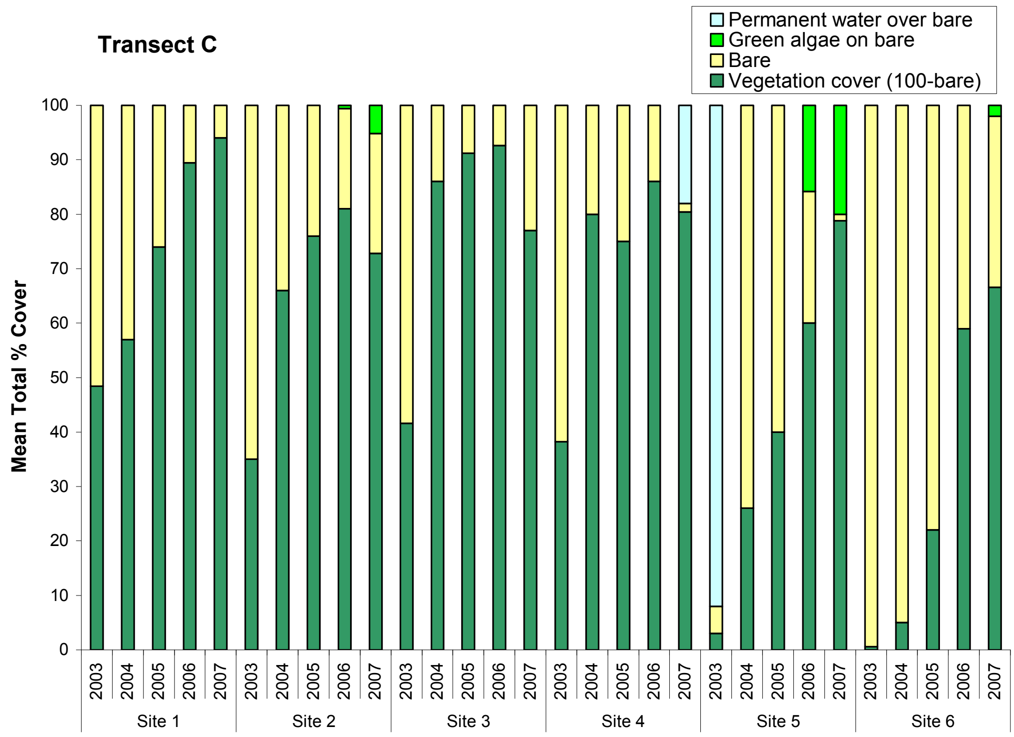


Figure 4.4. Mean total percentage vegetation ground cover (100%-bare estimate) on Transect C

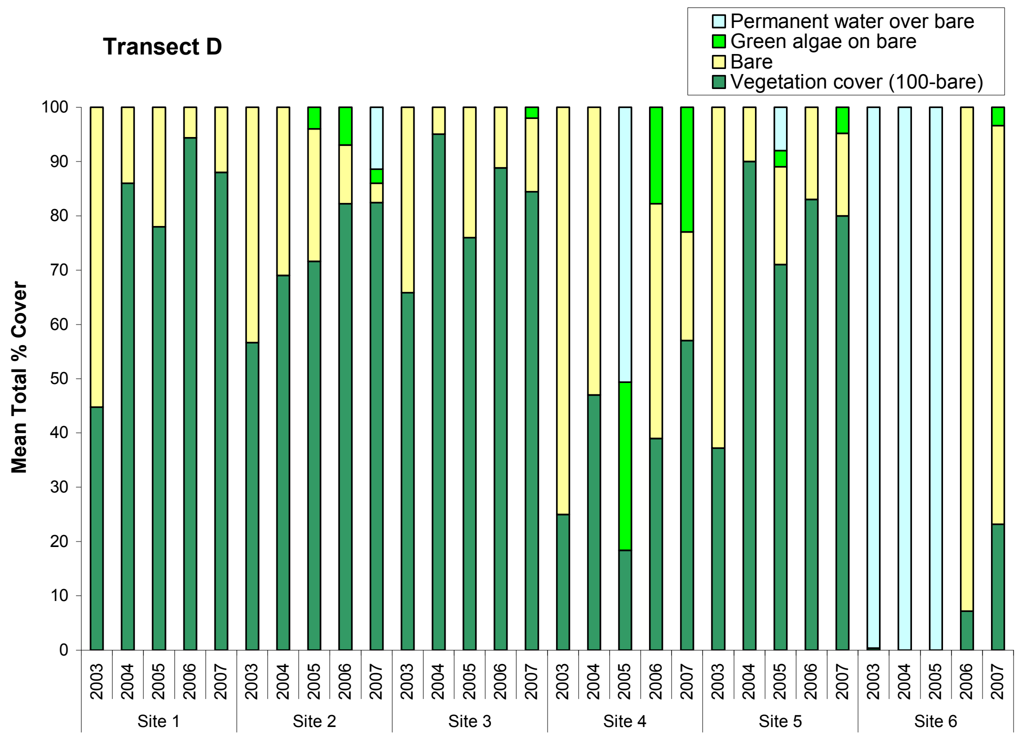


Figure 4.5. Mean total percentage vegetation ground cover (100%-bare estimate) on Transect D

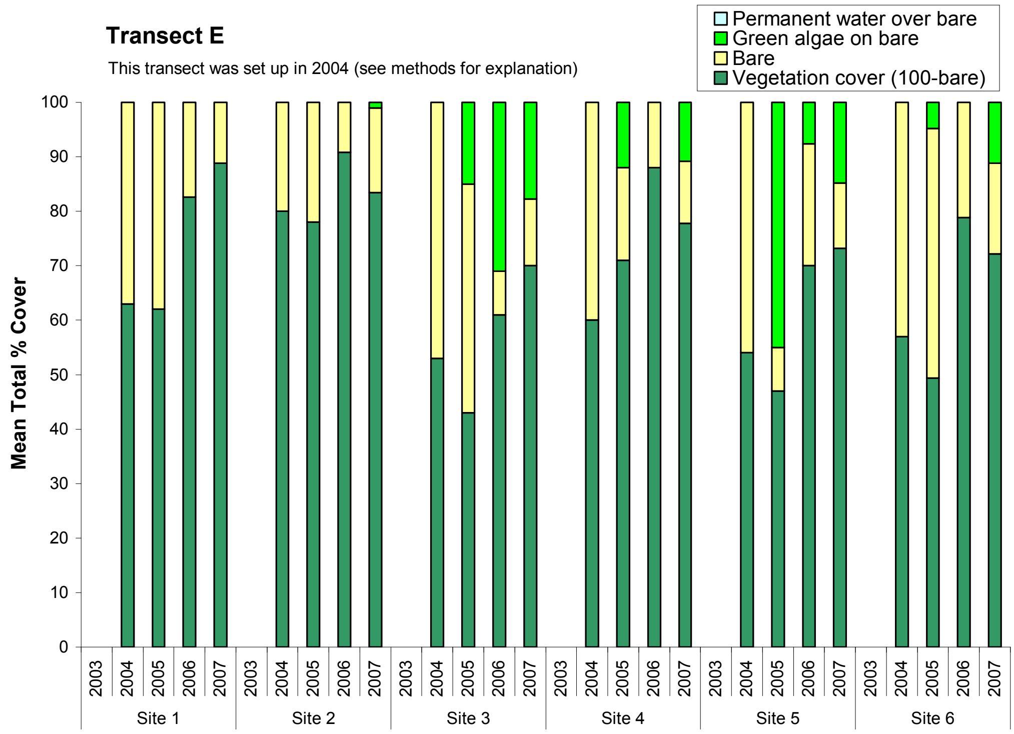


Figure 4.6. Mean total percentage vegetation ground cover (100%-bare estimate) on Transect E

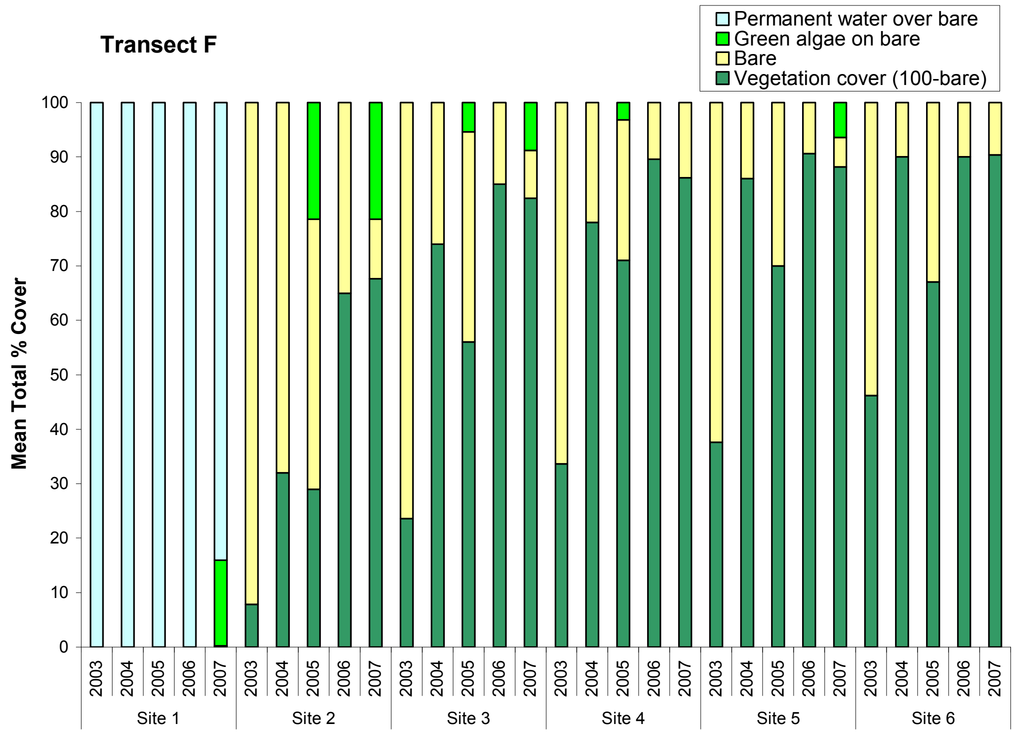


Figure 4.7. Mean total percentage vegetation ground cover (100%-bare estimate) on Transect F

Mean total ground cover on Transect E (Figure 4.6) sites 1, 2 and 4, ranged from 83-91% by 2006 and 78-89% in 2007. Mean cover was slightly lower in the other three sites (sites 3, 5 and 6) at 61-79% in 2006, and 70-73% in 2007. Three sites (2, 4, and 6) had slightly lower estimated ground cover values in 2007 compared with 2006.

Site 1 on Transect F (Figure 4.7) has been covered in several centimetres of standing water in all years and has not developed vegetation, although a small corner of the quadrat (≈16%) was uncovered by water this year during the survey, with one specimen of *Salicornia europaea* (Common Glasswort). Sites 2-6 have increased in vegetation ground cover over the five year monitoring programme, but with a slight drop in estimated cover between 2004 and 2005. Sites 3, 4, and 5 also dropped slightly in cover between 2006 and 2007. In 2007, mean ground cover estimates were 68% at site 2, and ranged from 82% to 90% at sites 3 to 6.

4.2 5 x 1 m^2 Quadrats: Mean Total Vegetation Cover Inside and Outside the Realignment Site at Equivalent Elevation Range

The mean total vegetation cover inside the realignment site (all sites) from 2003 to 2007 compared with outside at the same elevation range (2.7-3.3mODN) from 2002 to 2006 (no survey this year) is shown in Figure 4.8. Figure 4.9 shows the data excluding the two waterlogged sites without vegetation (TBS1, TFS1). Note that the data were compiled from the sum of individual species cover estimates (i.e. not ground cover from 100 - % bare estimate). The difference between ground cover and vegetation cover by the two estimates is zero with one species, very little with just a few species with little overlap, but it increases with more diverse intermingled vegetation and can exceed 100%, often over 120%, in dense vegetation because of species overlap even if there are a few percent of bare ground in the quadrat. Vegetation cover estimates from the sum of species cover gives a fairer comparison of vegetation density between the realignment site and the adjacent salt marsh because a site can be more diverse with overlapping species and effectively denser in vegetation cover even if the ground cover (and remaining bare estimate) is the same.

Mean total vegetation cover estimates outside the realignment site at 2.7-3.3mODN varied between 95% and 97% cover. Mean total cover has increased inside the realignment each year, from 35% in 2003 to 81% in 2006, with a further small increase after 2006 to 84% in 2007. Excluding the 2 flooded sites, mean total cover increased from 37% in 2003 to 86% in 2006 and 89% in 2007.

The continued increase in vegetation cover in the realignment appears to be on track for cover to reach an equivalent value to that outside (at the same elevation range) by 2010, as we suggested in the four year report (Brown *et al*. 2007). We noted that it may take longer than this for the realignment site to reach equivalent vegetation community composition and relative species abundance. The changes observed in species cover values are discussed later.

Elevation is a key factor for vegetation establishment and zonation of species, and is therefore the most useful basis for comparison of vegetation cover and species composition between the realignment site and the salt marsh outside. All of the monitoring sites in the realignment lie at elevations suitable for salt marsh establishment, between 2.7mODN and 3.3mODN (elevation measurements taken in 2005). Sites on the adjacent and fronting salt marsh lie at elevations between 2.1mODN and 3.3mODN. As the outside marsh was not surveyed in the final year of the monitoring programme, the data from 2002 (pre-breach) up to 2006 have been used to make comparisons.

Figure 4.10 shows the mean total percentage vegetation cover inside and outside the realignment site (excluding the two standing water sites), for sites grouped into elevation range categories.

Outside on the pioneer marsh (<2.7mODN) mean total vegetation cover increased each year, from 34% in 2002 to 61% by 2006.

In the lower half of the elevation range inside the realignment site (2.7-2.99mODN), mean total vegetation cover increased from 26% in 2003 to 72% in 2006 and to 80% by 2007. The mean total cover values outside the realignment site at this elevation varied between 88% and 93%.

At 3.0-3.15mODN mean total cover inside the realignment was 40% in 2003 and increased to 87% in 2006 and 90% in 2007. Outside at this elevation mean total cover values varied between 97% and 106% (values can be over 100% with species cover additions due to species overlap).

Vegetation spread was most rapid at the highest elevation category inside the realignment site (3.16-3.3mODN) at 43% mean total cover in 2003 which increased to 98% by 2005, and has changed little since (98% in 2006, 97% in 2007). The mean cover values in 2005 were comparable with vegetation cover outside at this elevation range (between 98% and 104%).

The realignment data is shown as a line plot in Figure 4.11, for easier visual comparison of rates of vegetation spread. This shows the highest rate of growth in the upper elevation category, levelling off after 2005, followed by the middle and then lower elevation range categories. The mean total cover value for the middle category levelled off between 2004 and 2005, and decreased slightly between these years in the lowest range category. This was due mainly to a marked decrease in the annual *Salicornia europaea* (Common Glasswort) cover between these two years, and the decrease in the size of these and annual *Suaeda maritima* (Annual Sea-blite) plants (discussed in Brown *et al.* 2007). Both these range categories showed a subsequent increase in vegetation cover between 2005 and 2007.

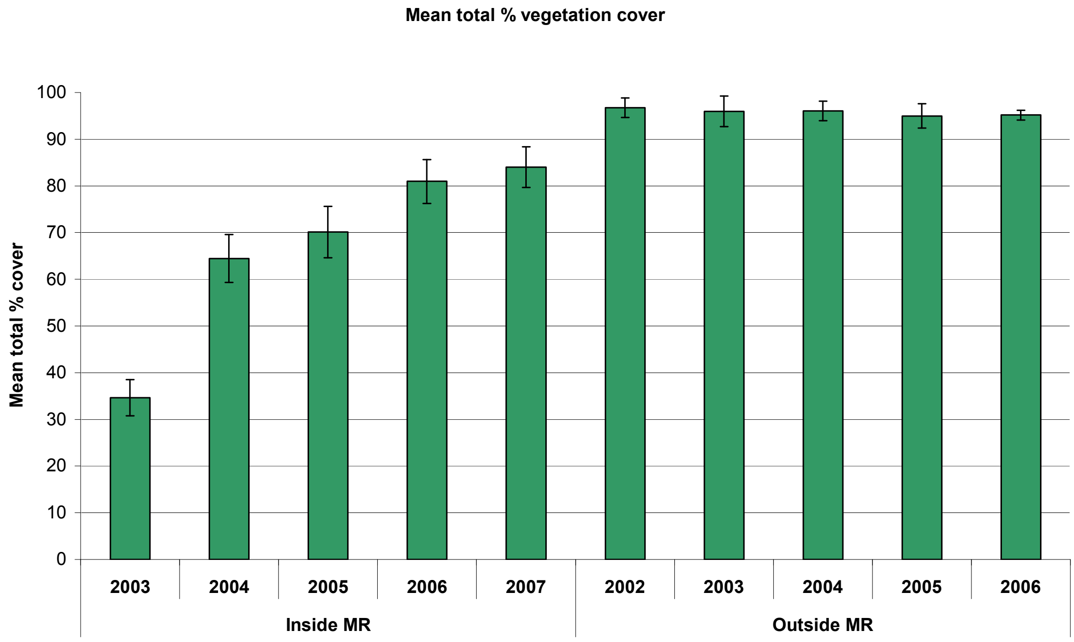


Figure 4.8. Mean total percentage vegetation cover inside and outside the managed realignment site at the equivalent elevation range (2.7-3.3mODN) ±SE. Values are calculated from the sum of individual species cover. No. of sites inside MR: 30 (2003), 36 (2004-2007).

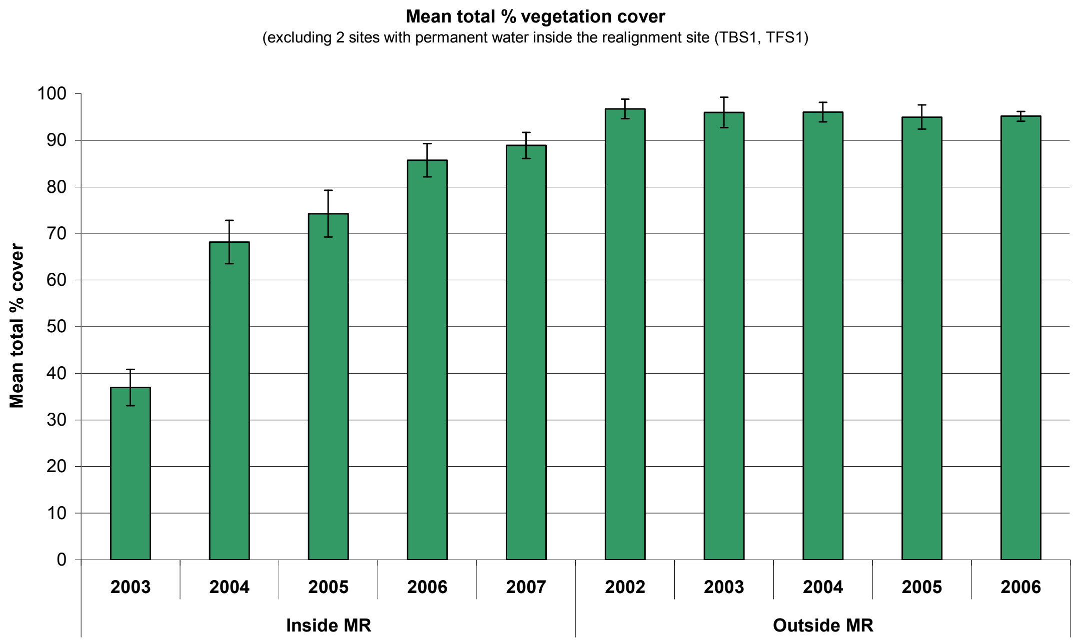


Figure 4.9. Mean total percentage vegetation cover inside and outside the managed realignment site at the equivalent elevation range (2.7-3.3mODN) ±SE, excluding 2 sites with permanent water cover (B1, F1). Values are calculated from the sum of individual species cover. No. of sites inside MR: 30 (2003), 36 (2004-2007).

Table 4.1. Summary means for total percentage vegetation cover in the 5 x 1m^2 quadrats, by elevation category

Category	No. of Sites ( )=sites in 2003*	ELEVATION (mODN) MEAN	MEDIAN	MEAN TOTAL % VEGETATION COVER (from sum of species cover) 2002	2003	2004	2005	2006	2007
INSIDE MR:									
Whole range: 2.7-3.3mODN	36 (30)	3.067	3.080		34.6	64.4	70.1	80.9	84.0
2.7- <3.0mODN	12 (9)	2.920	2.935		22.9	51.5	48.1	65.7	73.2
3.0-3.3mODN	24 (21)	3.141	3.130		39.6	70.9	81.2	88.6	89.3
3.0-3.3mODN divided into 2 categories:									
3.0-3.15mODN	13 (11)	3.080	3.080		36.3	66.4	67.3	80.4	82.8
3.16-3.3mODN	11 (10)	3.213	3.210		43.3	76.2	97.5	98.2	97.1
Excluding 2 sites with standing water:									
Whole range: 2.7-3.3mODN, excl. TBS1, TFS1	34 (28)	3.069	3.080		37.0	68.1	74.2	85.7	88.7
2.7- <3.0mODN, excluding TFS1	11 (8)	2.916	2.930		25.8	56.1	52.5	71.7	79.9
3.0-3.3mODN, excluding TBS1	23 (20)	3.141	3.130		41.4	73.9	84.7	92.4	93.2
3.0-3.15mODN, excluding TBS1	12 (10)	3.076	3.080		39.6	71.8	72.9	87.1	89.7
OUTSIDE MR:									
2.7-3.3mODN (= range in MR)	26	3.010	2.990	96.8	95.9	96.0	95.0	95.2	
<2.7mODN (no equivalent in MR)	12	2.483	2.550	33.8	32.5	40.2	42.4	60.9	
2.7- <3.0mODN	13	2.859	2.830	90.6	88.2	89.7	88.0	93.4	
3.0-3.3mODN	13	3.160	3.160	103.0	103.6	102.4	101.9	97.2	
3.0-3.3mODN divided into 2 categories:									
3.0-3.15mODN	6	3.070	3.060	101.2	105.5	102.4	102.7	96.6	
3.16-3.3mODN	7 (5,2006)†	3.237	3.260	104.5	102.0	102.4	101.3	97.9	

Notes: * No. of sites: ( ) = before Transect E was established
† 2 sites outside MR damaged by cattle in 2006

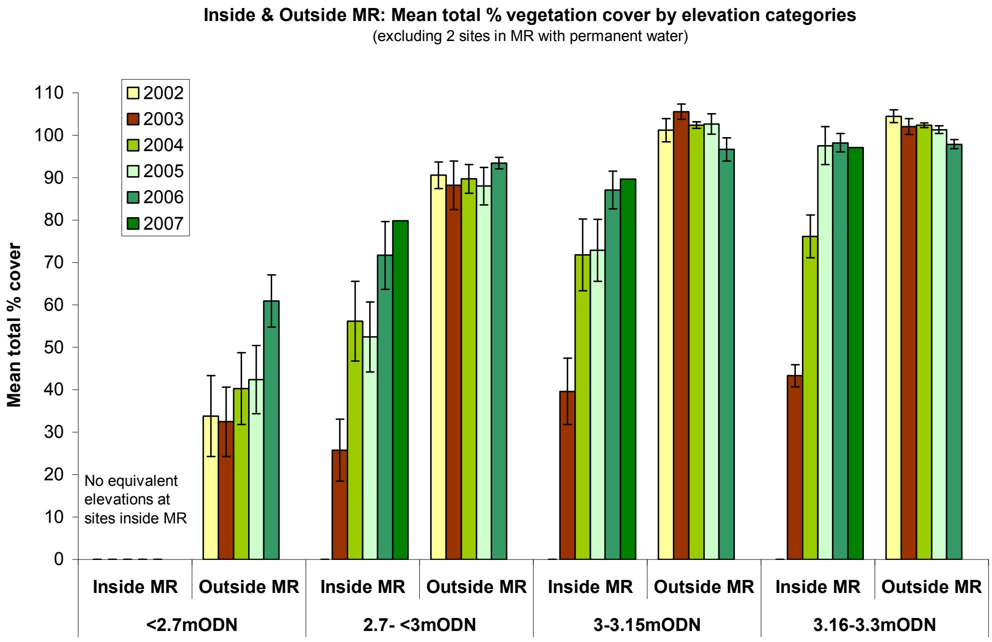


Figure 4.10. Mean total percentage vegetation cover inside and outside the managed realignment site at different elevation ranges ±SE. Values were calculated from the sum of individual species cover. No. of sites (n) inside MR: 2.7-<3.0mODN, n=12 (9 in 2003); 3.0-3.15mODN, n=13 (11 in 2003); 3.16-3.3mODN, n=11 (10 in 2003); outside MR: <2.7mODN, n=12; 2.7-3.0mODN, n=13; 3.0-3.15mODN, n=6; 3.16-3.3mODN, n=7 (5 in 2006 due to cattle damage)

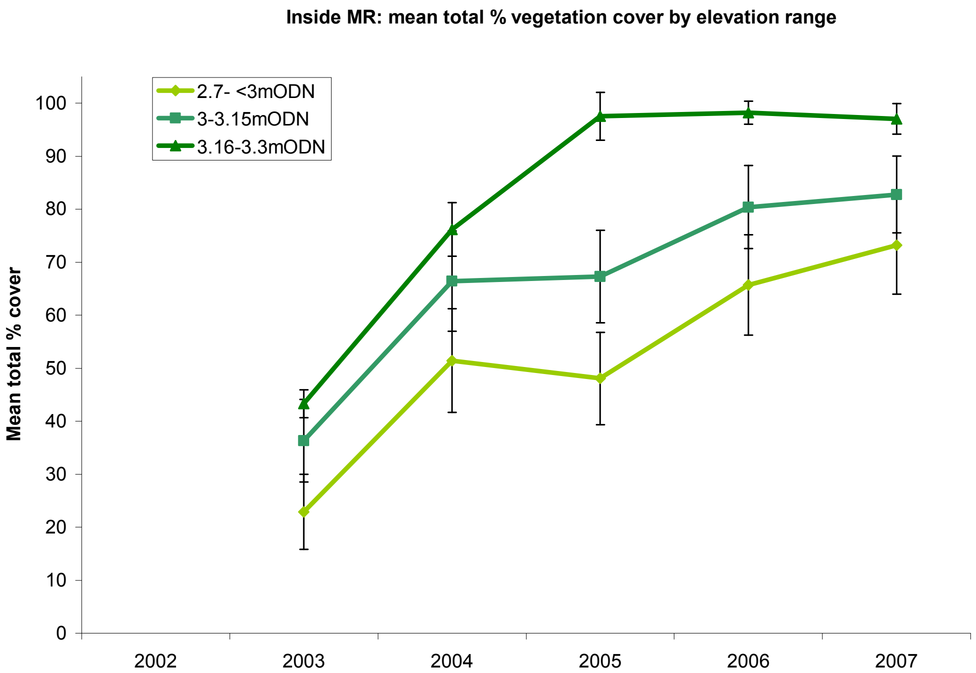


Figure 4.11. Line plot of mean total percentage vegetation cover by elevation category inside the managed realignment site

4.3 Number of Species Inside and Outside the Realignment Site

English names and Scientific (Latin) names for plant species found at Freiston are given in Appendix 1.

