Natural England Commissioned Report NECR185

The status of Habitats Directive Annex I saltmarsh habitats, transition zones and *Spartina* species in England

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Foreword

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Background

This report was commissioned to provide an inventory and description of Annex I saltmarsh habitats and transitional vegetation in England. The work involved reviewing existing data on distribution followed by surveys of selected locations of the rarest and most vulnerable saltmarsh habitats in England, including habitats that are a transition between saltmarsh and terrestrial/freshwater conditions. These are largely the communities defined by the presence of shrubby seablite, perennial samphire and the native small cord-grass, together with transitional zones of Morecambe Bay. The project also carried out a repeat survey of locations in Southampton Water to update knowledge about the range of cord-grass species present at that estuary complex, important as the location where hybridisation between introduced and native cord-grass species first occurred.

The vegetation surveys followed the National Vegetation Classification (NVC) criteria, and soil samples were also taken and analysed to increase understanding of some of the key physical factors influencing the vegetation.

The findings were compared with previous information where available to more authoritatively assess changes in the habitats, both nationally and at site level. The findings will be used by Natural England and others to:

- update future reporting on the conservation status of the habitats;
- contribute to wider studies of saltmarsh transition communities;
- improve our understanding of the underpinning processes of these habitats;
- increase the potential to recreate these elements of saltmarshes as part of intertidal restoration schemes

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Contents

Executive summary

On unmodified soft sediment coastlines, of which there are long lengths especially on the English east and south coasts, there should be a wide transitional zone between tidal areas and full terrestrial land. The conditions in this zone result in a rich and distinctive range of habitats. There are two saltmarsh habitats listed in Annex I of the Habitats Directive within this zone (H1420 *Mediterranean and thermo-Atlantic halophilous scrubs* and H1320 *Spartina swards,Spartinion maritimae)* reflecting its importance for nature conservation. At the time work for this project was started in 2012, the conservation status of these habitats was reported as 'unfavourable, bad and deteriorating'. Due to construction of artificial sea defences, these zones are now much reduced in extent and distribution and are under threat from a range of factors.

This project aims to provide an inventory and description of Annex I saltmarsh habitats and transitional vegetation in England. This will help to update future reporting on conservation status. The outcomes will also help improve understanding of the underpinning processes which can be used in design to improve the potential for recreating these elements of saltmarshes as part of intertidal restoration schemes. The project also provides an up to date assessment of *Spartina* alterniflora stands in the Solent SAC through review and field survey for 2012.

A review of *Spartina maritima* in England

A field survey of *Spartina maritima* was conducted through July 2012 to assess condition and extent. 48 sites in the south east of England from the Wash to Poole Harbour were surveyed using past records on presence as a guide (provided by the BSBI). Each site represented a species record in a different 1km square across the species range. Thirty seven populations were refound. The saltmarsh habitats immediately around extant populations of *S. maritima* were considered to be good examples of their type and no immediate threats were identified. There was a high degree of certainty that the 11 populations not relocated during the survey were extinct, rather than the survey team not being able to find the plants. In most of the 11 sites the marshes appeared to be either in the early phases of erosion, or severely eroded. The primary threat to the long term viability of *S. maritima* is the loss of saltmarsh extent (i.e. through 'coastal squeeze'). This was especially obvious around the Essex coast and the mainland coast of the Solent where the majority of salt marshes were cliffed on their seaward edge and suffering from internal erosion through creek expansion.

A review of *Suaeda vera* in England

Suaeda vera populations growing on saltmarsh were recorded within 31 1km squares resurveyed during July 2012. Outlying saltmarsh populations from North Norfolk to Poole Harbour were covered, in addition to the populations in the centre of the species range in Essex. All populations previously recorded since 1990 were still intact in 2012. The extent of the *Suaeda vera* bushes and habitat type varies across its range. The populations of *Suaeda vera* growing on salt marsh appeared to be good examples of the vegetation type with no immediate threats recorded. The most likely short to medium term potential threat is probably flood defence maintenance, especially in Essex where the majority of the population is situated on the strand line, or at the foot of the sea wall. Coastal squeeze and rising sea levels are longer term threats.

A review of *Sarcocornia perennis* in England

Sarcocornia perennis populations growing on saltmarsh were recorded within all of the planned 38 1km squares resurveyed during July 2012. Populations from North Norfolk to Poole Harbour were sampled, in addition to the populations in the centre of the species range in Essex. There was little variation in the habitat across the range of sites surveyed. *S. perennis* was, in most samples, a composite of an associated vegetation type rather than the dominant plant species. The salt marsh habitat immediately adjacent appeared to be intact and under no obvious short term threat. The primary threat to their mid to long term viability is the loss of extent (i.e. through 'coastal squeeze') and subsequent erosion of the adjacent saltmarsh as with *S. maritima*

Habitat creation potential for *Mediterranean and thermo-Atlantic halophilous scrubs* and *Spartina maritima swards*

The results from analysis of soil samples taken from each sample site show that there is a clear separation between the requirements of *Suaeda vera* and that of *Spartina maritima* and *Sarcocornia perennis* reflecting the relative differences in the tidal frame. The higher transitional strand line or creek side vegetation of *Suaeda vera* salt marsh was better drained and less saline than soils for the other two species. In recreating the right conditions for any of the three species or habitat types to establish, frequency of tidal inundation is certain to be the main driver. The ecological niche of saltmarsh plants has been well described and a species elevational range can be estimated with relative accurancy for any restoration scheme using information from the local species pool. *Spartina maritima* and *Sarcocornia perennis* are generally components of *Puccinellia maritima* and/or *Atriplex portulacoides* salt marsh, typical of the majority of marshes in the south east of England. *Sarcocornia perennis* has been recorded in several saltmarshes regenerated over agricultural land through managed realignment in the UK and *Spartina maritima* has been recorded once in a managed realignment site in the UK. *Sueada vera* plants appear to readily colonise new or abandoned sea walls within managed realignment sites and on embankments of primary defences.

Although it is potentially possible for the target species and habitats to colonise new ground if available, newly created habitats rarely represent all the species or functions of the target community. Every effort should be made to conserve naturally-functioning extant examples of *Mediterranean and thermo-Atlantic halophilous scrubs* and *Spartina maritima swards* in England where possible in addition to efforts to include niches for these species within intertidal creation schemes.

A review of saltmarsh to grassland transition zones

Transitions occur across salinity gradients along estuaries and across elevational gradients from intertidal to terrestrial environments. Transitional zones across both type of gradient are uncommon in England as a result of channel modification and embankment for flood defence. Many species characteristic of the upper saltmarsh transition zone also have annual life histories and occur in a narrow zone between the upper limits of salt marsh and neutral grassland, or in areas of saline seepage behind coastal defences. There is a suite of nationally and locally scarce species which are found on upper saltmarsh transitions to damp grassland and on coastal grazing marsh. However, there are few natural examples remaining of extensive salt marsh-grassland transitions. Many of the sites which retained elements of this transition have since been modified by more intensive agriculture. The overriding attribute for the re-creation of grassland transitional habitats is to have the space to realign the coastline to higher, naturally rising ground that is subject to occasional saltwater flooding, such as from a surge tide or minor overtopping of sea walls. This work was unable to specify whether soil type was critical to the establishment of the transitional grassland species.