All of the species found on the salt marsh outside the realignment site, except for one (*Triglochin maritima*, Sea Arrow-grass) had been found in the realignment site by 2006. *Triglochin maritima* was only seen rarely on the salt marsh outside the realignment at Freiston and it was not noted inside the site in 2007. Of course, it may exist, but we cover a large area of ground crossing the site to survey all the quadrats and sediment sampling stations, and have been keeping an eye out for this one remaining species. Therefore if it was present by 2007, it would have been very rare.

The common / abundant species outside were also all common inside. These were: the annuals *Salicornia europaea* (Common Glasswort) and *Suaeda maritima* (Annual Sea-blite), important colonizers of the pioneer zone and which were the dominant species inside the realignment in the first year; the perennials *Puccinellia maritima* (Common Saltmarsh-grass), *Atriplex portulacoides* (Sea purslane) and *Spartina anglica* (Common Cord-grass); and the biennial (sometimes annual) *Aster tripolium* (Sea Aster), all found occasionally with low cover in 2003 and which have all increased in the realignment since. The grass *Elytrigia atherica* (Sea Couch) established in small amounts inside the realignment at the highest points in 2003 and has spread into a large patch near the northwestern end (by the 5m x 5m quadrat, X4), with numerous smaller patches colonizing this corner of the site between 2005 and 2007. It has been recorded in one of the 5 x 1m^2 quadrats (TAS1) in the northwestern corner since 2005 and it was found in A3 (5 x 5m quadrat, near TAS3) in this part of the site in 2003 and 2007. This grass is more common inside the realignment site than outside (except at the base of and on the old breached embankment fenced off from cattle), presumably because it is protected from trampling and grazing by cattle which have access to the salt marshes north and south of the realignment.

Species found less frequently on the Freiston salt marshes than the abundant species listed above, but which have been monitored in the realignment site quadrats since 2003 include the Greater and Lesser Sea-spurreys *Spergularia media* and *Spergularia marina* (*S. marina* was not found in the quadrats after 2003), *Atriplex prostrata* (Spear-leaved Orache) found in two of the 5m x 5m quadrats, until 2004. *Cochlearia* sp. is common at the back of the realignment between the upper quadrat sites (Sites 1 on each transect) and the back fence, and was recorded in one of the large quadrats (X4) in 2007, and in one of the 5 x 1m^2 quadrats (TAS4) between 2004 and 2006. Two species, *C. anglica* (English Scurvy-grass) and *C. officinalis* (Common Scurvy-grass) occur in this area of the Wash, although we have not distinguished between them in the surveys as the very small non-flowering specimens found sometimes under other vegetation were difficult to differentiate. *Sarcocornia perennis* (Perennial Glasswort) was noted occasionally inside the realignment in 2006 and was found in two site quadrats, three in 2007. *Plantago maritima* (Sea Plantain) and

Limonium vulgare (Sea Lavender) occur occasionally on the outside salt marsh (locally common in a few places) and have also been found occasionally along the back of the realignment site between the upper quadrat sites and the back fence. Sea Wormwood (*Artemisia maritima*) occurs on an elevated mound between the embankment and Transect 1 Site 1 north of the realignment, and has also been found in the northwest corner below the car park on the embankment near the upper drift line of high spring tides which lies outside the realignment fence.

A total of 16 species had been noted in the managed realignment by 2006 (including two species for *Cochlearia* and the *Artemisia* just outside the fence in the northwest corner). Eleven species in total were recorded overall in the 36 (5 x $1m^2$) quadrats inside the realignment site between 2003 and 2007, although not all of these were found in all years (9 species in 2003, 2005, 2007; 8 species in 2004; 10 species in 2006). A total of 12 species were recorded overall in the 9 larger, 5 x 5m, quadrats between 2003 and 2007 (varying between 8 and 11 species in different years). Nine species were recorded in the 5 x $1m^2$ quadrats outside the realignment between 2002 and 2006 (no survey in 2007). Of the nine species, the seven most abundant species were common to both outside and inside the realignment site quadrats: *Aster tripolium*, *Atriplex portulacoides*, *Puccinellia maritima*, *Salicornia europaea*, *Spartina anglica*, *Spergularia media* and *Suaeda maritima*. A more occasional species, *Sarcocornia perennis* was first recorded in the realignment quadrats in 2006.

The mean number of species (and range) found in the permanent quadrats outside and inside the realignment at the elevation range of the realignment quadrats (2.7-3.3mODN) is shown in Figure 4.12. The values were calculated omitting the two flooded sites without vegetation in the realignment.

Outside the realignment site at 2.7-3.3mODN the mean number of species recorded in the quadrats (between 2002 and 2006) fluctuated between 5.46 and 5.77. Inside the realignment, mean species number has increased from 4.39 and 4.26 in 2003 and 2004 respectively to 5.71 in 2006, close to the mean value for the adjacent marsh. Therefore by 2006, the mean species number in the realignment site was equivalent to that outside (although the minimum and maximum range was still lower inside than outside). Note that the maximum range is not as great as the maximum number of species in all sites taken together, because it is the maximum range found at any individual site (a few of the less common species vary between sites). The lower value in 2006 outside the realignment (compared with 2004 and 2005) does not represent a real loss of species but was due to the loss of two sites at the upper end of the marsh to cattle damage (markers gone). The mean value of species inside the realignment had increased to 6.18 in 2007.

Figures 4.13 to 4.15 show the mean species number inside the realignment site to 2007 and outside to 2006 in sub-categories of the elevation range to show where most species were found.

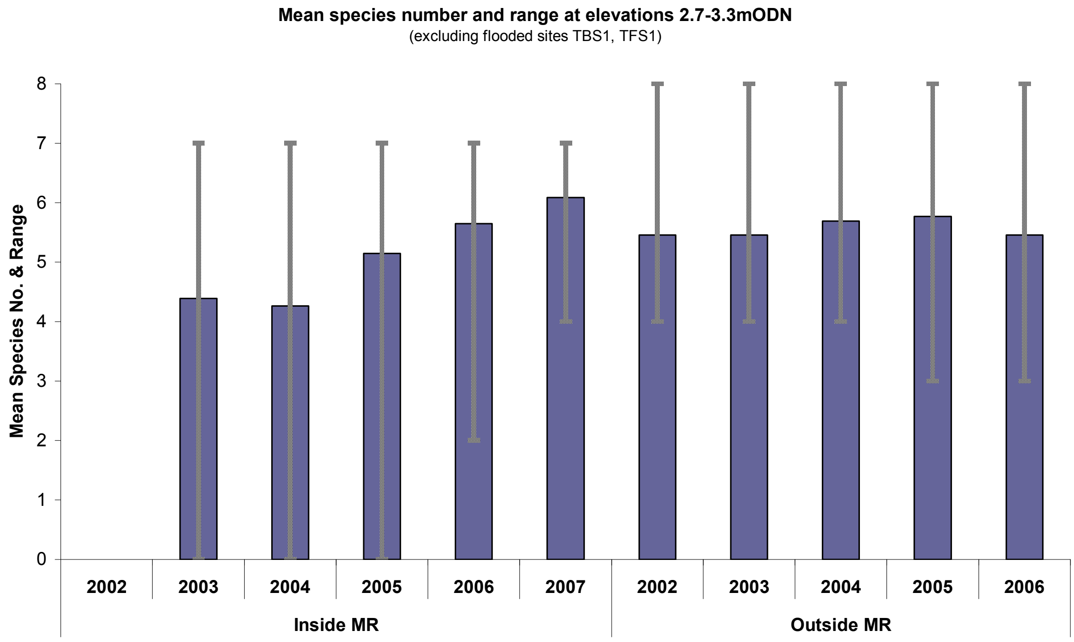


Figure 4.12. Mean species number in the realignment site and outside at the equivalent elevation range

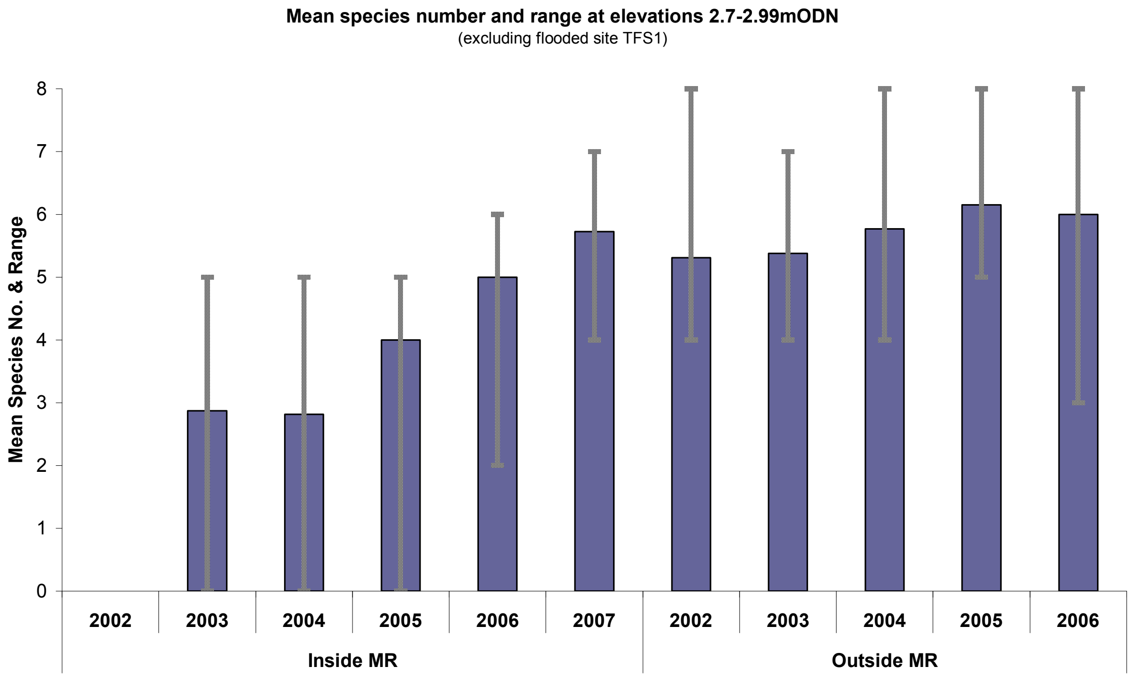


Figure 4.13. Mean species number inside the realignment site and outside at elevation range 2.7-2.99mODN

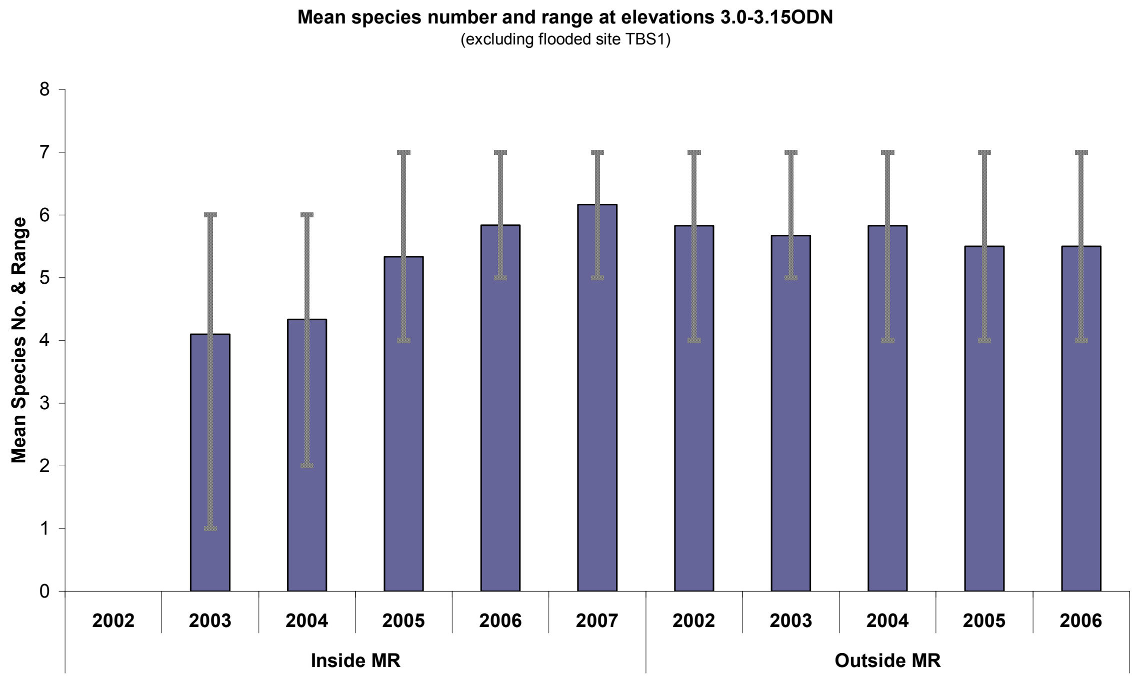


Figure 4.14. Mean species number inside the realignment site and outside at elevation range 3.0-3.15mODN

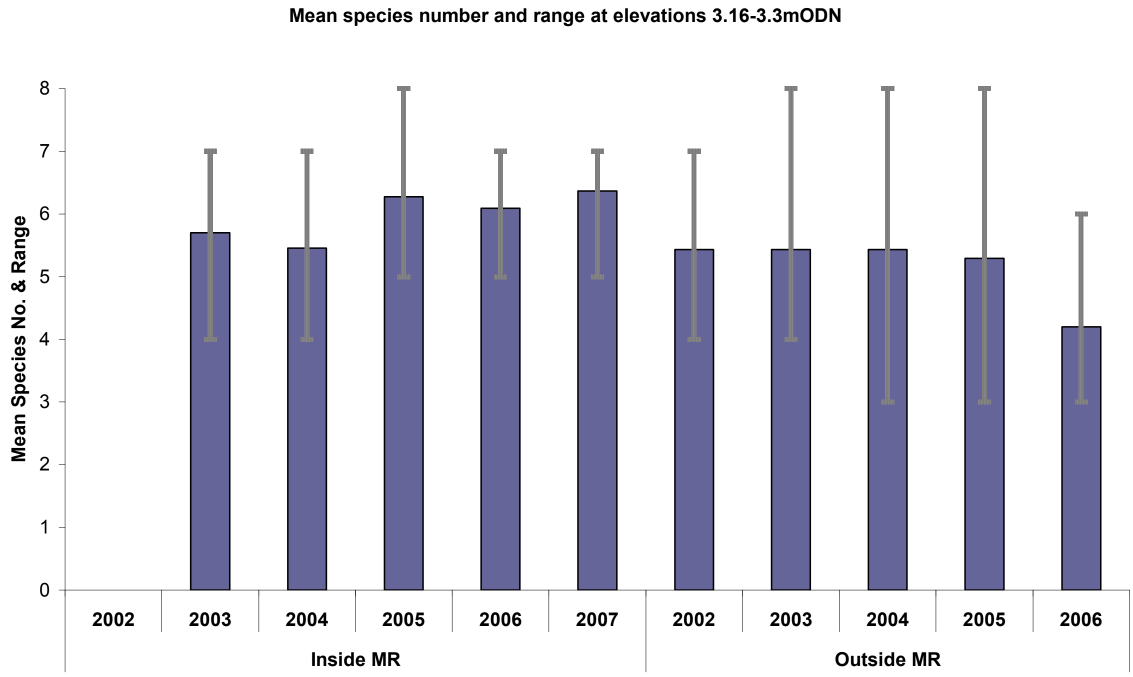


Figure 4.15. Mean species number inside the realignment site and outside at elevation range 3.16-3.3mODN

At 2.7-2.99mODN (Figure 4.13) mean species number on the salt marsh outside the realignment increased from 5.31 in 2002 to 6.15 in 2005 (6.0 in 2006). Inside the realignment at this range (excluding TFS1, underwater) mean species number was 2.88 in 2003 and 2.82 in 2004, but increased to 5.09 by 2006 and 5.73 by 2007.

At 3.0-3.15mODN (Figure 4.14) the mean number of species outside the site varied between 5.50 and 5.83. Inside the site (excluding TBS1, underwater) the mean species number increased from 4.10 in 2003 to 5.83 in 2006, the same mean value as outside in this range. Mean species number inside the realignment increased further to 6.17 in 2007.

At the highest elevation category (3.16-3.3mODN, Figure 4.15), mean plant species number on the salt marsh was between 5.30 and 5.43 in 2002 - 2005. The value decreased to 4.20 in 2006, but this was due to the loss of two relatively diverse sites after grazing cattle had broken the marker posts. The rate of increase in total vegetation cover inside the realignment was the greatest at the upper (highest) sites and this elevation category was also the most diverse in species composition from the outset; mean species number was slightly higher than outside over all years, fluctuating between 5.46 and 6.27 (from 2003 to 2006) and was 6.36 in 2007.

4.4 5 x 1 m^2 Quadrats: Plant Species Composition Inside and Outside the Realignment Site, according to Elevation

Plant species composition and percentage cover at each site inside the realignment are shown graphically in Appendix 2. Individual sites outside the realignment (surveyed to September 2006) were shown in the appendix in last year's report (Brown *et al*. 2007). However, the species compositions summarised for different elevation categories outside on the salt marsh up to 2006 are included in this report for comparison with the realignment site. The data are shown in Figures 4.16 to 4.21, and described below.

4.4.1 Outside and inside the realignment site at elevation range 2.7-2.99mODN (Figures 4.16 and 4.17)

Eight species were recorded in the quadrats outside the realignment site at this elevation range (Figure 4.16). Annual *Salicornia europaea* was still the main cover species outside the realignment site at this elevation range by 2006, although its mean percentage cover had decreased from 40% in 2002 to 27/28% in 2005/6, followed by another annual species, *Suaeda maritima*, which fluctuated in mean cover between 19% and 24% between 2002 and 2006. *Aster tripolium* mean cover varied between 8.5% and 15%, *Spartina anglica* cover was stady at 10-11% between 2002 and 2005, increasing to 14% in 2006. *Puccinellia maritima* increased in mean cover from 7% in 2002 to 14% in 2004, but subsequently dropped to 6.6% estimated mean cover in 2006.

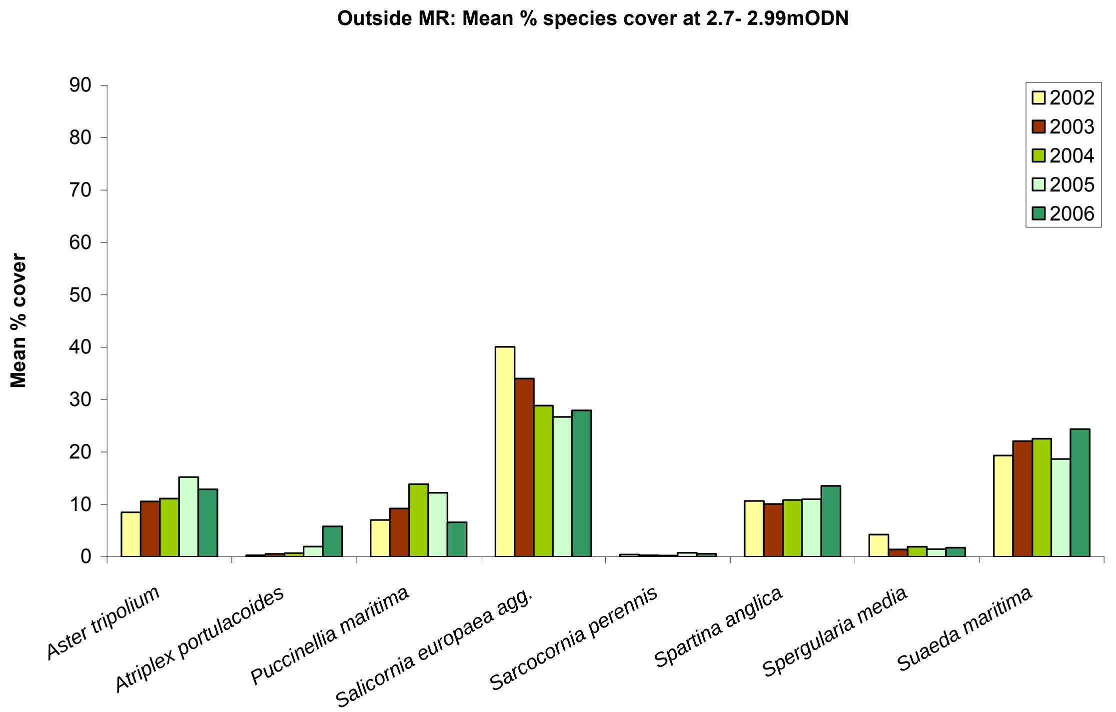


Figure 4.16. Mean percentage species cover on the salt marsh outside the realignment at elevation range 2.7-2.99mODN

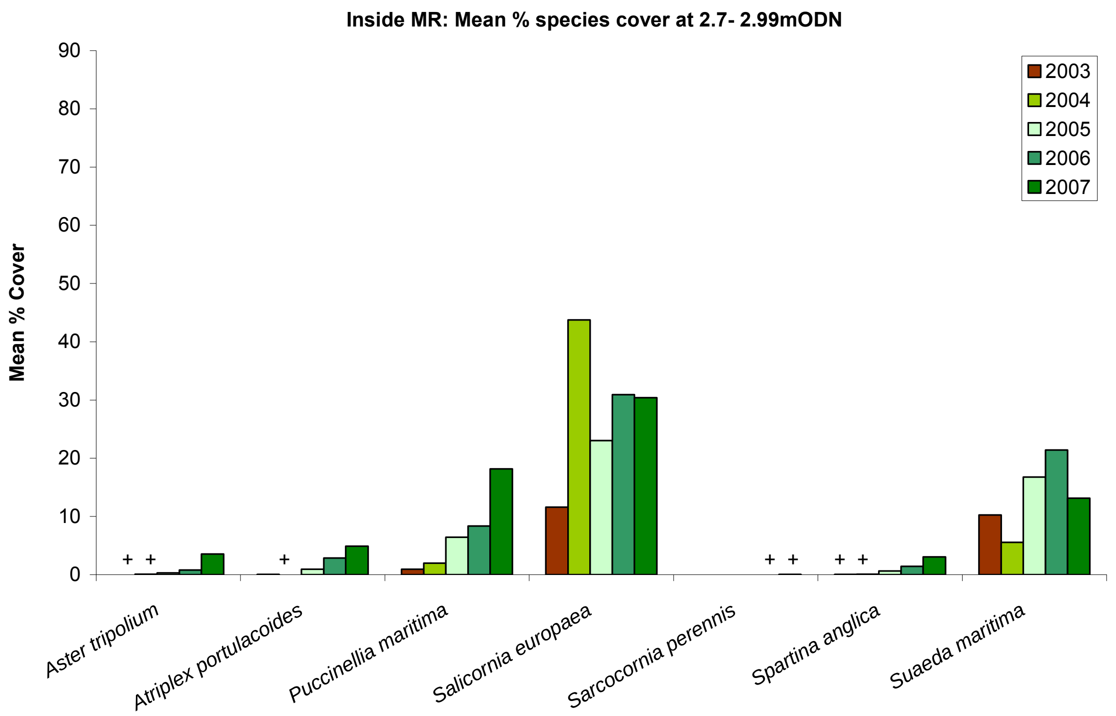


Figure 4.17. Mean percentage species cover inside the realignment at elevation range 2.7-2.99mODN [+ = species present at <0.2% mean cover]

Spergularia media was recorded with mean cover values between 1.4% and 4.3% (1.7% in 2006). *Atriplex portulacoides* increased steadily at this elevation outside on the salt marsh from 0.3% in 2002 up to 5.8% in 2006. Perennial Glasswort, *Sarcocornia perennis*, was also found in this range but occurred infrequently with mean cover values between 0.2% and 0.8%.

In summary, *Salicornia europaea*, followed by *Suaeda maritima* were still the most abundant species outside the realignment site at this elevation range by 2006. *Salicornia europaea* and *Puccinellia maritima* decreased in mean cover over the survey period, while *Atriplex portulacoides*, which was rare in 2002, increased in mean cover to 6%. After the two most important cover species (the pioneer annuals) the remaining species, in descending order of cover importance in 2006 (from 14% mean cover down to 0.5%) were: *Spartina anglica* > *Aster tripolium* > *Puccinellia maritima* > *Spergularia media* > *Sarcocornia perennis*.

By 2007, 7 species were found in the quadrats inside the realignment site at this elevation range (Figure 4.17). In the first year (2003), the two pioneer annuals *Salicornia europaea* and *Suaeda maritima* were the only species found with a mean cover greater than 1%, at 12% and 10% respectively, and they remained the dominant species at this elevation range up to 2006. *Salicornia europaea* was found at its highest mean cover of 44% in 2004, dropping to 31/30% in 2006/2007. *Suaeda maritima* was at its lowest cover in 2004 (6%), increased to 21% in 2006, but dropped to 13% in 2007. By 2006, both these species were found with similar mean cover values to sites on the salt marsh in 2006 at this elevation (*Salicornia* 28%, *Suaeda* 24%). *Aster tripolium* and *Spartina anglica* were found in all years at relatively low cover values, but both have increased between 2003 and 2007 (*Aster*: <<0.1% increasing to 3.6%, *Spartina*: <0.1% increasing to 3.0%). *Puccinellia maritima* has spread steadily from 1% in 2003 to 8% in 2006 and more than doubled its mean cover by 2007 to 18%. A tiny specimen of *Atriplex portulacoides* was found at one site in 2003, and although not recorded in the quadrats in 2004, it has increased in the last three years to 4.9% mean cover. This was not much lower than its mean cover of 5.8% outside in 2006. *Sarcocornia perennis* was first recorded in the quadrats at this elevation in 2006, but only present at one site (TES6) with a mean cover over all sites in this range of just 0.003% in 2006 and 0.03% in 2007. Only one species, *Spergularia media*, found outside at this elevation range at low mean cover (1.7% in 2006) has not yet been recorded in the realignment quadrats to date (2007).

In summary, *Salicornia europaea* followed by *Suaeda maritima* were still the most abundant species inside the realignment in 2006, with fluctuating cover values but showing an overall increase in cover between 2003 and 2006. These two pioneer annuals were found at similar cover values to those outside on the salt marsh. *Puccinellia maritima* has increased in mean cover each year and by 2007 its cover was greater than its peak value outside (in 2004). Other species (in descending order of cover in 2007): *Atriplex portulacoides*, *Aster tripolium* and *Spartina maritima* have all increased their mean cover values since 2003 to between 3% and 4.9% in 2007, although all were found at lower cover than outside in 2006 at this elevation range (*A. portulacoides* only slightly lower). *Sarcocornia perennis* was not recorded inside the site quadrats until 2006, with lower cover than outside at equivalent elevations, and was very occasional inside the realignment site in general.

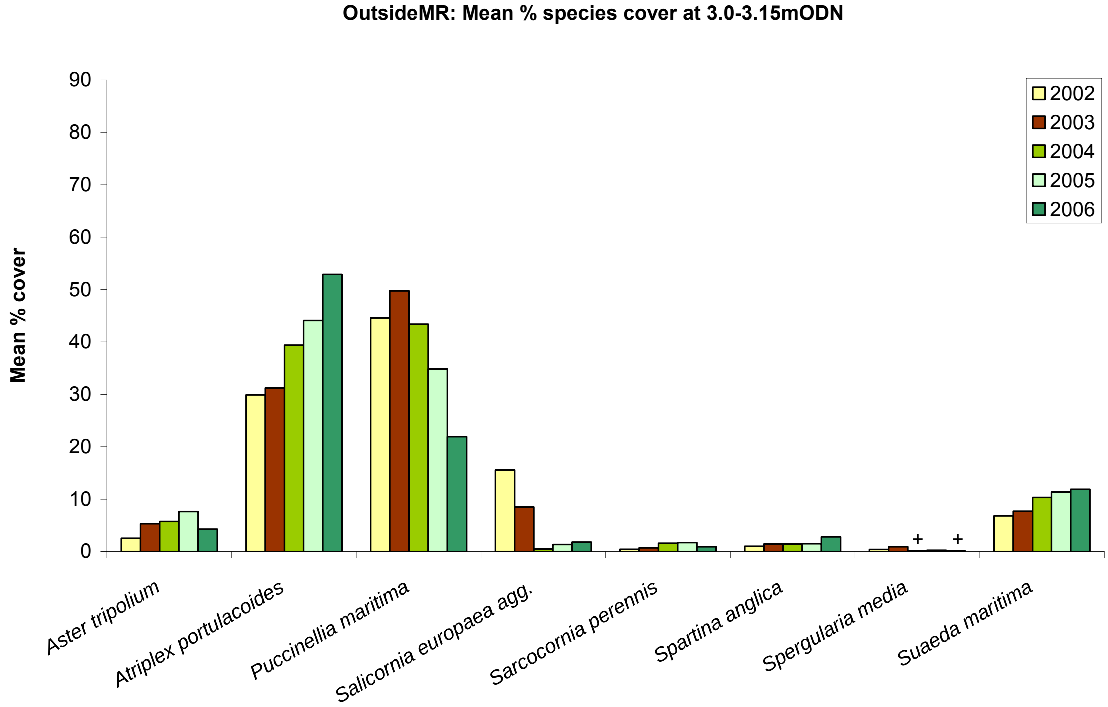


Figure 4.18. Mean percentage species cover on the salt marsh outside the realignment at elevation range 3.0-3.15mODN [+ = species present at <0.2% mean cover]

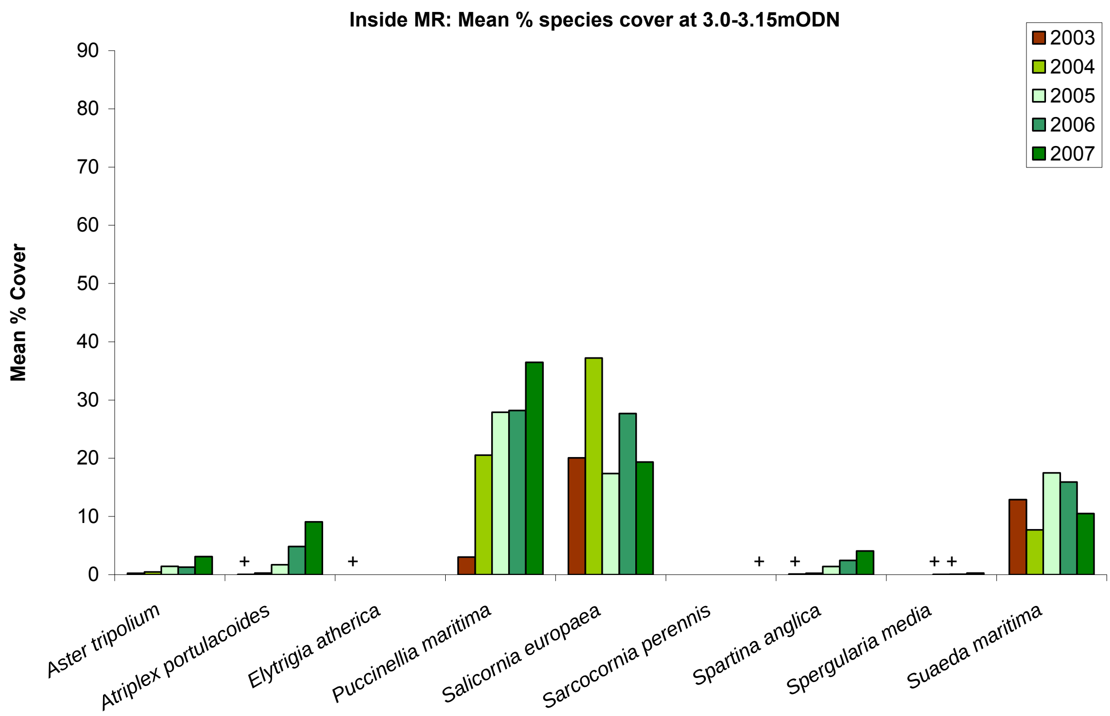


Figure 4.19. Mean percentage species cover inside the realignment at elevation range 3.0-3.15mODN [+ = species present at <0.2% mean cover]

4.4.2 Outside and inside the realignment site at elevation range 3.0-3.15mODN (Figures 4.18 and 4.19)

Eight species were recorded outside on the salt marsh at 3-3.15mODN (Figure 4.18). *Puccinellia maritima* had the highest mean cover value between 2002 and 2004 (43-50%), peaking at 50% in 2003, but declining to 22% by 2006. *Atriplex portulacoides* increased from 30% mean cover in 2002 to 53% in 2006 and had taken over as the most abundant species by 2005. *Salicornia europaea* decreased its cover from 16% in 2002 to just 0.5% in 2004 and 1.8% in 2006. *Suaeda maritima* increased its cover over the 5 years surveyed, mainly between 2002 and 2004 from 6.8% to 10.3%, and was at 11.9% mean cover in 2006, and *Aster tripolium* varied between 2.5 and 7.6%. *Spartina anglica* was found between 1% to 2.8% and *Spergularia media* between <0.1% to 0.9%.

In summary, *Puccinellia maritima* was the dominant species at this elevation on the salt marsh in 2002, but has since declined along with *Salicornia europaea*, while *Atriplex portulacoides* has spread to become the most abundant species by 2005. *Suaeda maritima* has increased in cover slowly and *Aster tripolium* cover has varied. Remaining species: *Sarcocornia perennis* and *Spergularia media* were recorded at <1% in 2006.

Up to nine species were recorded inside the realignment (Figure 4.19) at this elevation; eight in 2007. These were the same eight species as outside but a small single specimen of *Elytrigia atherica* was also noted in one site inside in 2003 but has not been recorded since, probably because the elevation is still a little too low for this upper marsh species to withstand the inundation regime. *Salicornia europaea* was the most abundant species in 2003 and 2004 (20% and 37% mean cover) followed by *Suaeda maritima* in 2003 (13%). *Salicornia europaea* mean cover has fluctuated between 17% and 37% and *Suaeda maritima* between 7.7% and 17% during the 5 year monitoring period, with a declining trend in the last two to three years. *Puccinellia maritima* spread considerably after the first year, from just 3% mean cover in 2003 to 21% in 2004. By 2005 it was the most abundant species at this elevation range and it has continued to expand its cover to 36% in 2007. *Atriplex portulacoides* was just present in 2003 at 0.02% mean cover but has since increased steadily to 9% in 2007, *Spartina anglica* has increased slowly from 0.1% to 4.1%, and *Aster tripolium* has spread from 0.2% to 3.1% mean cover in 2007. *Spergularia media* was first recorded in 2005 (<0.1% in 2005 and 2006) and was still present at low mean cover (0.28%) in 2007. *Sarcocornia perennis* was first recorded at this elevation range in 2007 at just 0.015% mean cover.

In summary, *Salicornia europaea* followed by *Suaeda maritima* were the most abundant species in the realignment site in 2003, but have shown fluctuations in mean cover values since. *Puccinellia maritima* increased most rapidly between 2003 and 2005, to become the most abundant species and has continued to spread. Other typical perennial salt marsh species, *Atriplex portulacoides* and *Spartina anglica* were found in these quadrats in 2003 and have increased their cover each year. *Aster tripolium* has increased its cover slowly since 2003 and *Spergularia media* was recorded more rarely at <<1% mean cover. With the appearance of *Sarcocornia perennis* in 2007, all species found outside have now been recorded in the realignment site at this elevation range.

4.4.3 Outside and inside the realignment site at elevation range 3.16-3.3mODN (Figures 4.20 and 4.21)

Nine species have been recorded outside on the salt marsh in this highest elevation category during the survey period (Figure 4.20), but four of them were found only occasionally (low mean percentage cover). *Atriplex portulacoides* was the most abundant species and it has also increased its mean cover from 47% in 2002 to 65% in 2005 (and 90% in 2006, although this marked increase in mean cover was influenced by the loss of two sites). At the same time, *Puccinellia maritima* decreased from 44% in 2002 to 24% in 2005 and 5% in 2006. The apparent spurt in *Atriplex portulacoides* expansion by 2006, and marked decline in *Puccinellia maritima* to just 5% in 2006 was probably due largely to the loss of two out of seven sites in this range to cattle damage. These two sites had the lowest cover values for *Atriplex portulacoides*, and highest for *Puccinellia maritima* in all years. *Salicornia europaea* was found at mean cover values between 4.1% and 7.9% in 2002-2005, with no records in the 5 remaining sites in 2006, and *Suaeda maritima* was recorded with mean cover values between 2.8% and 7.3% over the monitoring period. Remaining species were found at <2% cover: *Aster tripolium* varied between 0.3% and 1.9%, *Spartina anglica* between 0.04% and 1.1%, and *Spergularia media* between 0.2% and 0.6% mean cover in the first 4 years, but with no records in the remaining 5 sites in 2006. There was just one site with *Limonium vulgare* (0.03-0.23% mean cover), and a single specimen of *Sarcocornia perennis* (<0.01% mean cover) was found at one site in 2003 only.

In summary, *Atriplex portulacoides* was the most abundant species in 2002, but followed closely by *Puccinellia maritima*. During the 5 years of surveying *Atriplex portulacoides* has increased steadily while *Puccinellia maritima* has decreased rapidly. *Suaeda maritima* and *Aster tripolium* were recorded in 2006 at <3% and <1%, and *Spartina anglica* and *Limonium vulgare* found only rarely at <<1% mean cover. *Salicornia europaea* was not found in 2006 (although 2 out of the 7 sites in this elevation range were lost to cattle damage).

Eleven species were recorded during the 5 years of surveys inside the realignment site at 3.16-3.3mODN (Figure 4.21), of which five were found only very occasionally and one (*Spergularia marina*) was only recorded in 2003. There were 8 species in 2003 and 2004, 9 species in 2005 and 2007, and 10 species in 2006. The annual pioneer species were the most abundant plants in the first year (2003), although *Suaeda maritima* was more prevalent than *Salicornia europaea* at this higher elevation range, at 25% mean cover compared with 14% for *Salicornia europaea*. The best year for annual *Salicornia* recruitment and establishment was 2004 (31%), but it declined to less than 2.5% mean cover by 2007, and *Suaeda maritima* cover has decreased each year since 2003 to 5.9% mean cover in 2007. In 2003, *Puccinellia maritima* was recorded with a mean cover of 2.8% but it spread rapidly to 58% mean cover by 2005, when it took over as the dominant plant.

Subsequently, this species has changed little in cover (59% in 2006, 60% in 2007).

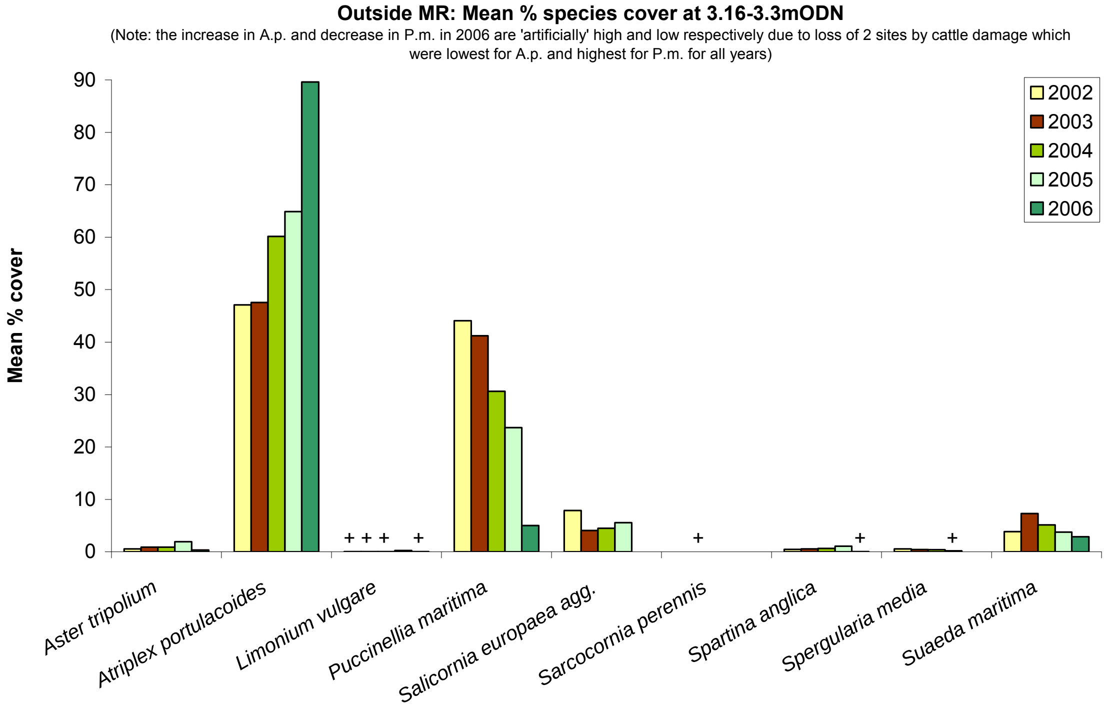


Figure 4.20. Mean percentage species cover on the salt marsh outside the realignment at elevation range 3.16-3.3mODN [+ = species present at <0.2% mean cover]

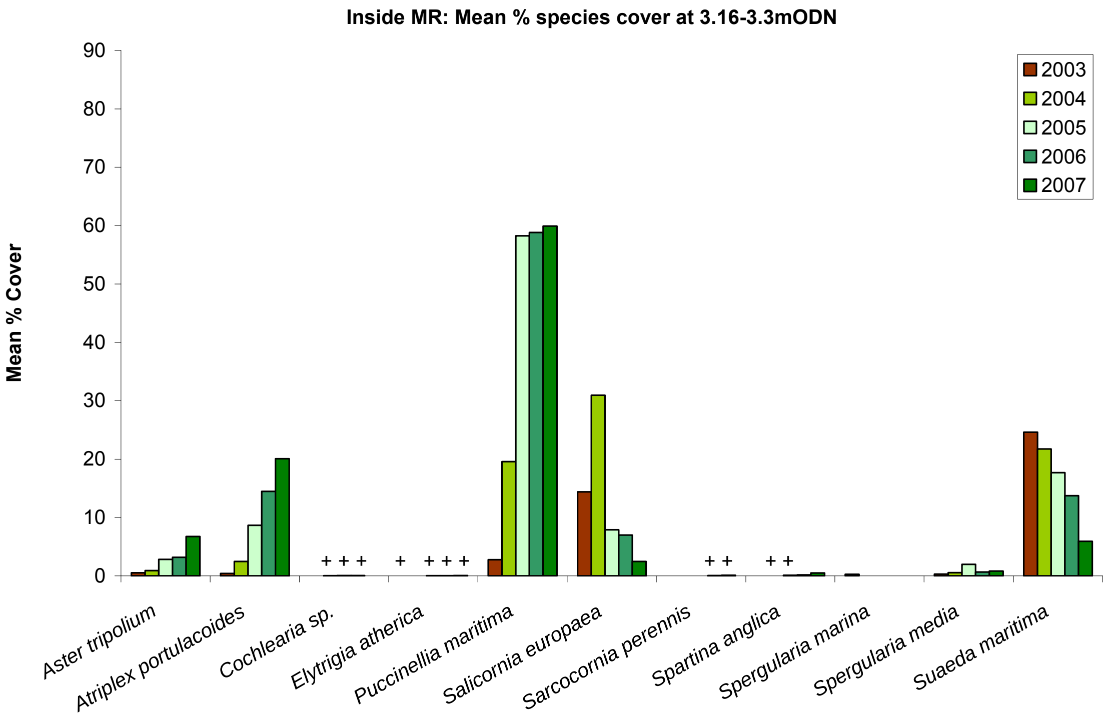


Figure 4.21. Mean percentage species cover inside the realignment at elevation range 3.16-3.3mODN [+ = species present at <0.2% mean cover]

The main difference between inside and outside at this elevation was the relative abundances of *Puccinellia maritima* and *Atriplex portulacoides*. *Atriplex portulacoides* was already the dominant species outside in 2002 however it has shown signs of rapid expansion beginning inside the site, having spread quickly from a mean cover value of only 0.4% in 2003 to 20% in 2007. *Aster tripolium* has increased more slowly from 0.5% to 6.8% in 2007. Remaining species were recorded with low mean cover values, for example *Spergularia media* varied between 0.3% and 2%, *Spartina anglica* was first recorded in 2004 at 0.01% and had increased to 0.48% in 2007, and *Cochlearia* sp. was present at low mean cover in 2004 to 2006 (<0.1%). *Elytrigia atherica* was still only occasional in the quadrats by 2007, at 0.06% mean cover. Patches of *E. atherica* were noted in the north east corner of the site by 2005-2006 and this species is likely to increase its cover in future in sites in this area (upper half of Transect A). *Sarcocornia perennis* was first found in the quadrats above 3.15mODN in 2006 at 0.07% mean cover (0.11% in 2007). *Spergularia marina* was recorded in the quadrats in 2003 (<0.3% mean cover) but has not been noted since. This species favours more open situations such as patches of bare or disturbed ground in upper areas of salt marsh (Rodwell 2000), therefore it is not surprising that it has not been recorded since the sward has closed over with spreading perennial species.

In summary, *Suaeda maritima* followed by *Salicornia europaea* were the most abundant species in the first year but both have declined in mean cover. *Puccinellia maritima* spread rapidly, particularly between 2004 and 2005 to become the dominant species. *Atriplex portulacoides* has increased steadily each year to become the second most important cover species by 2006. *Aster tripolium* has increased, but more slowly. Other species: *Spartina anglica*, *Spergularia media*, *Cochlearia sp.* and *Elytrigia atherica* were found at low cover (<1%) in 2006 and 2007, and *Sarcocornia perennis* was first recorded this year. The only species found outside in the quadrats but not in the realignment quadrats was *Limonium vulgare*, however this species has been noted at upper parts of the site, mainly amongst the *Puccinellia maritima* between the upper sites on the transects (Site 1) and the back fence.

4.4.4 Summary of Vegetation Establishment and Succession

The expansion and decline of different species at different elevations appears quite complex when the percentage cover for each species is included in the text, therefore the main points about the vegetation establishment, spread and succession are described again here.

The pioneer annuals were the first to colonise the realignment and *Salicornia europaea* and *Suaeda maritima* were the dominant species throughout the site in 2003, at all elevations. Between 2003 and 2006, these pioneer annuals remained the most abundant species at lower elevations in the realignment, although by 2007 *Puccinellia maritima* had spread to become the second most abundant species after *Salicornia europaea* (overtaking *Suaeda maritima*) in the lowest elevation range category. Perennial species have established and spread, particularly at the higher elevations, where the annuals have been replaced by *Puccinellia maritima* as the dominant species. *Atriplex portulacoides*, extremely abundant outside on the salt marsh at higher elevations has shown a steady increase at higher elevations in the realignment site, and by 2006 was the second most important cover species after *Puccinellia* in the highest elevation range category (3.16-3.3mODN).

The species mix in each elevation range was similar inside and outside, although the relative species abundances were still different by 2007, particularly for the major species in the two upper elevation categories.

At the lowest elevation range (2.7-2.99mODN) the two annual pioneer species, *Salicornia europaea* and *Suaeda maritima*, were the most important cover species both outside and inside the realignment up to 2006 (*Puccinellia maritima* had just overtaken *Suaeda maritima* in cover abundance in the realignment in 2007). The main difference between the realignment site and the salt marsh outside at the lower elevation range is that *Salicornia europaea* and *Puccinellia maritima* cover have decreased outside (*Salicornia* since 2002, *Puccinellia* since 2004). In the realignment site *Puccinellia maritima* was still increasing in cover by 2007, although *Salicornia europaea* was at a similar cover value to that in 2006. *Aster tripolium* and *Spartina maritima* were found at greater mean cover outside than inside, but they have both been increasing in cover inside the realignment each year. *Atriplex portulacoides* has increased in cover both outside and inside the realignment site at this elevation range.

The main difference between the salt marsh and realignment site at elevation range 3.0-3.15mODN is that *Puccinellia maritima* was dominant in 2002 on the salt marsh but subsequently decreased in mean cover along with *Salicornia europaea*, while *Atriplex portulacoides* increased its cover to become the most abundant species by 2005 and increased its cover further to 53% by 2006. In the realignment area, *Puccinellia maritima* spread very rapidly between 2003 and 2005 to become the most abundant species at this elevation and expanded its cover further to 36% in 2007. *Atriplex portulacoides* increased steadily each year to 9% mean cover in 2007, but was still at a much lower cover value in 2007 than outside at equivalent elevations.

The main difference at elevation range 3.16-3.3mODN is that *Atriplex portulacoides* was dominant in 2002 on the salt marsh outside and has increased its mean cover steadily while *Puccinellia maritima* has decreased in cover. Inside the Freiston realignment *Suaeda maritima* followed by *Salicornia europaea* were the dominant species in 2003, but both have decreased in cover since. *Puccinellia maritima* spread rapidly to become the most abundant species by 2005 (58%) although its cover has changed little since (60% in 2007), and it may have reached its peak cover abundance. *Atriplex portulacoides* has increased steadily to become the second most important cover species by 2006, and may replace *Puccinellia maritima* as the dominant cover type in future.

The overall impression is that succession of perennial species in the upper half of the elevation range of the site is now occurring rapidly and to a rough approximation is one 'elevation category' behind the community composition outside the realignment.

4.5 5 x 5 m^2 Quadrats inside the Realignment Site: Summary of plant Species Composition and Percentage Cover

The 5m x 5m quadrats were set up primarily to provide ground reference data for aerial remote sensing of the Freiston realignment site and adjacent salt marsh, but the data from the quadrats are shown here and show similar trends to those described for the smaller quadrats at similar elevations. Positions of the large quadrats are shown in Figure 2.3 in the methods section.

The quadrats are grouped into similar elevation range categories as the smaller quadrats as far as possible, but there is only one example in the range between 3.0 and 3.15mODN, at the very lowest end of this range (3.0mODN), so this was grouped with two quadrats at elevations between 2.9 and 2.99mODN. Two of the large quadrats were above 3.3mODN (higher than the upper 5 x 1m^2 quadrats).

4.5.1 2.9-3.0mODN (Quadrats X2, X1, and D5, Figures 4.22-4.24)

Two quadrats (X2 and X1) were at a mean elevation of 2.94mODN and 2.99mODN, respectively. *Salicornia europaea* has been the dominant cover species over the five year monitoring period, followed by *Suaeda maritima* until 2006 in both quadrats. Other species such as *Aster tripolium*, and *Spartina anglica* were found at low cover values (no more than 1% up to 2006), although *Spartina anglica* increased its cover in quadrat X1 between 2006 and 2007 to 7.5%. *Puccinellia maritima* has increased slowly in cover in Quadrat X2 and showed a marked increase in cover between 2006 and 2007 in Quadrat X1 to become the second most important cover species (at 23% cover) after *Salicornia europaea*. *Sarcocornia perennis* was first recorded (in Quadrat X1) in 2007.

Quadrat D5, with a slightly higher mean elevation than X2 and X1, at 3.0mODN was colonised primarily by the annual pioneer species, *Suaeda maritima* (approximately 80% cover in 2005 and 2006) except for 2004 when *Salicornia europaea* replaced *Suaeda maritima* as the main cover species. *Puccinellia maritima* cover increased each year from 2% in 2003 to 20% in 2007. *Aster tripolium* and *Spartina anglica* have been present at low levels to 2006 (0.5-1%), although both increased their cover between 2006 and 2007. *Atriplex portulacoides* was first recorded in this quadrat in 2006 and increased its cover value by 2007 to 3%.

The trends observed for these quadrats were similar to those in the smaller quadrats at similar elevations.

4.5.2 3.15-3.3mODN (Quadrats D3, C4, A3 and B2, Figures 4.25-4.28)

These four quadrats were at mean elevations between 3.18 and 3.25mODN. The annuals *Suaeda maritima* and/or *Salicornia europaea* were the most important cover plants in the first two years, with *Suaeda* reaching between 36% and 48% in these quadrats and *Salicornia* at its highest cover in 2004 (between 23% and 47%). *Puccinellia maritima* spread rapidly in all of these quadrats following colonisation in 2003 to replace the annual plants as the dominant cover species by 2005, at between approximately 50% and 75% in the 4 quadrats. *Atriplex portulacoides* showed a steady increase each year in quadrats D3, A3 and B2 to 18-20% in 2007, and an increase in quadrat C4, although not as much (4%) as in the other three. *Spartina anglica* (absent in quadrat B2) and *Aster tripolium* were found at lower cover but the values have increased since 2003 (generally 1-5% in 2007, except for *Aster* in quadrat A3 where it had spread to 18% cover). *Spergularia media* was occasional (low cover of 0.5% or less).

The patterns of species composition, plant establishment and spread, and vegetation succession in these large quadrats was similar to those in the smaller quadrats at this elevation range.

4.5.3 Quadrats X4 and Y1, mean elevation 3.39 and 3.40mODN (Figures 4.29-4.30)

These two quadrats were at higher elevations than any of the smaller quadrats and were selected specifically for their plant composition to provide additional ground reference data for remote sensing images.

Elytrigia atherica colonised quadrat X4 in the first year, along with the pioneer annuals *Salicornia europaea* and *Suaeda maritima*, and it has been the dominant cover species throughout the monitoring programme, peaking at 88% cover in 2006. The annuals declined in cover after 2003 and by 2006 *Salicornia europaea* had gone. *Aster tripolium* and *Puccinellia maritima* were recorded with fluctuating cover values (between 0.5% and 6%) and *Spergularia media* was found at low cover (0.2-0.5%) throughout. The only species which has spread steadily in spite of the relatively dense cover of *Elytrigia atherica* was *Atriplex portulacoides* which was recorded with 20% cover in 2007.

Quadrat Y1 was set up in 2005 as an example of *Atriplex portulacoides* cover type. This species had reached 75% cover here within two years from the site breach in 2003 (89% and 85% in 2006 and 2007). *Puccinellia maritima* was the next most important species at 8% cover in 2007, with other species (*Aster tripolium*, *Spartina anglica* and *Spergularia media*) at 1-2% cover in 2007, and the annuals *Salicornia europaea* and *Suaeda maritima* just present (<<1%).

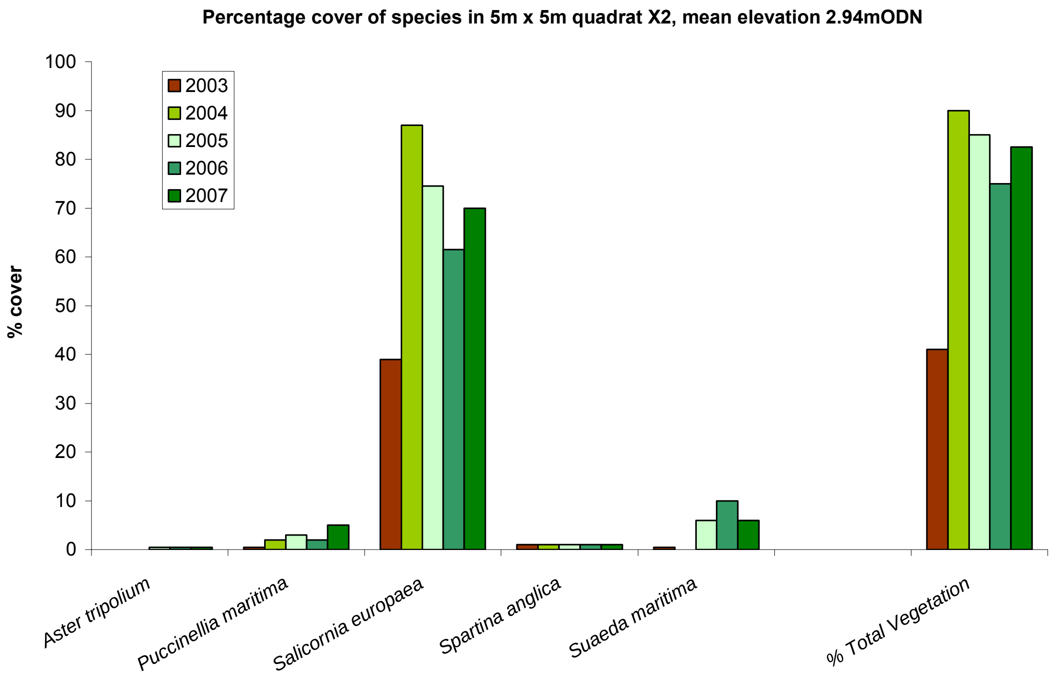


Figure 4.22. Percentage species cover in quadrat X2, mean elevation 2.94mODN

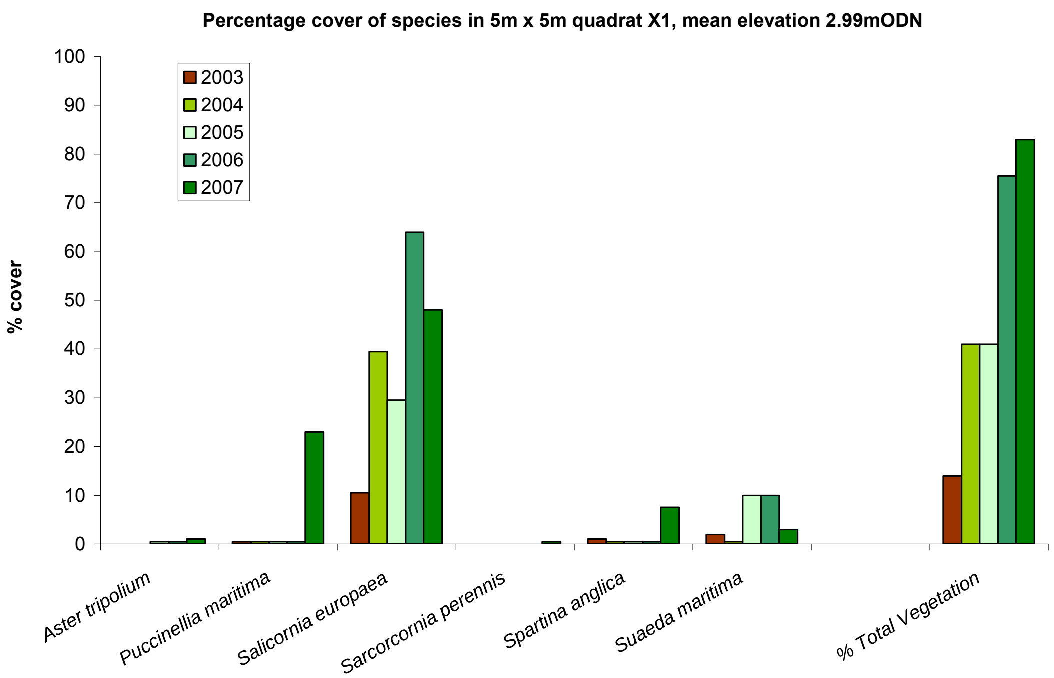


Figure 4.23. Percentage species cover in quadrat X1, mean elevation 2.99mODN

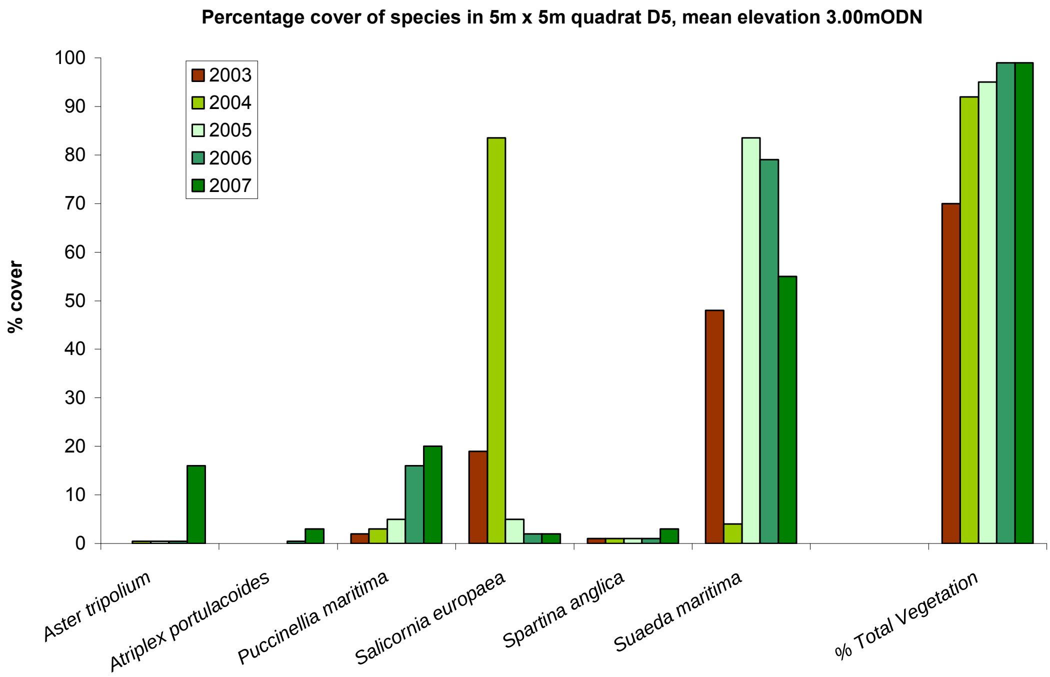


Figure 4.24. Percentage species cover in quadrat D5, mean elevation 3.00mODN

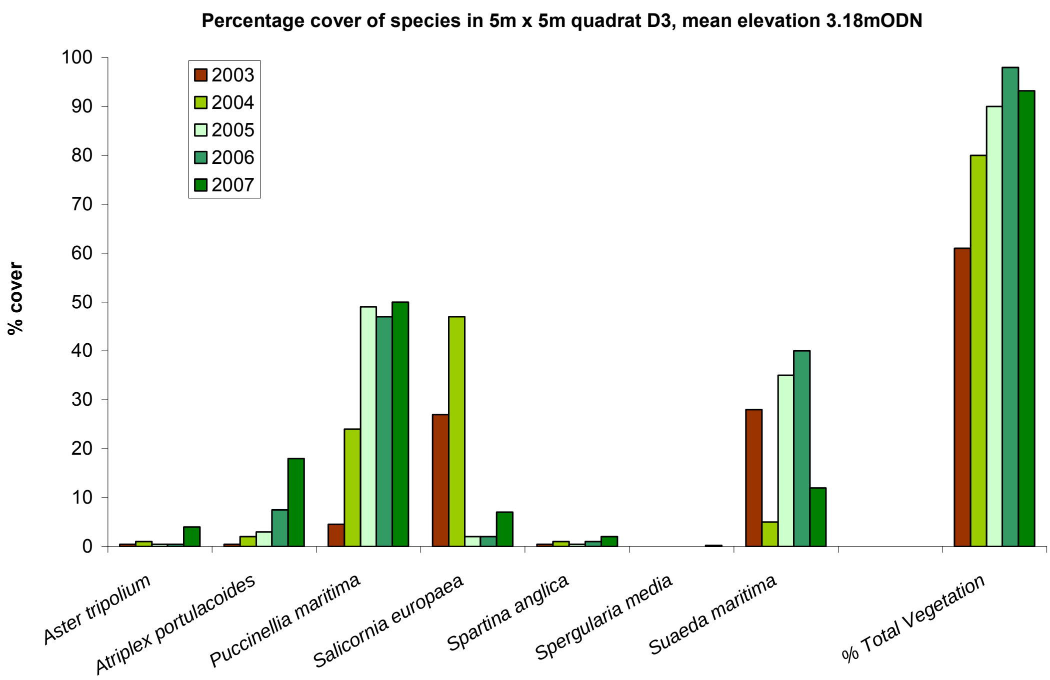


Figure 4.25. Percentage species cover in quadrat D3, mean elevation 3.18mODN

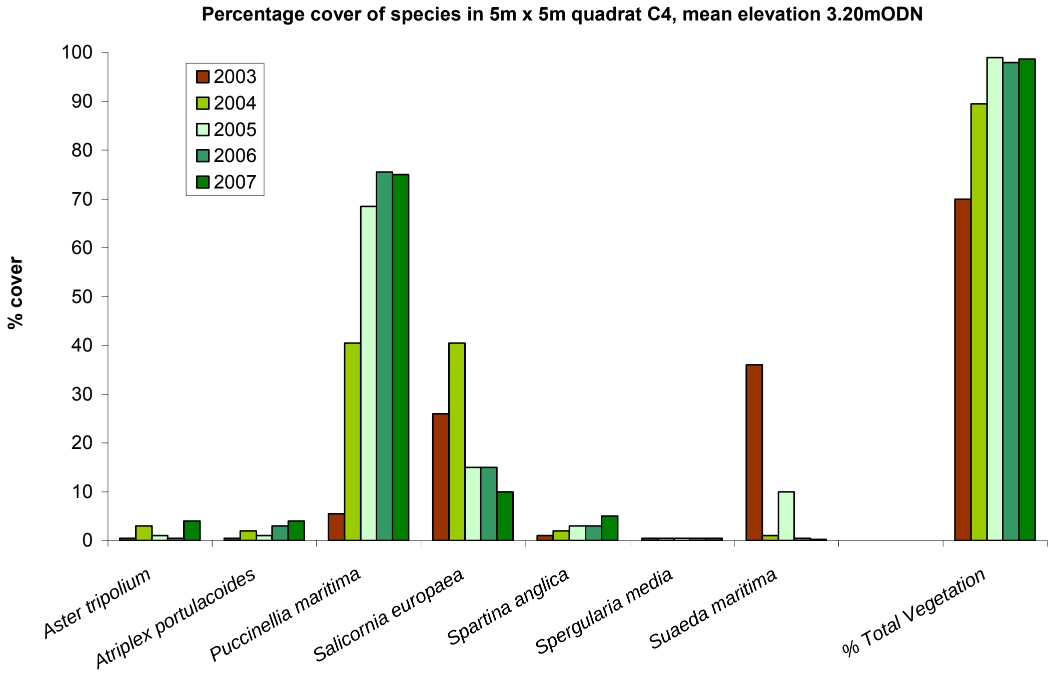


Figure 4.26. Percentage species cover in quadrat C4, mean elevation 3.20mODN

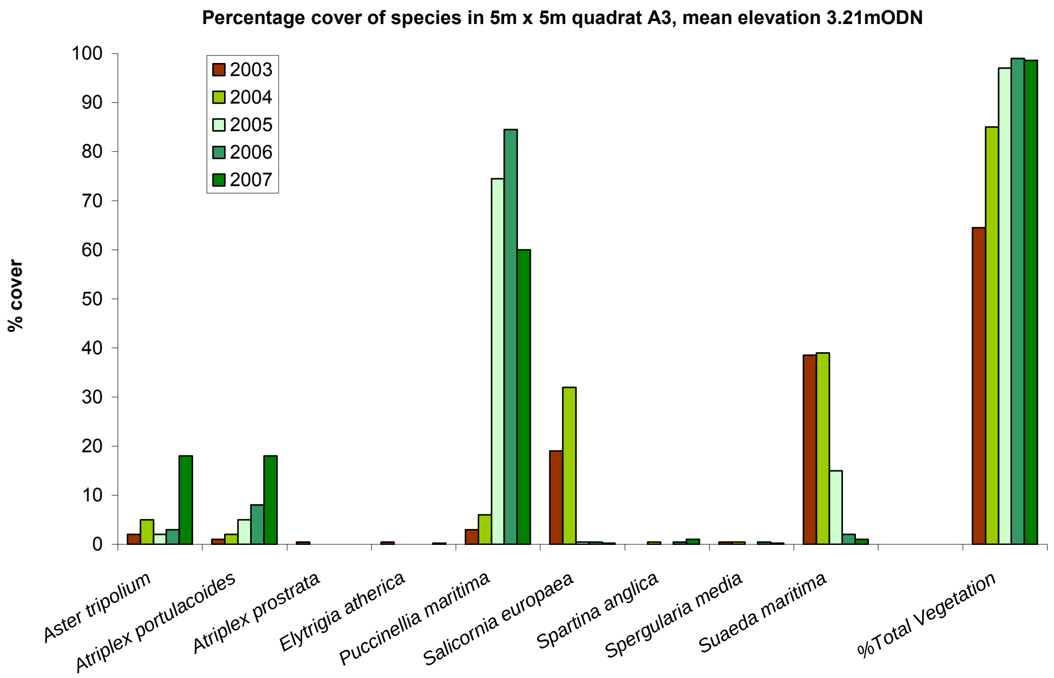


Figure 4.27. Percentage species cover in quadrat A3, mean elevation 3.21mODN

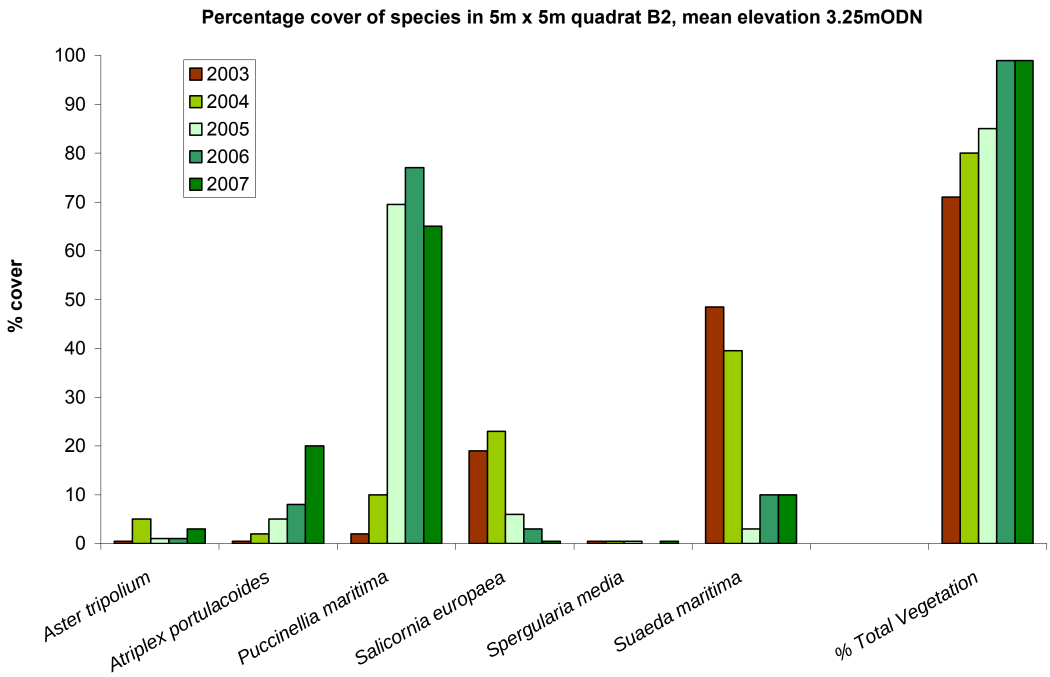


Figure 4.28. Percentage species cover in quadrat B2, mean elevation 3.25mODN

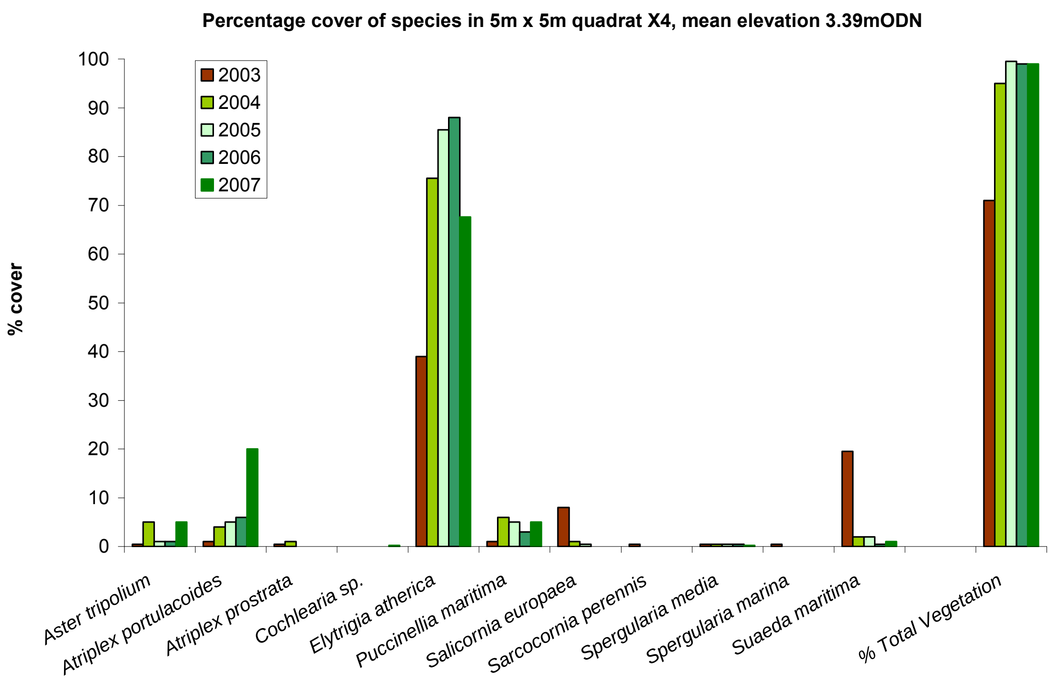


Figure 4.29. Percentage species cover in quadrat X4, mean elevation 3.39mODN

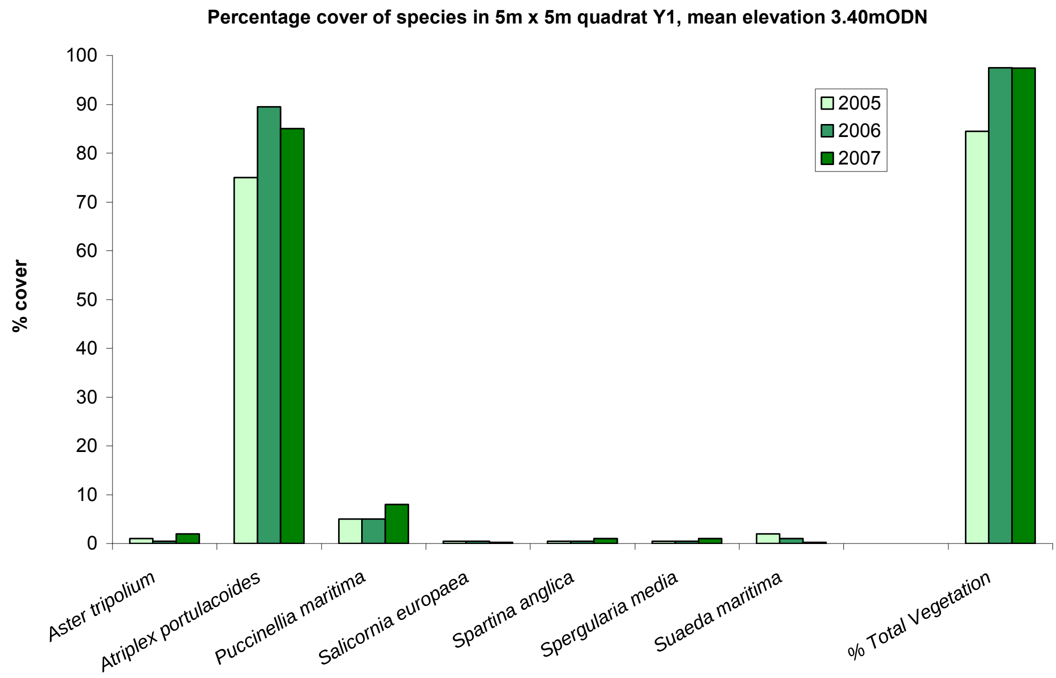


Figure 4.30. Percentage species cover in quadrat Y1, mean elevation 3.40mODN

5. Discussion and Conclusions

Some discussion and explanation of the results is given with the description of the data in the results section. This discussion summarises the main findings from this years survey in relation to previous years and includes comments on other observations made at the site, and also at Paull Holme Strays in the Humber Estuary which was breached a year after Freiston in early September 2003.

The accretion measurements have shown a continued build up of sediment inside the realignment site (and outside on the vegetated salt marsh in surveys from 2002-2006). Elevation is well known to be of key importance for the amount of net accretion along the profile of a salt marsh. On the gently sloping wide salt marshes around the Wash, the highest accretion is found generally in the zone of continuous vegetation behind the salt marsh front and pioneer zone, and decreases with increasing elevation (S. L. Brown personal observations of several Wash sites) as higher sites experience fewer tidal inundations and sediment drops out when wave energy is reduced by the vegetation cover.

A significant inverse relationship was found between accretion rates and elevation on the salt marsh outside the Freiston site (in Brown *et. al.* 2007), and also for the realignment site once the two highest accretion sites near the central breach (TCS5 & 6) were removed. The relationship was further improved when additional sites near the central breach were removed from the analysis.

The very high accretion sites near the central breach have a major influence on the mean values for accretion in the realignment site, making comparison difficult with rates on the natural salt marsh. When the mean annual accretion rates were plotted for all sites in the realignment (Figure 3.9 in this report), the rate was significantly higher in the first year (2002-2003) compared with subsequent years. However, when the rates were re-calculated without the anomalously high sedimentation sites (and submerged sites where accretion has been erratic) a good agreement was found with rates on the salt marsh outside and the interannual trends were also matched. Natural interannual and seasonal variations in sedimentation and net accretion are caused by a variety of factors such as wind strength and direction, wave energy and so on that affect the amount of sediment in suspension, and post-depositional processes such as resuspension, drying out in hot weather and subsequent lifting and erosion of cracked surface sediment.

The high rates at Sites TCS5 and 6 (Figure 3.5) settled down after the first 1-2 years (the line plots are more or less parallel with sites higher on this transect, further away from the breach). The only site in the realignment to show a clear increase in accretion rate after the first two years was site TDS6. This site was poorly drained up to 2005 and in the first year the surface was liquid mud and impossible to measure. The accretion rate here has increased since the survey in April 2005 (Figure 3.6), and by April 2007 total accretion at this site was greater than at TCS5. This is the lowest elevation site in the realignment

(2.76mODN) so accretion would be expected to be highest here. Another possible reason for high deposition here may be the headward progression of a wide creek which has cut back from the central breach towards this site (shown in Photos 9.10-9.13 in Brown *et al.* 2007). By April 2007 the head of this creek was just a few metres from site TDS6 and by September 2007 it had turned within 2 metres of site TDS6 and was heading towards the back of the realignment site. Large blocks of loose soil have been breaking off the creek sides and so there must be a considerable load of loose sediment moving around in this area when the site is flooded and drained.

In the last report we also noted that accretion rates inside and outside the realignment overlapped at elevations between approximately 2.95 and 3.2mODN, but at lower elevations accretion was generally higher in the more sheltered conditions of the realignment site than on the more exposed marsh outside. It was suggested that shelter may be an important factor because a similar effect was found at the Paull Holme Strays realignment site in the Humber Estuary (Brown and Brown 2006, 2007) and it was particularly marked for the low mudflat areas. The inverse relationship between accretion and elevation found for vegetated salt marsh breaks down on the more dynamic mudflat zone in front of a salt marsh, and this was the case for the mudflat outside the Paull Holme Strays site. However, the relationship continued inside the site (from approximately 2.3mODN down to 2.0mODN) and estimated mean total accretion for our sites on the realignment mudflat was more than half a metre (579mm) in four years from the time of the breach, and four times greater than on the more exposed mudflat outside the site.

Accretion rates tend to decline as the sediment surface level builds up (and therefore experiences shorter periods of tidal inundation). There was no evidence to date of accretion rates changing in any one direction during the monitoring programme in any of the elevation categories. Mean accretion rates for the realignment site overall (excluding outliers) and for the adjacent salt marsh at similar elevations have shown inter-annual variations of approximately 5.7 to 9mm year^{-1}. The total accumulated sediment below 3mODN (the lowest category) has only been about 70mm on average, so it was not surprising to find no consistent change to date.

Accretion rates have been steady at Paull Holme Strays on the salt marsh zones since the breach in September 2003, but there has been a clear decline in the rates on the mudflat, at elevations below 2.6mODN (elevations measured in 2005), which has accreted a thick layer of sediment. The mean total accretion at 2.3-2.6mODN at Paull Holme Strays was 385mm in four years and 579mm (as noted above) between 2.0-2.3mODN.

A general description of the salt marsh species found on the adjacent marsh at Freiston, and a discussion of the vegetation changes recorded between 2003 and 2006 compared with the adjacent salt marsh (2002-2006) was provided in Brown *et al.* (2007). Vegetation data has been summarised according to elevation, a key environmental variable influencing salt marsh plant species distribution, and this has been a useful approach to compare vegetation establishment in the managed realignment site with the 'reference' marsh outside and to assess the success of the scheme.

All plant species found outside on the salt marsh (except for one) had been seen in the realignment area by 2006, four years after the breach. The missing species was *Triglochin maritima*, found only occasionally on the salt marsh outside. At Paull Holme Strays, all species noted outside on the salt marsh were found in the realignment site in 2007 (four years after the breach), and all were found in the general site quadrats, except for *Triglochin maritima*. This species was seen in the realignment site at Paull Holme Strays in 2007 in one or two places and it was also found in one of the additional higher (transition zone) quadrats at the base of a sloping hill. It is more common outside on the salt marsh at Paull Holme Strays than it is at Freiston but it was still slow to appear inside the realignment.

Vegetation established quickly at the Freiston realignment site and cover has continued to increase overall and appears to be on track to reach equivalent cover values (but perhaps not relative species abundances) to the salt marsh outside at equivalent elevation by about 2010 as predicted in our last report.

Vegetation spread was most rapid at the highest elevation category in the Freiston realignment site reaching a mean total cover value (from the sum of species cover) of approximately 98% by 2005 (three years after the breach) with little change since. Vegetation colonisation was also the greatest at higher elevations in the Paull Holme Strays managed realignment site (Brown and Brown 2007) and reached a peak (to date) by 2006, also three years after the breach. The mean total cover at the upper sites at Paull decreased slightly from 2006 to 2007, in part due to poor drainage at some sites, but also because the early colonisers decreased in cover rapidly. These were being replaced by typical perennial salt marsh species, but their increased cover was not sufficient by 2007 to offset the decline in initial colonisers. This effect with replacement species was thought to also be the reason for the slight decline in vegetation cover in some sites at Freiston between 2006 and 2007.

Although there are similarities that can be drawn between the salt marsh development at Freiston and Paull Holme Strays, there are also differences. For example, the initial colonisers at Freiston were the two annual pioneer species, *Salicornia europaea* and *Suaeda maritima*, abundant on the extensive pioneer zone in the wide adjacent salt marshes of the Wash. These pioneers are less common on the narrower steeper salt marshes of the Humber Estuary where *Spartina anglica* is the main pioneer plant, and the important early colonisers at Paull Holme Strays (depending on elevation) were two ground-spreading salt tolerant species, *Atriplex prostrata* and *Spergularia marina*. These two species did well on the bare ground created after the site breach, and were common in sites above about 3mODN. We predicted that these species would decline under increasing competition (Brown and Brown 2006) as the sward closed over with more abundant typical salt marsh plants and they have dropped rapidly in cover, frequency of occurrence, and in size of individual plants.

At Freiston, the species mix at each elevation in the realignment has generally been similar to that on the salt marsh at the same elevations since the early years of site development (2003, 2004) at least for the common species. However, the relative species abundances were still different in 2007.

The pioneer annuals, *Salicornia europaea* and *Suaeda maritima* were the first species to colonise the realignment site in any great quantity and in the first year (2003) they were the dominant species at all elevations. These two species have fluctuated in cover inside and outside the site at lower elevations, as might be expected for annual species which are recruited each year, although they have shown declining trends at higher elevations under competition from spreading perennial plants. The annuals have persisted as the dominant species in the lower elevation range category (2.7-2.99mODN) and were also the most abundant outside on the salt marsh at these elevations between 2002 and 2006. The relative species abundances between the realignment and the adjacent marsh were most similar at lower elevations although cover of *Spartina anglica* (perennial) and *Aster tripolium* (annual or short-lived perennial, Blamey and Grey Wilson 1989) was still lower in the realignment site in 2007 than outside. However, the perennial *Puccinellia maritima* has spread each year in the realignment site and by 2007 its mean cover was slightly higher than *Suaeda maritima* cover.

A good agreement was found between species present in the vegetation inside and outside the realignment at all elevations by 2007. An additional species, *Sarcocornia perennis*, found outside occasionally (with low mean cover, and mainly in the lower and middle elevation categories) was first recorded in the realignment quadrats at all elevation ranges in 2007.

The main differences between outside and inside the realignment site in the two higher elevation categories were in relative cover abundances and successional trends of the two common perennial salt marsh species, *Puccinellia maritima* and *Atriplex portulacoides*.

In the middle elevation category (3.0-3.15mODN) *Salicornia europaea* cover inside the realignment site was still greater in 2007 than it was outside where it has decreased in cover since 2002, and there were still marked differences in relative cover abundances of *Puccinellia maritima* and *Atriplex portulacoides.* Outside the realignment site *Puccinellia maritima* cover has decreased from 2003 and *Atriplex portulacoides* has increased its cover each year. *Puccinellia maritima* was still increasing in cover by 2007 inside the site. *Atriplex portulacoides* has also spread each year but mean percentage cover was one quarter of the area covered by *Puccinellia* and still only one third of its cover abundance estimated outside on the salt marsh in 2002.

From our observations of these two species, we would expect the cover of *Salicornia europaea* to decline in future concurrent with the spread of *Puccinellia maritima*, but with eventual decline of the latter as well and replacement by *Atriplex portulacoides*, if succession continues to approach the species composition mix found outside on the salt marsh in this elevation range.

Atriplex portulacoides was recorded with a similar (slightly higher) cover to *Puccinellia maritima* in 2002 outside the realignment site in the highest elevation category (3.16-3.3mODN). Its cover has increased each year with a corresponding annual decline in *Puccinellia maritima* cover. Inside the realignment site, the cover abundance of the annuals *Salicornia europaea* and *Suaeda maritima* had dropped by 2007 to similar cover values found outside. *Puccinellia* increased rapidly at this elevation and was the dominant species by 2005. *Atriplex portulacoides* has spread each year to become the second most important cover species by 2006 but its mean percentage cover value was still only one third of that estimated for *Puccinellia* in 2007. It is more difficult to compare estimated cover values in the realignment at this elevation range with those outside the site in 2006 because the markers for two of the sites outside (out of seven) were lost to cattle damage. The two missing sites had the lowest cover of *Atriplex portulacoides* and the highest cover of *Puccinellia maritima* therefore the marked increase of the former and marked decrease of the latter between 2005 and 2006 is exaggerated by the loss of these sites in the mean calculations. However, the mean cover values for *Puccinellia maritima* and *Atriplex portulacoides* in 2007 were still much higher and lower, respectively, than their cover values outside the realignment site in 2005.

From the trends displayed by these two species outside the realignment site it is expected that *Atriplex portulacoides* will eventually replace *Puccinellia maritima* to become the most abundant plant species inside the realignment site in the highest elevation category, or it may itself replaced by *Elytrigia atherica* in time if the site remains fenced and inaccessible to cattle.

The overall impression from the species composition and abundance data up to 2006 (Brown *et al*. 2007), and from comparison of NVC community designations, was that succession of perennial species in the upper half of the elevation range of the realignment site was occurring rapidly, and to a rough approximation was one ‘elevation category’ behind the communities on the salt marsh at equivalent elevations. It is difficult to predict how long it will take for the realignment site to reach equivalent species abundance, but I suggested that if the major perennials continued to spread at the rates we observed between 2004-2006, a close match could be achieved within a further five years. The trends have continued in the expected direction between 2006 and 2007.

In conclusion, the Freiston realignment site overall has accreted sediment at a rate comparable with the adjacent salt marsh, so the underlying physical process that influences species zonation and succession is operating at a similar scale inside and outside the site. Vegetation colonisation and establishment has been rapid, and all species found outside except for one have been seen in the realignment site. All common species found outside have been recorded as important cover species in the realignment quadrats and were present at their expected elevations. Mean species number was comparable with the outside salt marsh by 2006 and greater than outside at the highest elevation sites. Perennial species such as *Puccinellia maritima* and *Atriplex portulacoides* have increased their cover year on year and replaced the annual pioneer plants as the dominant cover types in the upper half of the elevation range. Successional trends up to 2006, and beyond to 2007, suggest that community composition and relative species abundance in the realignment site and on the adjacent salt marsh are converging. It remains to be seen how long it will take for the vegetation in the site quadrats to reach equivalent species relative abundance to that outside on the salt marsh at the same elevations but from our observations of progress to date it is possible that this might be achieved within a further 5 years.

6. References

Blamey, M. and Grey-Wilson, C. 1989. *The Illustrated Flora of Britain and Northern Europe*. Hodder and Stoughton, London.

Brown, S.L. 1998. Sedimentation on a Humber saltmarsh. *In*: K.S.Black, D.M.Paterson and A.Cramp (eds) *Sedimentary Processes in the Intertidal Zone.* Geological Society, London, Special Publications, **139**, 69-83.

Brown, S. L. and Brown, S. 2006. *Paull Holme Strays, Intertidal Vegetation, Accretion and Erosion Monitoring 2006*. Report to Halcrow Group Ltd. and the Environment Agency. NERC Centre for Ecology and Hydrology, CEH Dorset. 197 pages.

Brown, S. L. and Brown, S. 2007. *Paull Holme Strays, Intertidal Vegetation, Accretion and Erosion Monitoring 2007*. Report to Halcrow Group Ltd. and the Environment Agency. NERC Centre for Ecology and Hydrology, CEH Wallingford. 229 pages.

Brown, S.L., Pinder, A., Scott, L., Bass, J., Rispin, E., Brown, S., Garbutt, A., Thomson, A., Spencer, T., Moller, I., Brooks, S.M. 2007. *Wash Banks Flood Defence Scheme, Freiston Environmental Monitoring 2002-2006*. Four Year Report to the Environment Agency. NERC Centre for Ecology and Hydrology, Dorset. 360 pages.

Rodwell, J. S. 2000. *British Plant Communities Volume 5*. Maritime communities and vegetation of open habitats. Cambridge University Press.

Stace, C. 1997. *New Flora of the British Isles*. Second Edition, Cambridge University Press.

7. Appendix

7. 1 Appendix 1. Scientific and common names of plants recorded in quadrats or noted at Freiston.

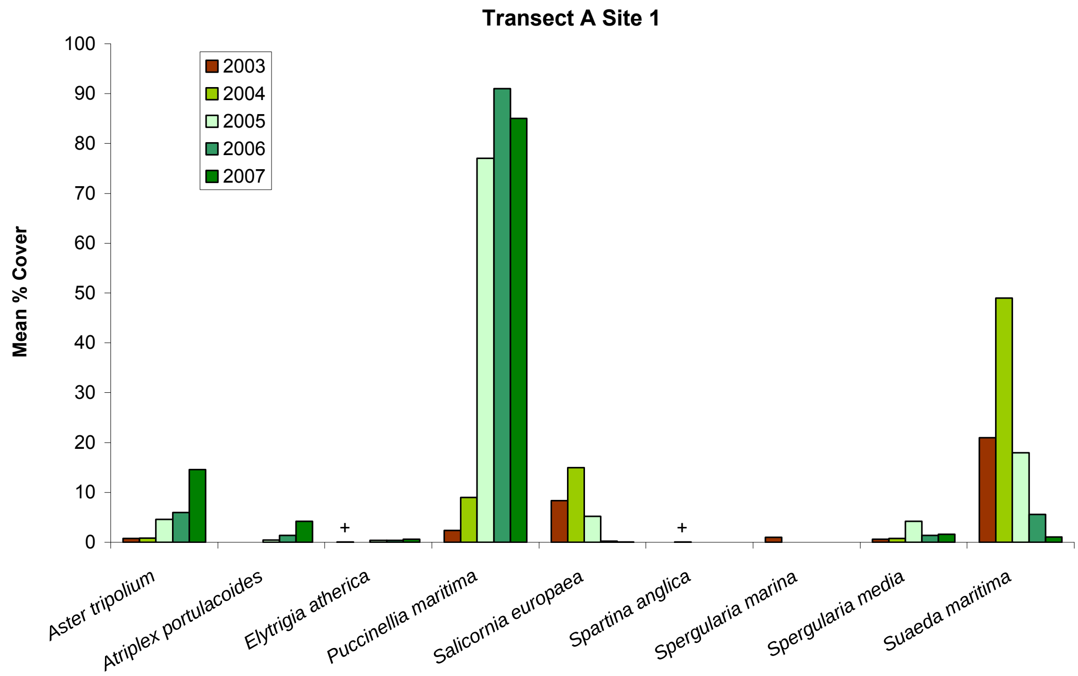
Nomenclature follows Stace (1997)

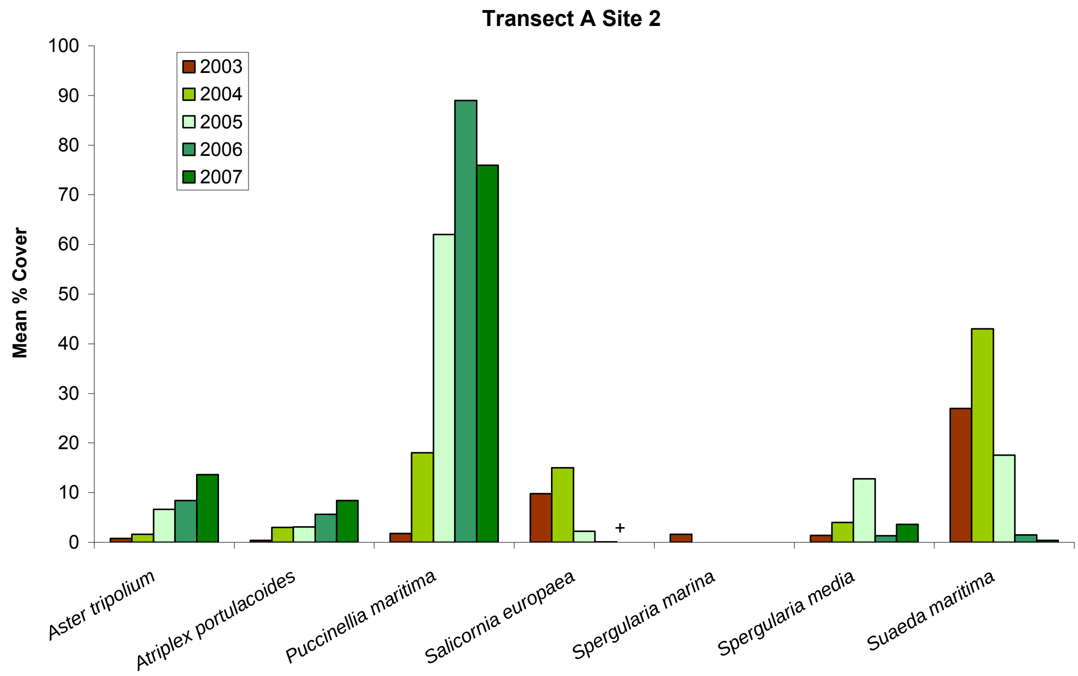
Scientific Name	Common Name
Artemisia maritima	Sea Wormwood
Aster tripolium	Sea Aster
Atriplex portulacoides	Sea-purslane
Atriplex prostrata	Spear-leaved Orache
Cochlearia anglica	English Scurvygrass
Cochlearia officinalis	Common Scurvygrass
Elytrigia atherica	Sea Couch
*Festuca rubra**	Red Fescue
*Glaux maritima***	Sea-milkwort
Limonium vulgare	Sea Lavender
Plantago maritima	Sea Plantain
Puccinellia maritima	Common Saltmarsh-grass
Salicornia europaea	Common Glasswort
Sarcocornia perennis	Perennial Glasswort
Spartina anglica	Common Cord-grass
Spartina maritima ***	Small Cord-grass
Spergularia marina	Lesser Sea-spurrey
Spergularia media	Greater Sea-spurrey
Suaeda maritima	Annual Sea-blite
Triglochin maritima	Sea Arrow-grass

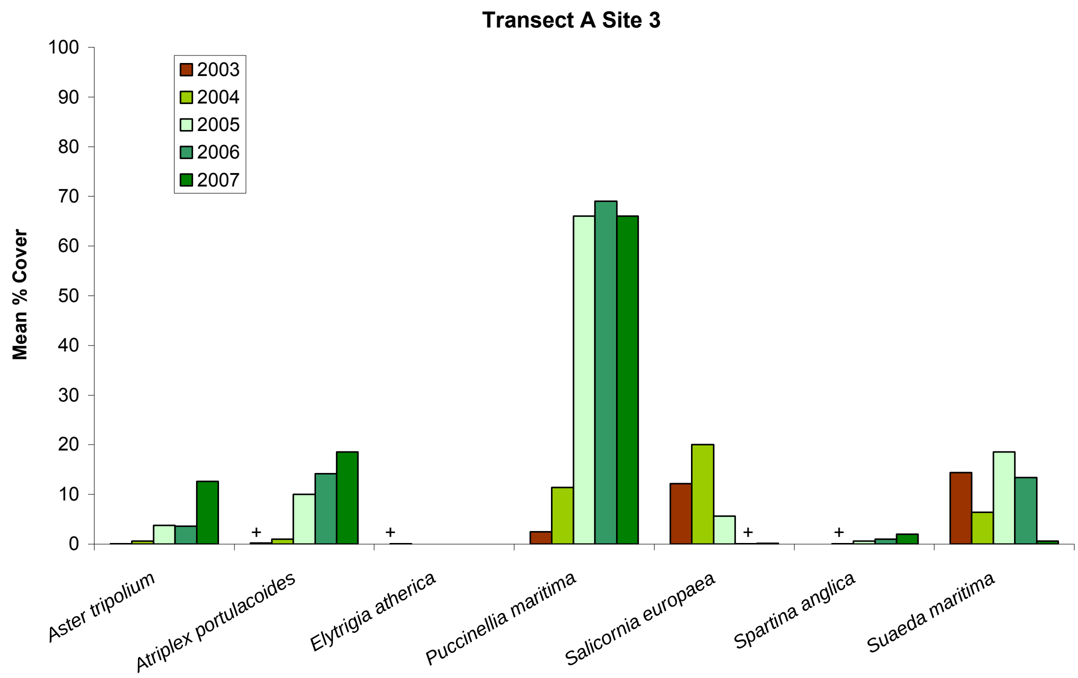
* *Festuca* occurs occasionally in a narrow strip at the base of the embankment on this side of the Wash and may occur around Freiston, but it is not common.
** *Glaux* also occurs occasionally in a narrow strip at the base of the embankment on this side of the Wash, but it has not been seen at Freiston
*** One patch of *Spartina* closely resembling *Spartina maritima* (3-4m diameter) was found in the 1990s on Transect 6 just seaward of Site 2 (S.L.Brown's former LOIS transect) and was seen until recently, but may have

gone now. This plant has been recorded (post 1930) at two sites on this side of the Wash in Perring and Walters 1976.

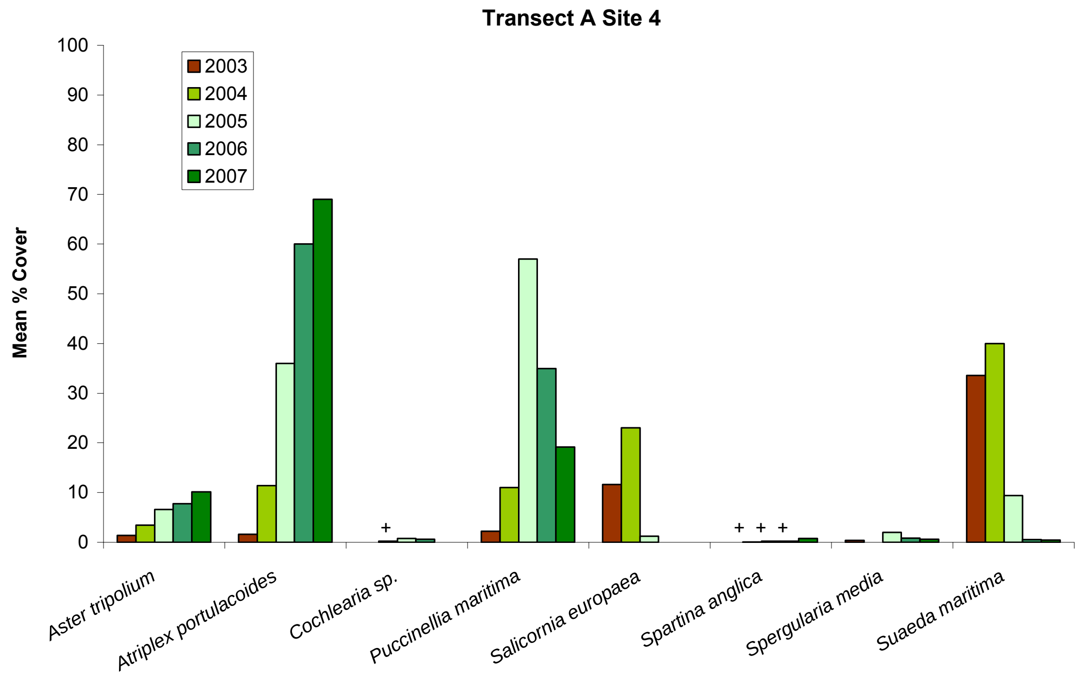
7.2 Appendix 2. Mean Percentage Cover of Plant Species at Individual Sites in the Freiston Managed Realignment





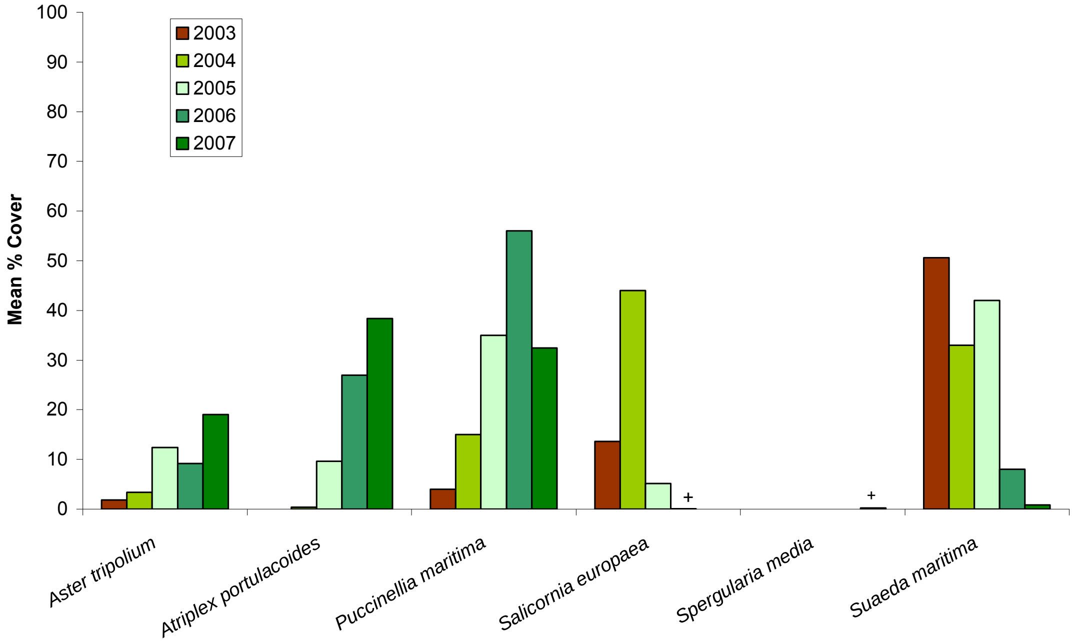


Transect A Site 3
Mean % Cover
100
90
80
70
60
50
40
30
20
10
0
2003
2004
2005
2006
2007
+
+
+
+
Aster tripolium
Atriplex portulacoides
Elytrigia atherica
Puccinellia maritima
Salicornia europaea
Spartina anglica
Suaeda maritima

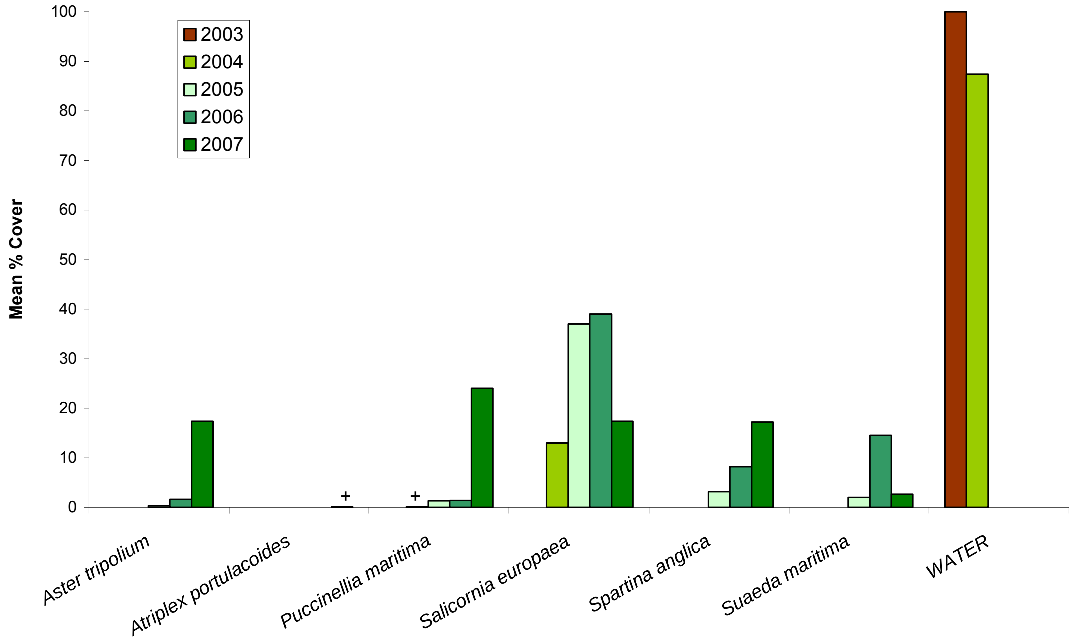


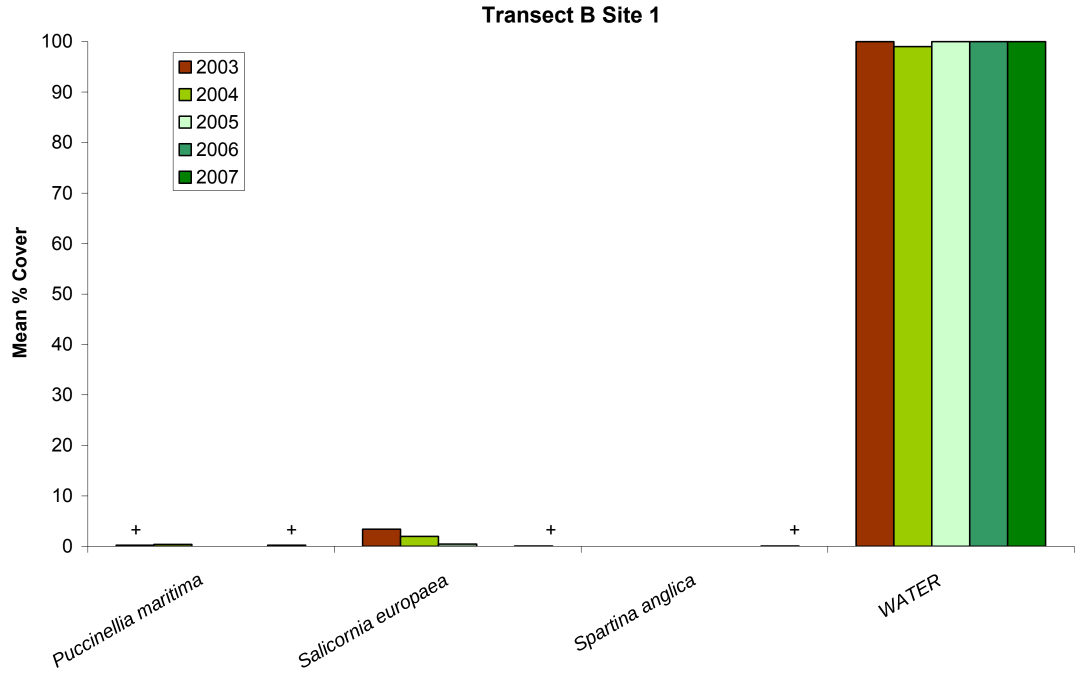
Transect A Site 4
Mean % Cover
100
90
80
70
60
50
40
30
20
10
0
2003
2004
2005
2006
2007
+
+ + +
Aster tripolium
Atriplex portulacoides
Cochlearia sp.
Puccinellia maritima
Salicornia europaea
Spartina anglica
Spergularia media
Suaeda maritima

Transect A Site 5

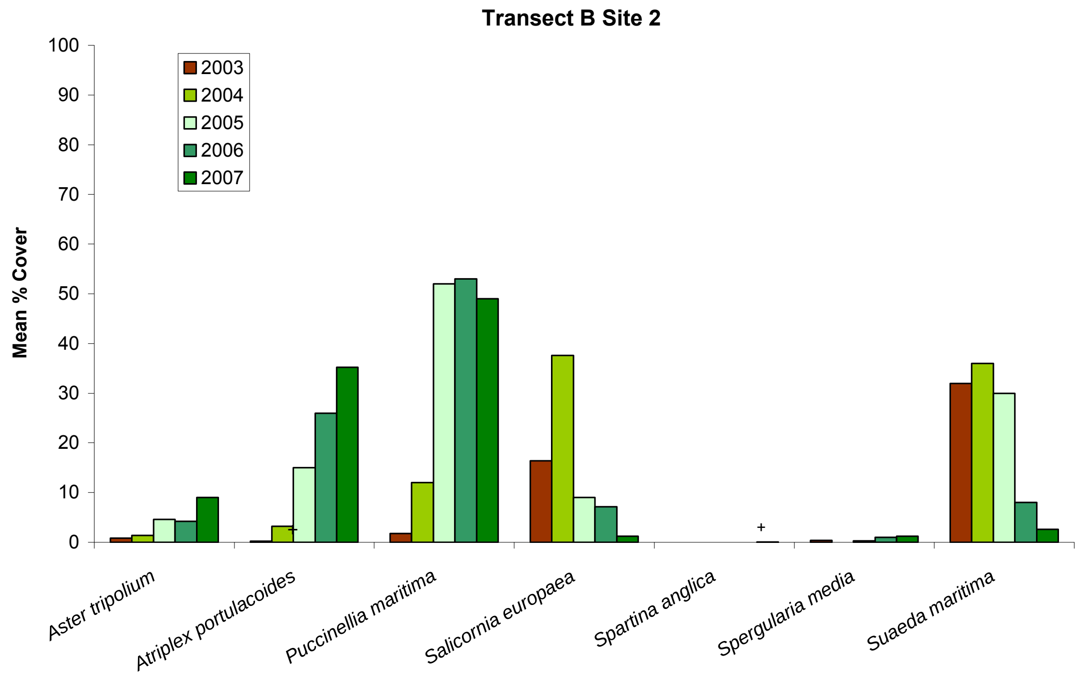


Transect A Site 6

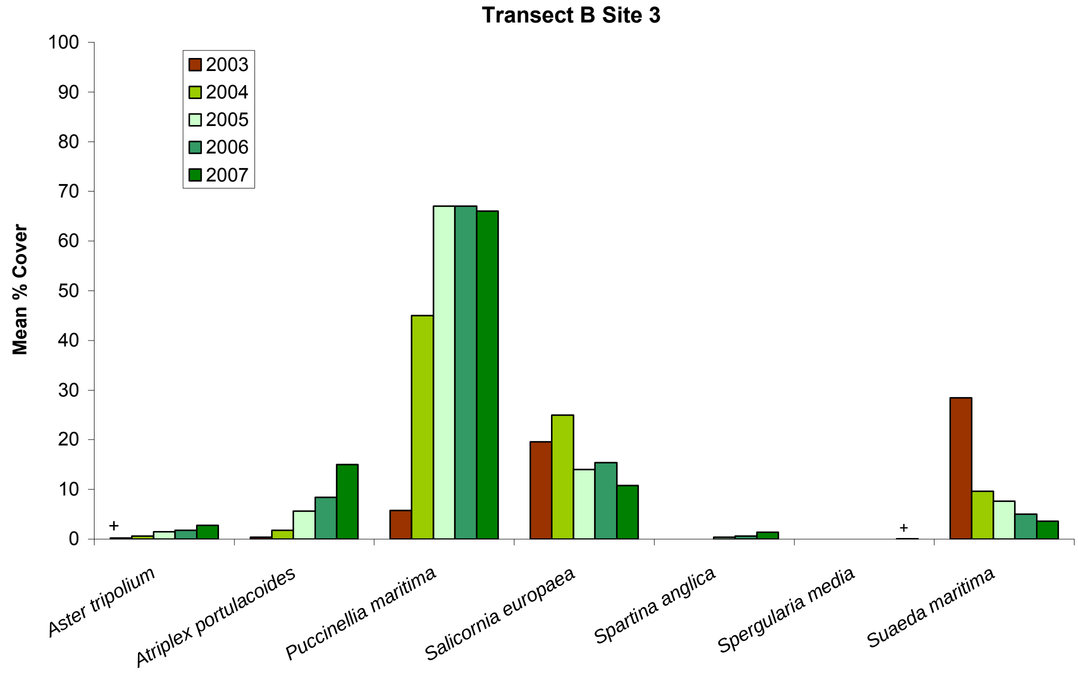


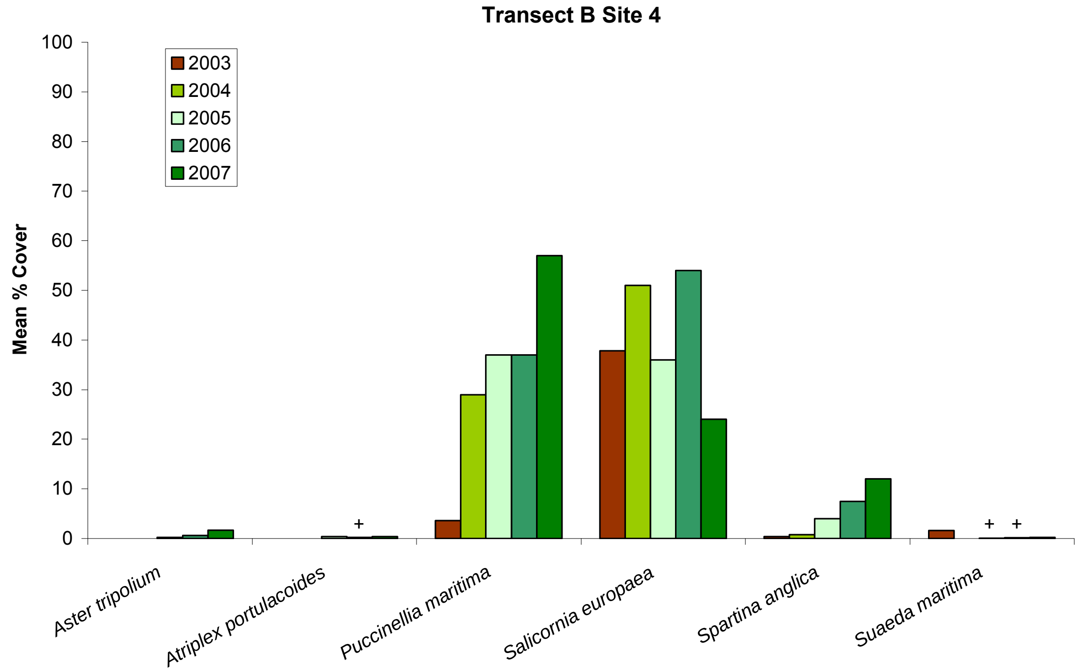


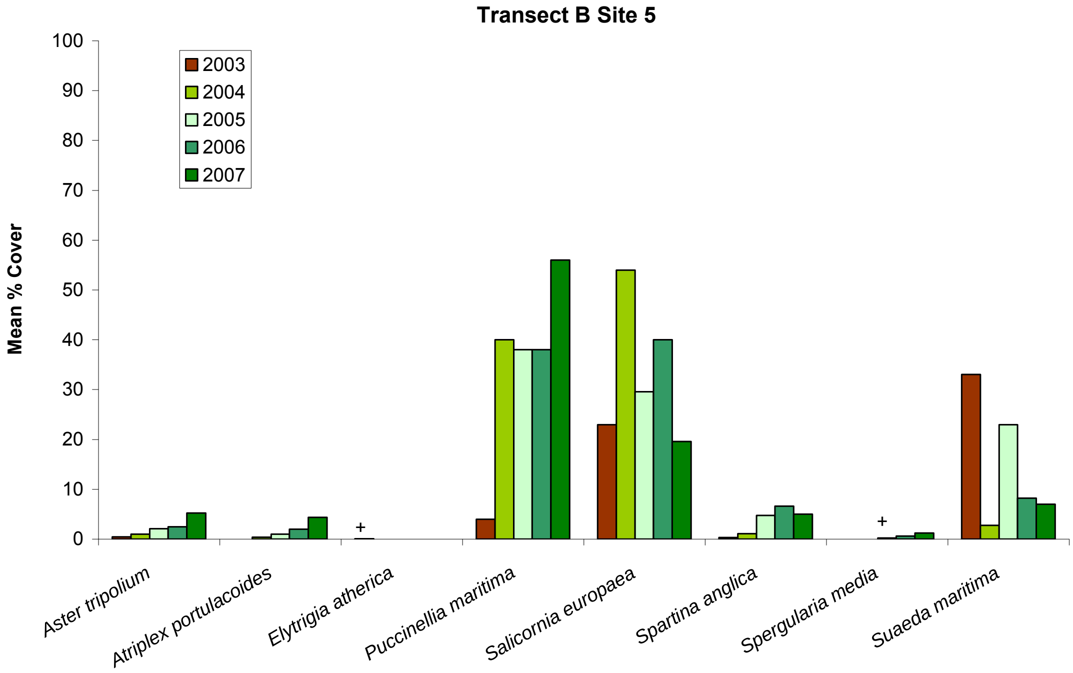
Transect B Site 1
Mean % Cover
100
90
80
70
60
50
40
30
20
10
0
2003
2004
2005
2006
2007
+
+
+
+
Puccinellia maritima
Salicornia europaea
Spartina anglica
WATER

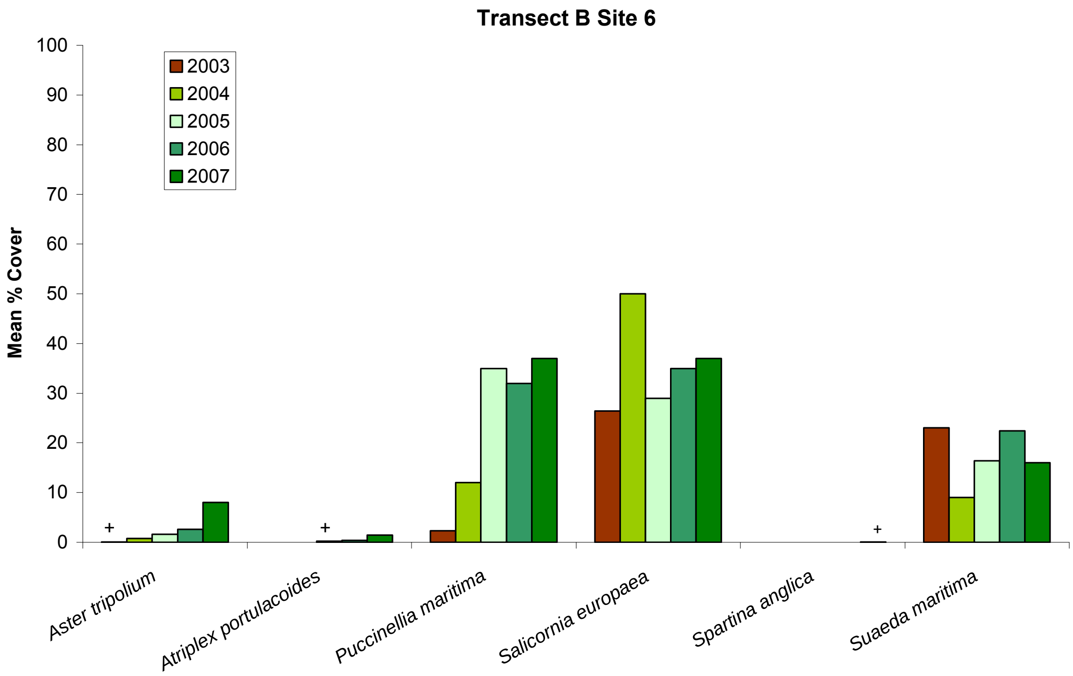


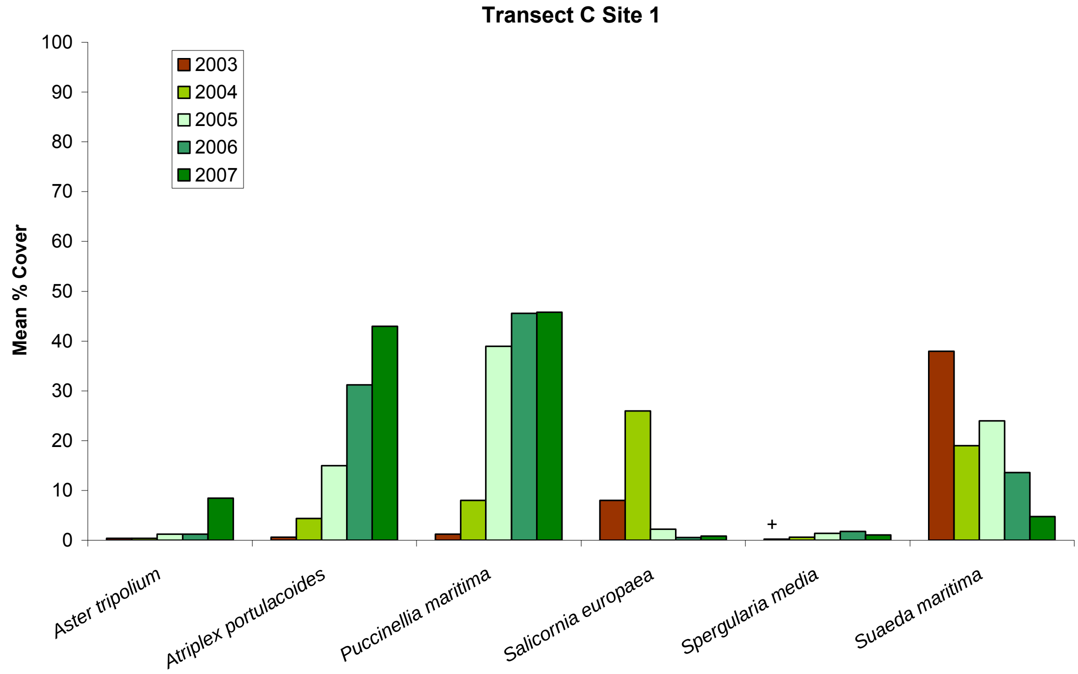
Transect B Site 2
Mean % Cover
100
90
80
70
60
50
40
30
20
10
0
2003
2004
2005
2006
2007
+
+
Aster tripolium
Atriplex portulacoides
Puccinellia maritima
Salicornia europaea
Spartina anglica
Spergularia media
Suaeda maritima

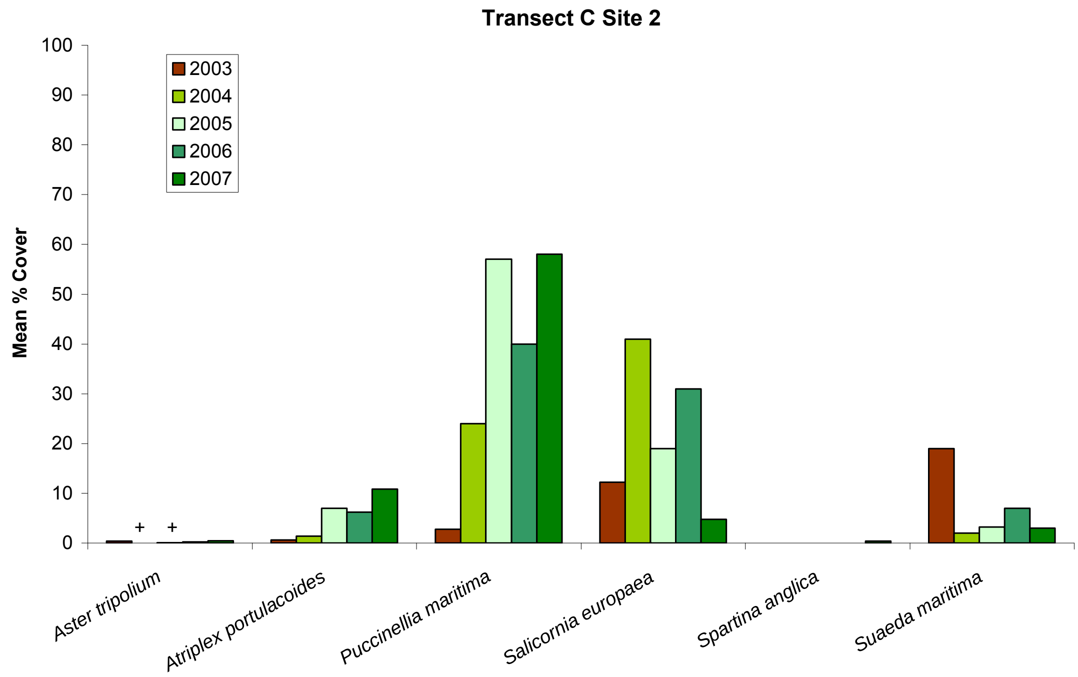

Transect B Site 3
Mean % Cover
100
90
80
70
60
50
40
30
20
10
0
2003
2004
2005
2006
2007
+
+
Aster tripolium
Atriplex portulacoides
Puccinellia maritima
Salicornia europaea
Spartina anglica
Spergularia media
Suaeda maritima

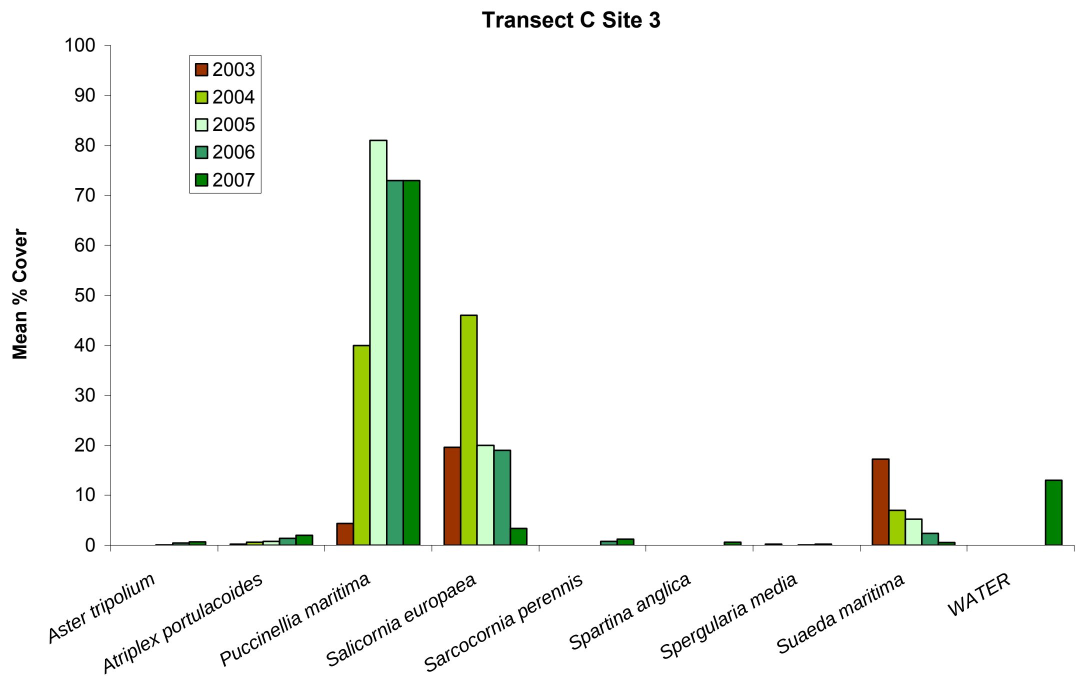

Transect B Site 4
Mean % Cover
100
90
80
70
60
50
40
30
20
10
0
2003
2004
2005
2006
2007
+
+
+
Aster tripolium
Atriplex portulacoides
Puccinellia maritima
Salicornia europaea
Spartina anglica
Suaeda maritima

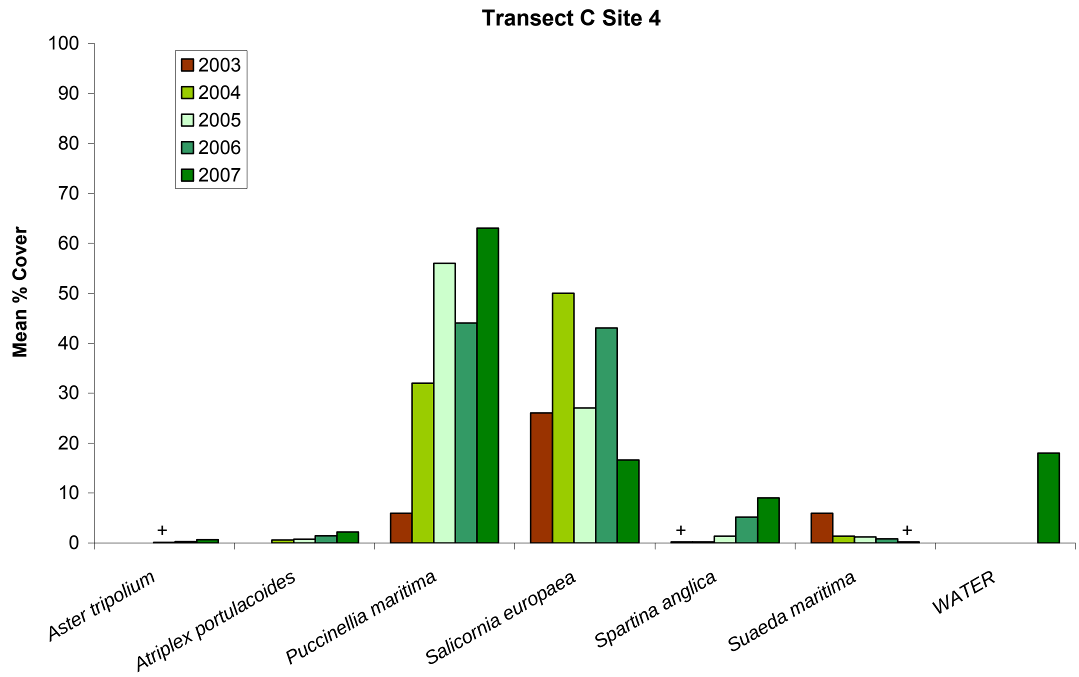

Transect B Site 5
Mean % Cover
100
90
80
70
60
50
40
30
20
10
0
2003
2004
2005
2006
2007
+
+
Aster tripolium
Atriplex portulacoides
Elytrigia atherica
Puccinellia maritima
Salicornia europaea
Spartina anglica
Spergularia media
Suaeda maritima

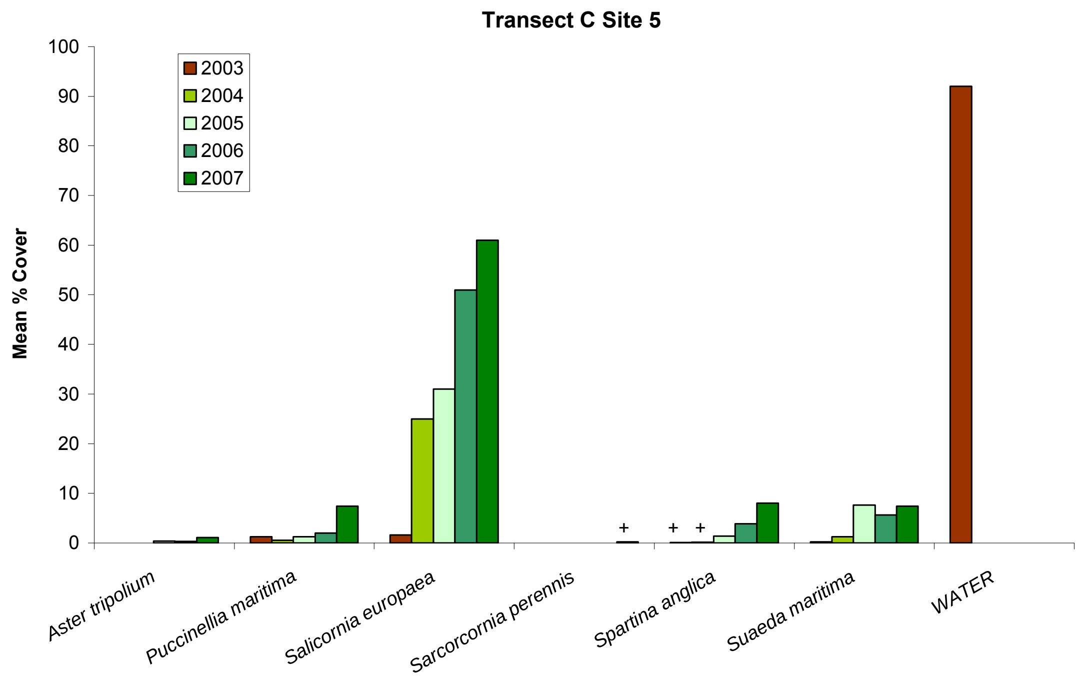

Transect B Site 6
Mean % Cover
100
90
80
70
60
50
40
30
20
10
0
2003
2004
2005
2006
2007
+
+
+
Aster tripolium
Atriplex portulacoides
Puccinellia maritima
Salicornia europaea
Spartina anglica
Suaeda maritima

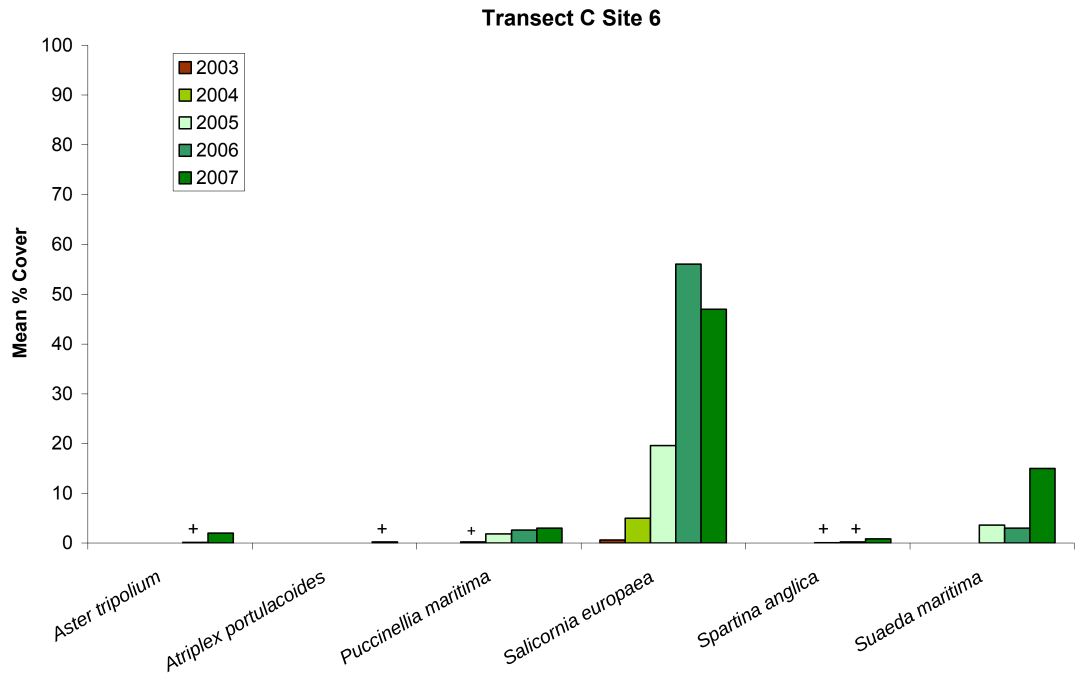

Transect C Site 1
Mean % Cover
100
90
80
70
60
50
40
30
20
10
0
2003
2004
2005
2006
2007
+
Aster tripolium
Atriplex portulacoides
Puccinellia maritima
Salicornia europaea
Spergularia media
Suaeda maritima

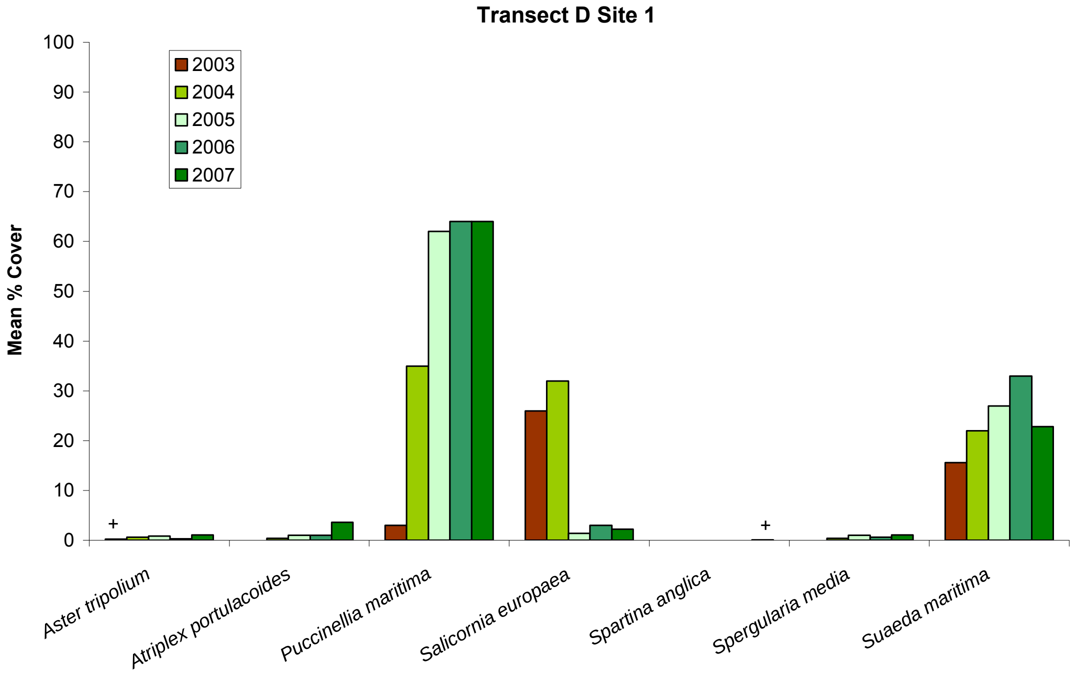

Transect C Site 2
Mean % Cover
100
90
80
70
60
50
40
30
20
10
0
2003
2004
2005
2006
2007
+
+
Aster tripolium
Atriplex portulacoides
Puccinellia maritima
Salicornia europaea
Spartina anglica
Suaeda maritima

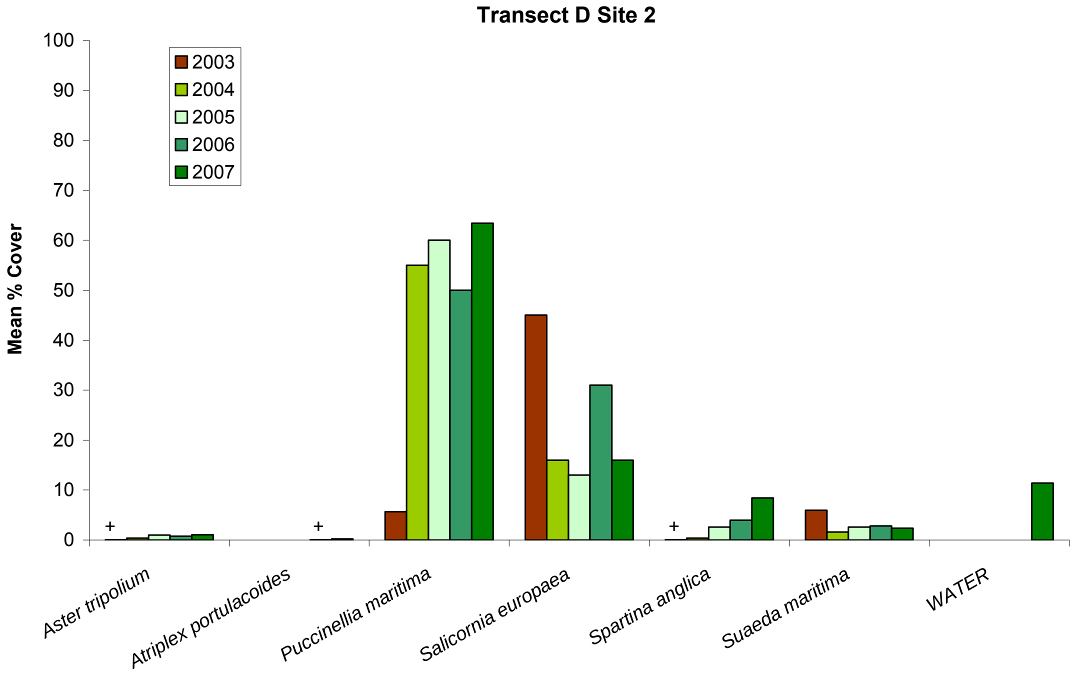

Transect C Site 3
Mean % Cover
100
90
80
70
60
50
40
30
20
10
0
2003
2004
2005
2006
2007
Aster tripolium
Atriplex portulacoides
Puccinellia maritima
Salicornia europaea
Sarcocornia perennis
Spartina anglica
Spergularia media
Suaeda maritima
WATER

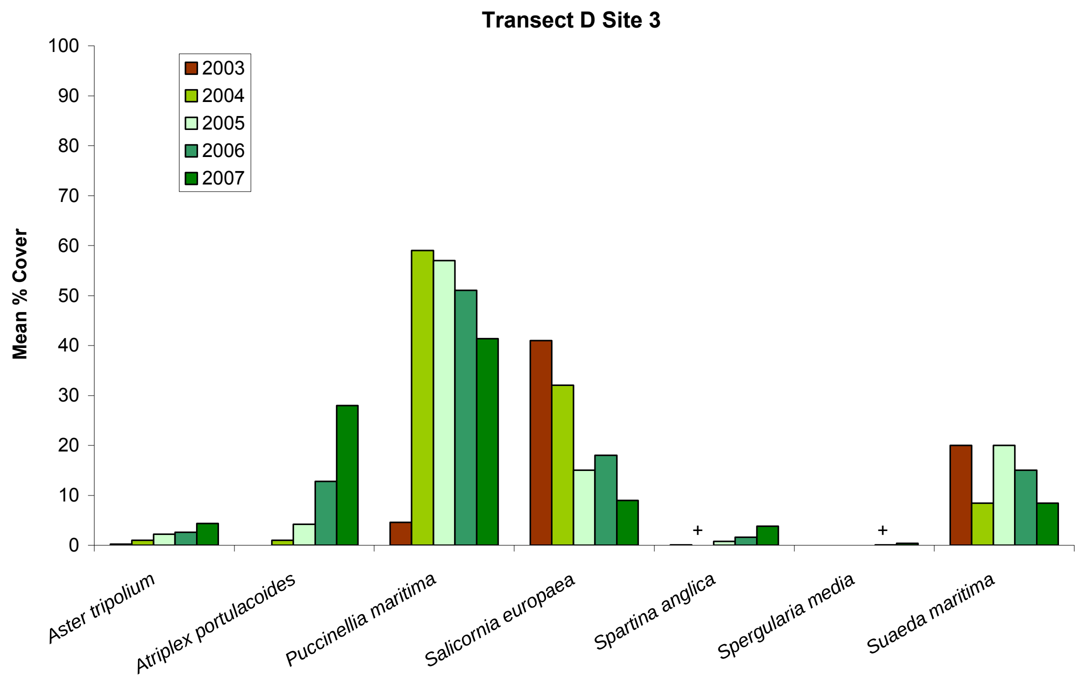

Transect C Site 4
Mean % Cover
100
90
80
70
60
50
40
30
20
10
0
2003
2004
2005
2006
2007
+
+
+
Aster tripolium
Atriplex portulacoides
Puccinellia maritima
Salicornia europaea
Spartina anglica
Suaeda maritima
WATER

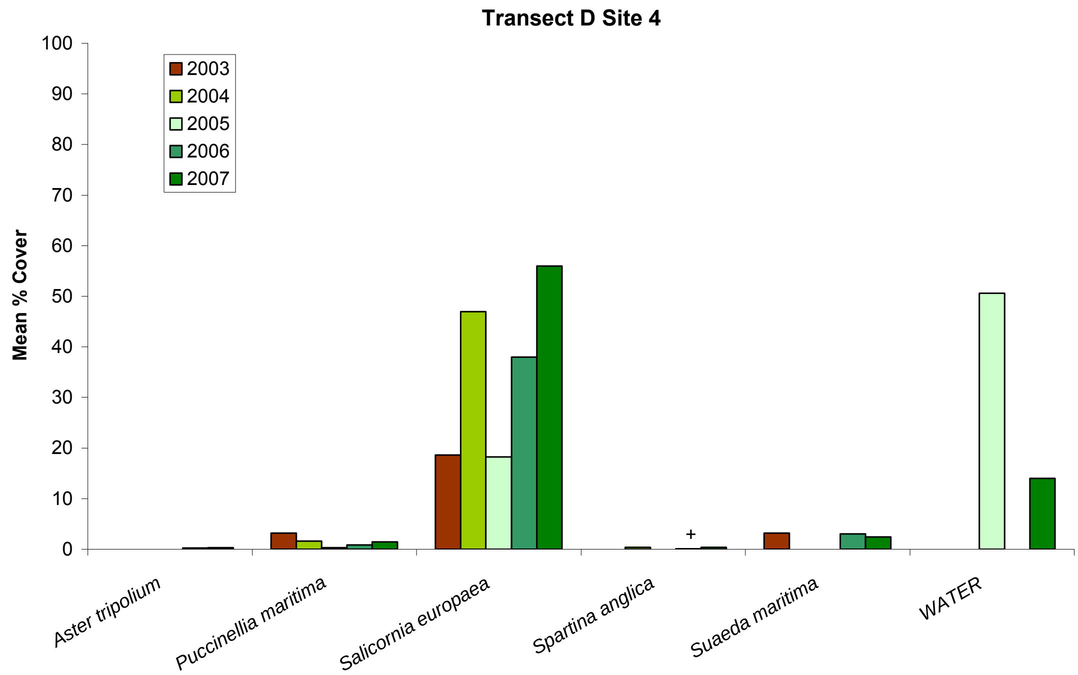

Transcect C Site 5
Mean % Cover
100
90
80
70
60
50
40
30
20
10
0
2003
2004
2005
2006
2007
+
+
+
Aster tripolium
Puccinellia maritima
Salicornia europaea
Sarcorcornia perennis
Spartina anglica
Suaeda maritima
WATER

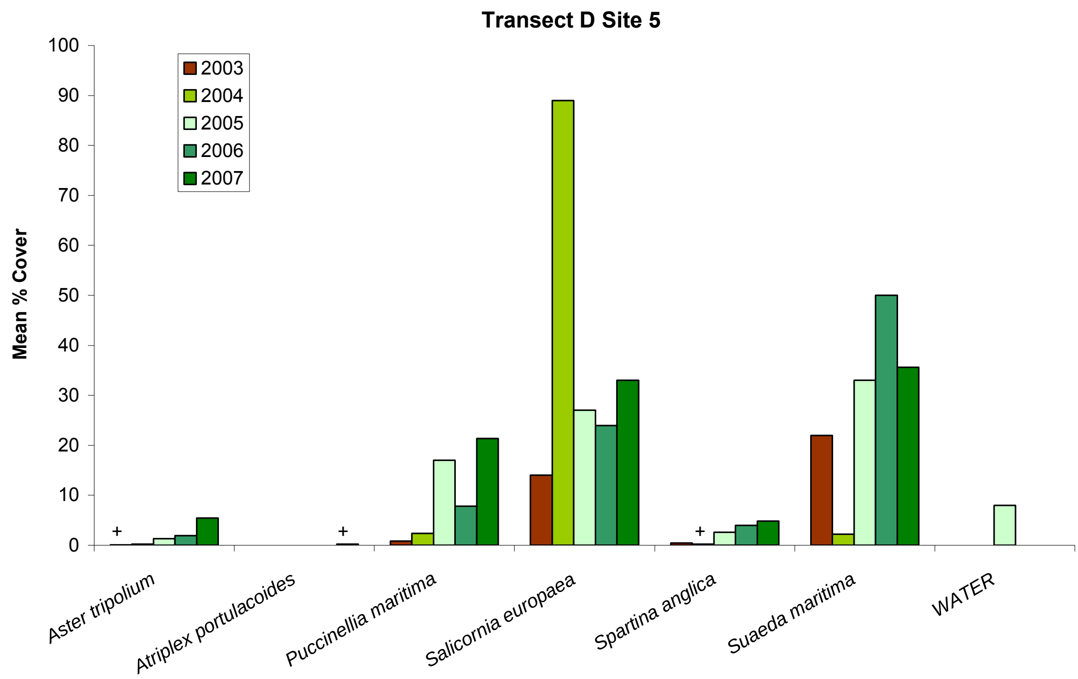

Transcect C Site 6
Mean % Cover
100
90
80
70
60
50
40
30
20
10
0
2003
2004
2005
2006
2007
+
+
+
+
+
Aster tripolium
Atriplex portulacoides
Puccinellia maritima
Salicornia europaea
Spartina anglica
Suaeda maritima

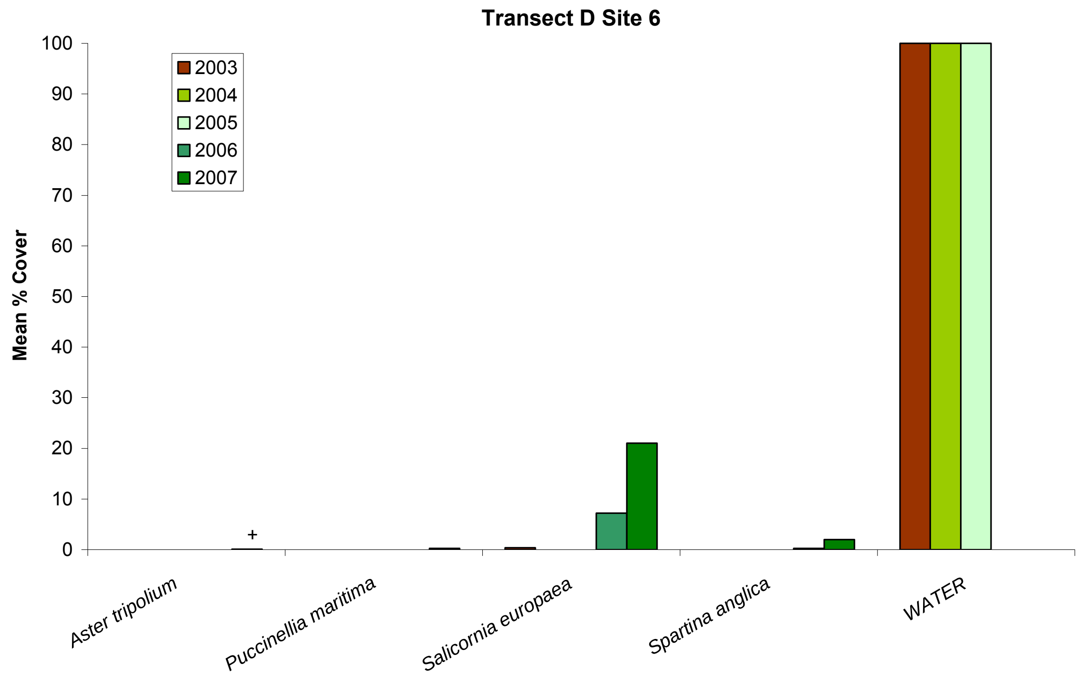

Transect D Site 1
Mean % Cover
100
90
80
70
60
50
40
30
20
10
0
2003
2004
2005
2006
2007
+
+
Aster tripolium
Atriplex portulacoides
Puccinellia maritima
Salicornia europaea
Spartina anglica
Spergularia media
Suaeda maritima

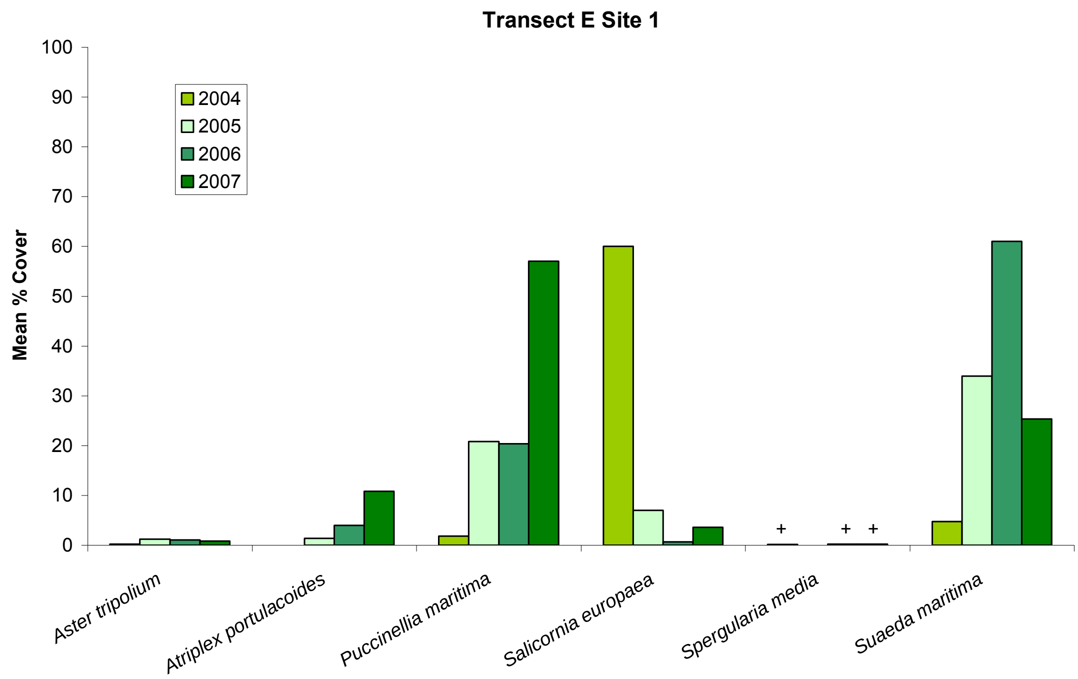

Transect D Site 2
Mean % Cover
100
90
80
70
60
50
40
30
20
10
0
2003
2004
2005
2006
2007
+
+
+
Aster tripolium
Atriplex portulacoides
Puccinellia maritima
Salicornia europaea
Spartina anglica
Suaeda maritima
WATER

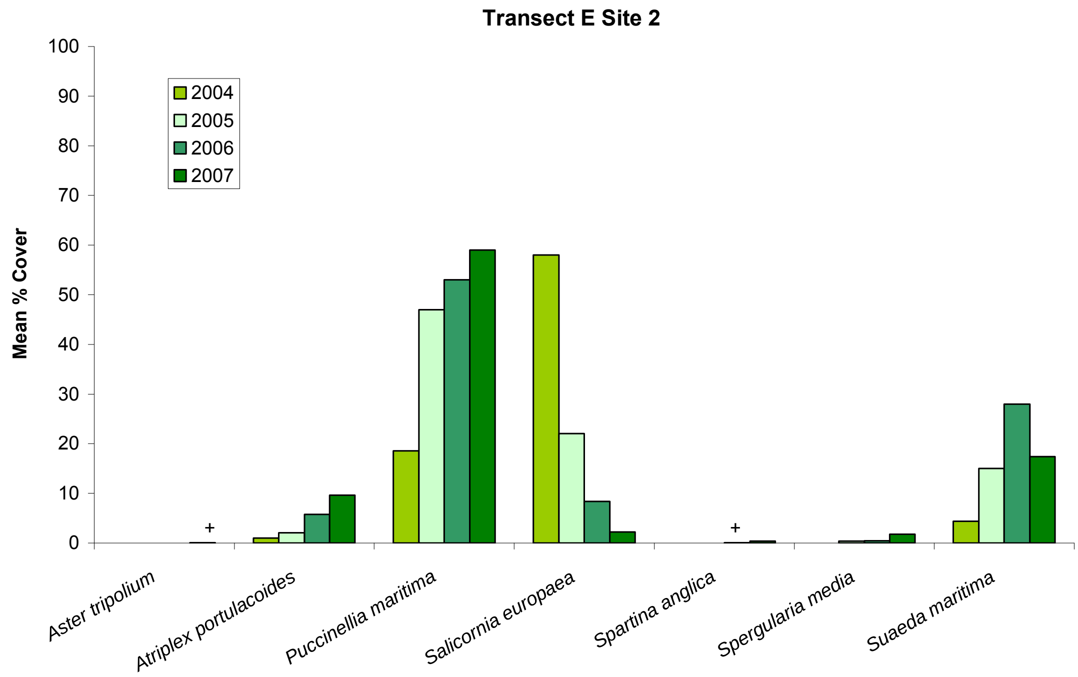

Transect D Site 3
Mean % Cover
100
90
80
70
60
50
40
30
20
10
0
2003
2004
2005
2006
2007
+
+
Aster tripolium
Atriplex portulacoides
Puccinellia maritima
Salicornia europaea
Spartina anglica
Spergularia media
Suaeda maritima

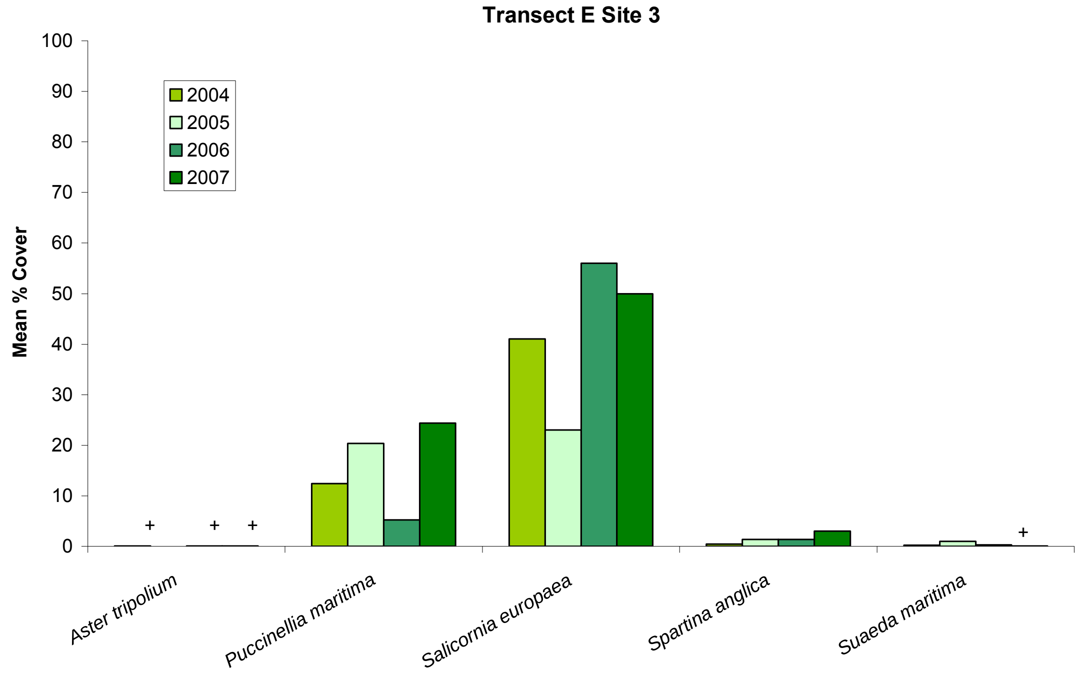

Transect D Site 4
Mean % Cover
100
90
80
70
60
50
40
30
20
10
0
2003
2004
2005
2006
2007
+
Aster tripolium
Puccinellia maritima
Salicornia europaea
Spartina anglica
Suaeda maritima
WATER

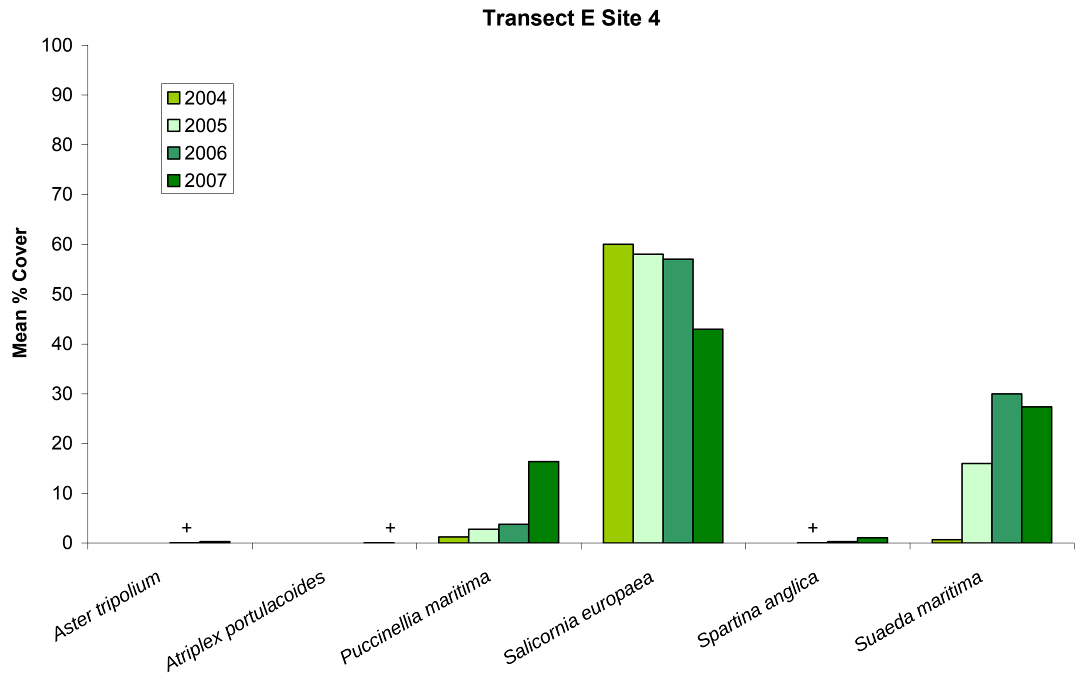

Transect D Site 5
Mean % Cover
100
90
80
70
60
50
40
30
20
10
0
2003
2004
2005
2006
2007
+
+
+
Aster tripolium
Atriplex portulacoides
Puccinellia maritima
Salicornia europaea
Spartina anglica
Suaeda maritima
WATER

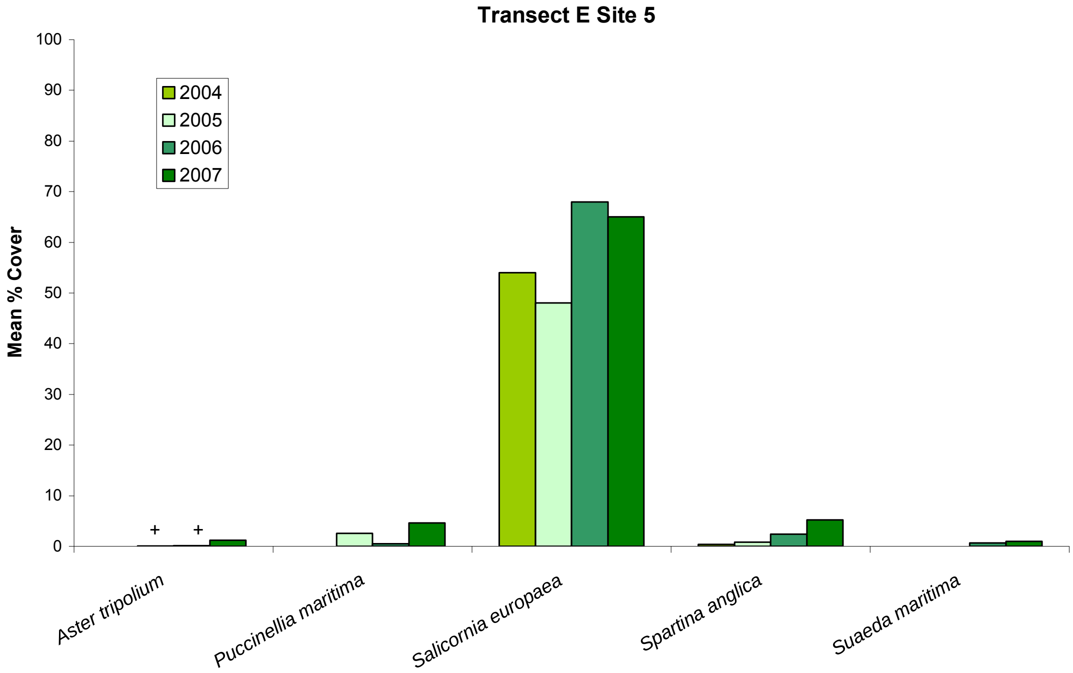

Transect D Site 6
Mean % Cover
100
90
80
70
60
50
40
30
20
10
0
2003
2004
2005
2006
2007
+
Aster tripolium
Puccinellia maritima
Salicornia europaea
Spartina anglica
WATER

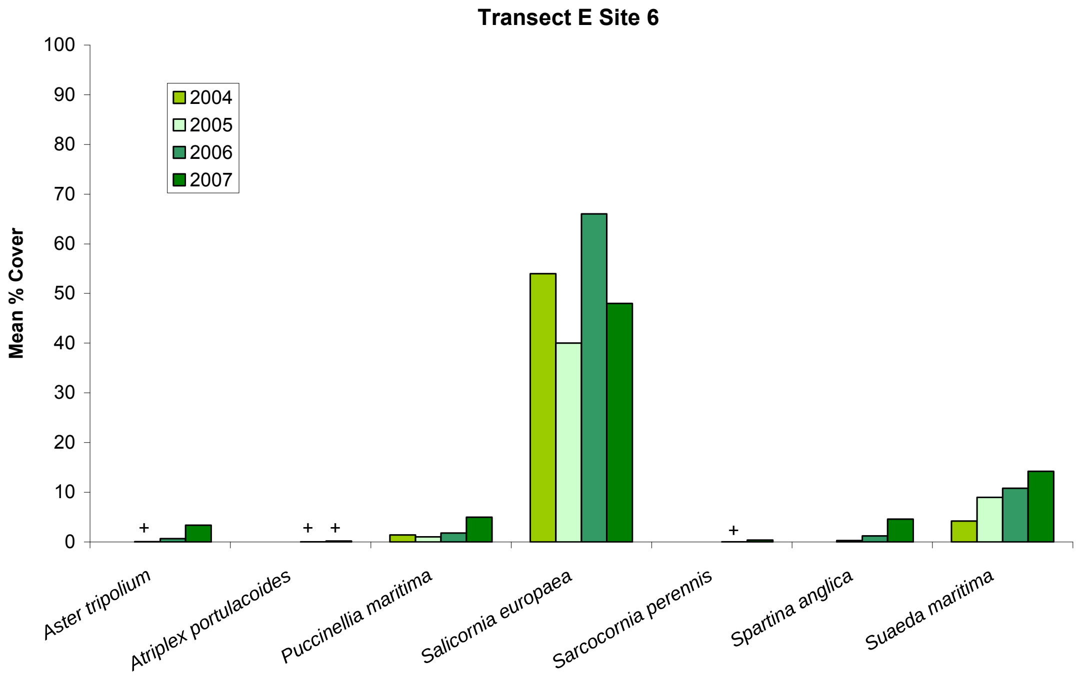

Transect E Site 1
Mean % Cover
100
90
80
70
60
50
40
30
20
10
0
2004
2005
2006
2007
+
+ +
Aster tripolium
Atriplex portulacoides
Puccinellia maritima
Salicornia europaea
Spergularia media
Suaeda maritima

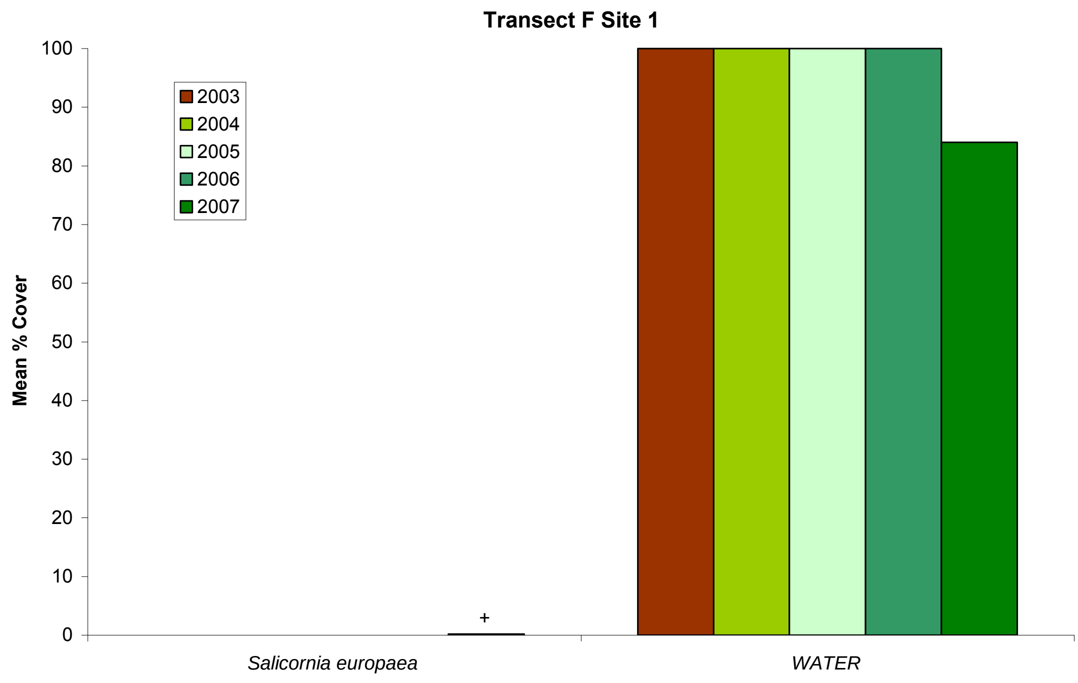

Transect E Site 2
Mean % Cover
100
90
80
70
60
50
40
30
20
10
0
2004
2005
2006
2007
+
+
Aster tripolium
Atriplex portulacoides
Puccinellia maritima
Salicornia europaea
Spartina anglica
Spergularia media
Suaeda maritima

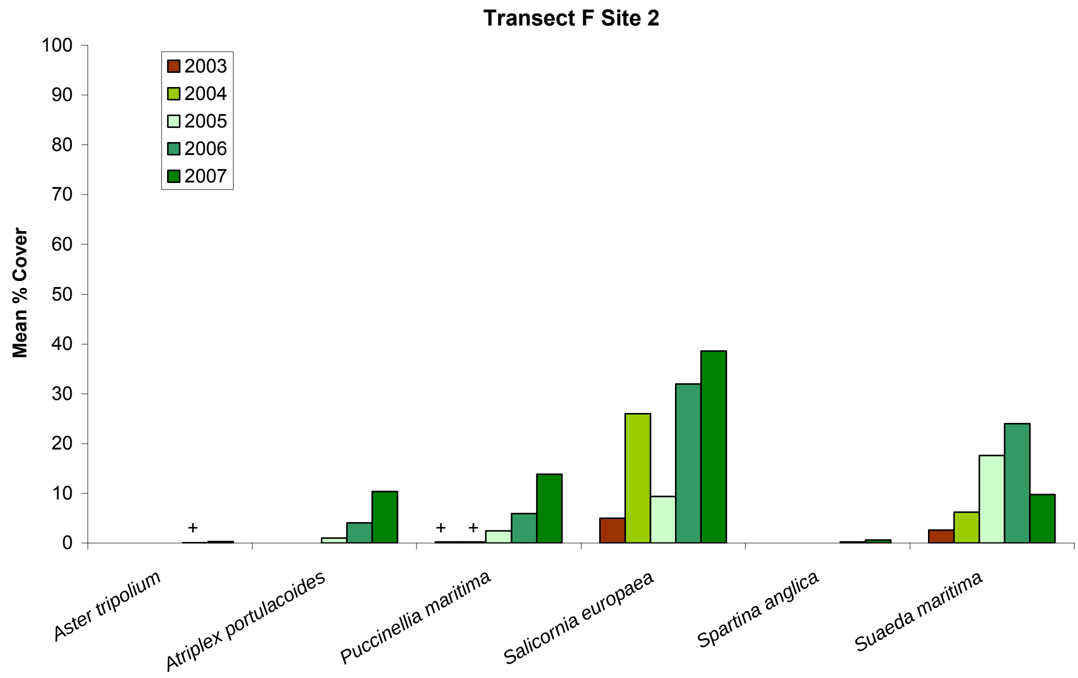

Transect E Site 3
Mean % Cover
100
90
80
70
60
50
40
30
20
10
0
2004
2005
2006
2007
+
+
+
+
Aster tripolium
Puccinellia maritima
Salicornia europaea
Spartina anglica
Suaeda maritima

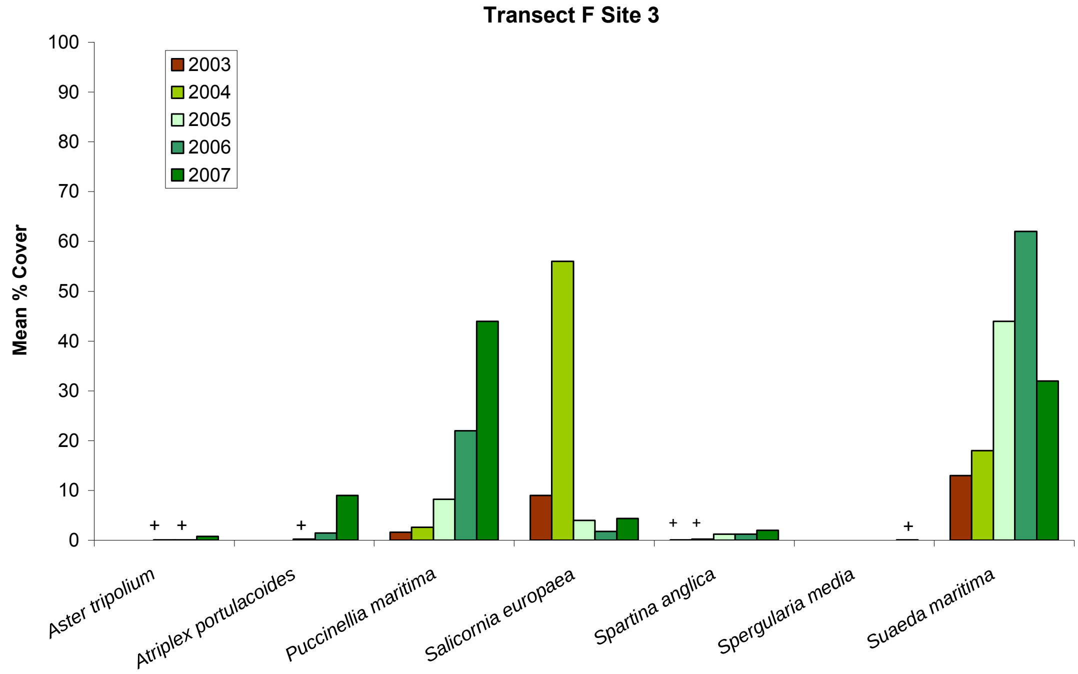

Transect E Site 4
Mean % Cover
100
90
80
70
60
50
40
30
20
10
0
2004
2005
2006
2007
+
+
+
Aster tripolium
Atriplex portulacoides
Puccinellia maritima
Salicornia europaea
Spartina anglica
Suaeda maritima

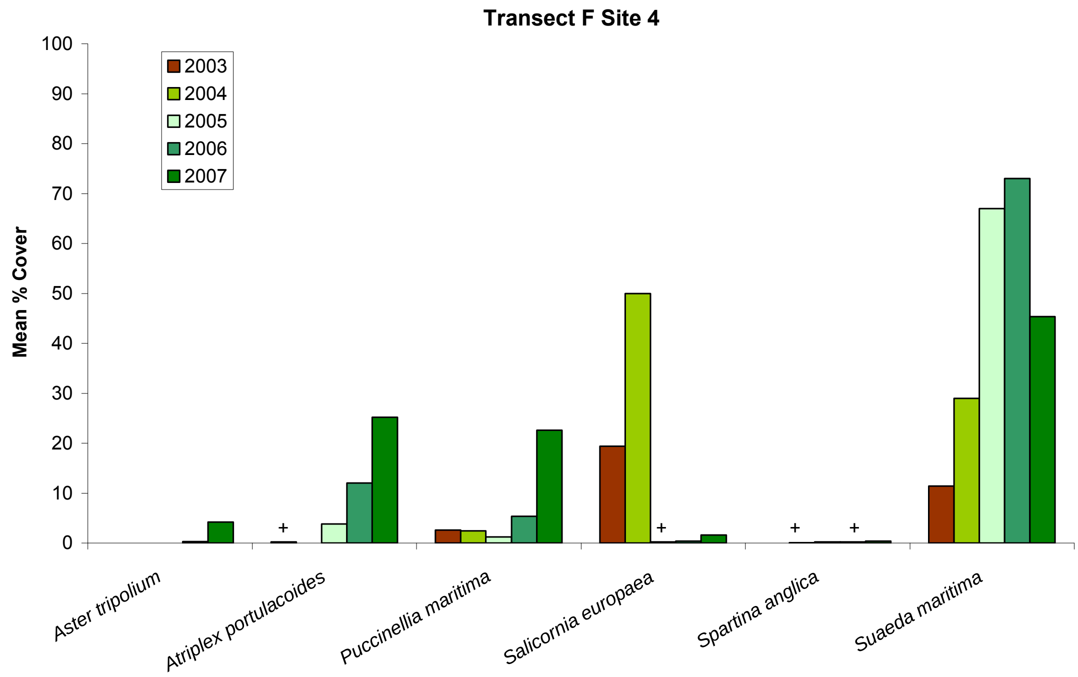

Transect E Site 5
Mean % Cover
2004
2005
2006
2007
+
+
Aster tripolium
Puccinellia maritima
Salicornia europaea
Spartina anglica
Suaeda maritima

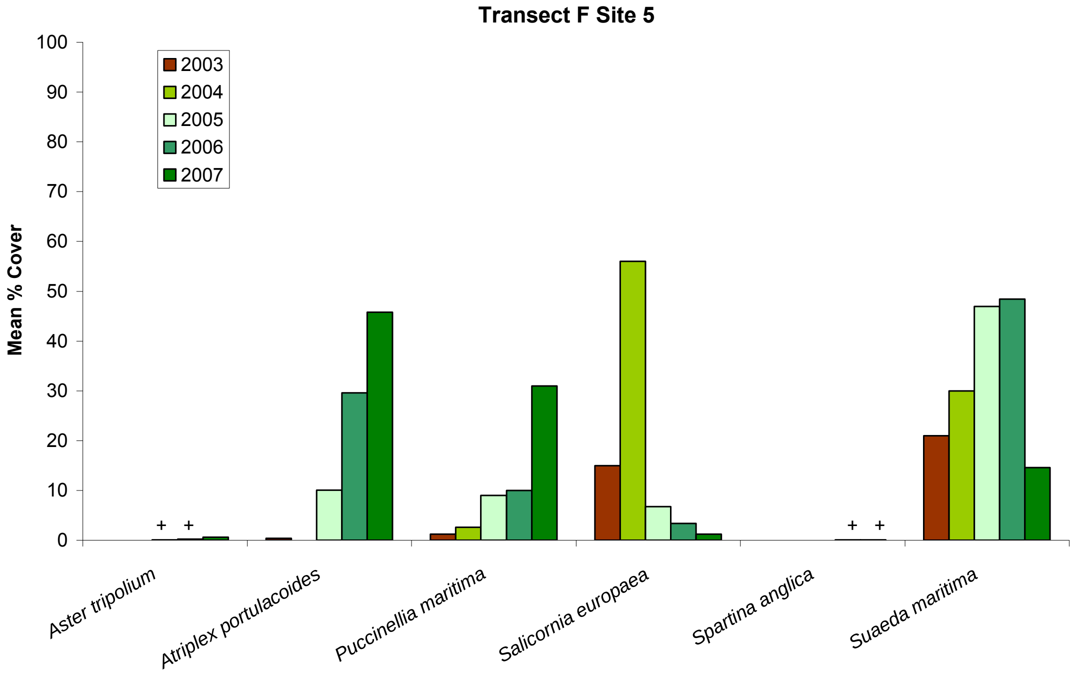

Transect E Site 6
Mean % Cover
2004
2005
2006
2007
+
+
+
+
Aster tripolium
Atriplex portulacoides
Puccinellia maritima
Salicornia europaea
Sarcocornia perennis
Spartina anglica
Suaeda maritima

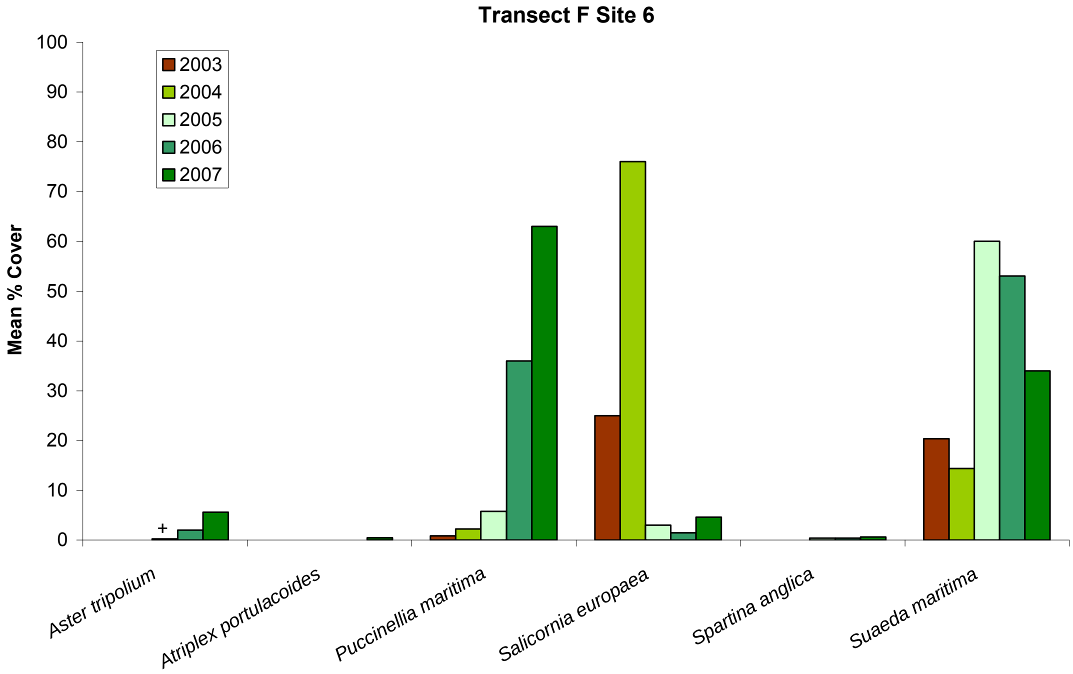

Transect F Site 1
Mean % Cover
100
90
80
70
60
50
40
30
20
10
0
2003
2004
2005
2006
2007
+
Salicornia europaea
WATER


Transect F Site 2
Mean % Cover
100
90
80
70
60
50
40
30
20
10
0
2003
2004
2005
2006
2007
+
+
+
Aster tripolium
Atriplex portulacoides
Puccinellia maritima
Salicornia europaea
Spartina anglica
Suaeda maritima


Transect F Site 3
Mean % Cover
100
90
80
70
60
50
40
30
20
10
0
2003
2004
2005
2006
2007
Aster tripolium
Atriplex portulacoides
Puccinellia maritima
Salicornia europaea
Spartina anglica
Spergularia media
Suaeda maritima


Transect F Site 4
Mean % Cover
100
90
80
70
60
50
40
30
20
10
0
2003
2004
2005
2006
2007
Aster tripolium
Atriplex portulacoides
Puccinellia maritima
Salicornia europaea
Spartina anglica
Suaeda maritima


Transect F Site 5
Mean % Cover
100
90
80
70
60
50
40
30
20
10
0
2003
2004
2005
2006
2007
+ +
+ +
Aster tripolium
Atriplex portulacoides
Puccinellia maritima
Salicornia europaea
Spartina anglica
Suaeda maritima


Transect F Site 6
Mean % Cover
100
90
80
70
60
50
40
30
20
10
0
2003
2004
2005
2006
2007
+
Aster tripolium
Atriplex portulacoides
Puccinellia maritima
Salicornia europaea
Spartina anglica
Suaeda maritima

Ergon House
Horseferry Road
London SW1P 2AL

www.defra.gov.uk

Department for Environment
Food and Rural Affairs