Survey of potential locations for freshwater-saltmarsh transition zones in Morecambe Bay

A total of 13 locations were visited around Morecambe Bay, extending from Bolton-Le-Sands in the south to Roudsea Woods in the north. The aim was to carry out a rapid vegetation survey targeting areas at the upper saltmarsh boundary where vegetation assemblages were transitional in character often reflecting brackish conditions where freshwater flow from streams and ditches appeared to interface with salt water. Results from the survey suggest that saline intruson through over-topping or underground seepage of sea water has an important role to play in the development of salt to freshwater transition habitats. Following extensive searches only four species typical of these habitats (*Apium graveolens, Potamogeton pectinatus*, *Ruppia maritima, Ranunculus sceleratus*) were recorded during the survey, emphasising the relative scarceness of the habitat. The recreation of freshwater habitats with the right biogeochemical conditions to host coastal specialist species is likely to be locally dependant on the right physical environment and results are likely to be highly variable. Where the recreation of both grassland and freshwater transitions are likely to be limitied by availablitiy of raising ground and angle of slope, transitions to freshwater are likely to have suitable water chemistry as an added consideration for successful restoration.

An assessment of *Spartina* species in the Solent Maritime SAC

The main objective of this study was to assess the current status of *Spartina alterniflora* in Southampton Water. The Solent Maritime Special Area of Conservation (SAC) is designated for the Annex I features '*Spartina swards'*, hence it is important to understand the status of the component species within the site. *Spartina alterniflora* is one of the species found in this location. This work included an assessment of distribution and status at the one site where it is known to occur (Bury marsh, Marchwood). The population at Bury Marsh, Marchwood was mapped and surveyed with an electronic theodolyte to determine its physical niche in 1999 and this survey repeated that work. This study also repeated a survey of other *Spartina* species at Hythe marsh (*S x townsendii*, *S. anglica* and *S. glabra*).

Bury marsh, Marchwood

S.alterniflora is found throughout the marsh in both low-lying and elevated areas (vertical limits range from 1.3mOD to 1.76mOD). It has only declined slightly in abundance at Marchwood since the stands were last mapped in 1999 (previous to that changes may have been more extensive). Possible reasons which were suggested in the 1999 survey still apply although given that many patches have been maintained only two reasons seem to cover these recent changes. They include:

1. Regular dredging of the deep-water channel and alteration of tidal movement and scour may have caused erosion of the marsh and reduced the amount of material available for deposition.
2. Potentially competition between *S.anglica* and *S.alterniflora*, the vertical limits of distribution are similar and it is noticeable that *S. alterniflora* is absent from areas described as 'mixed' by Marchant (1964), suggesting that *S. anglica* has replaced it.

Other sites in Southampton Water

The loss of *Spartina alterniflora* throughout Southampton Water has been due mainly to the development of many sites. As well as the direct impacts of such developments by loss of saltmarsh habitat there are indirect impacts such as changes in wave action and tidal currents, changes in sediment deposition and pollution which have implications for the whole of the estuary system. We visited marshes which may potentially be good habitat for *S.alterniflora*, but there is currently no *S. alterniflora* at these sites and they have their own problems (e.g. erosion at Bunny Meadows).

Survey of other *Spartina* species at Hythe

A survey was undertaken at Hythe in 2000 which mapped the populations *of S x townsendii, S. anglica* and *S. glabra*. The site was re-visited in 2012 and it was determined that the *S. glabra* patches had reduced in extent.

Recommendations

S. alterniflora has shown a slight decline at Marchwood between 1999 and 2012. *S. glabra* has reduced in extent from three discrete stands to a single patch. Several saltmarsh sites around Southampton Water have either been lost to development, erosion, or are in the process of degrading. Without action, it is expected that over time further losses will take place. There should be continued monitoring of the other *Spartina* species at Hythe.

We consider the best strategy for conservation of *S. alterniflora* to be conservation of its habitat at Marchwood. We recommend periodic monitoring of the site to determine whether erosion at the front of the marsh is continuing and whether *S. alterniflora* populations are being invaded by other species.

If the dieback of *Spartina alterniflora* on the remaining sections of marsh since 1964 is due to the loss of sediment, it may be appropriate to transplant tillers of *S. alterniflora* to areas that have been artificially elevated at selected locations within the site. Since dredging already occurs at the Bury swinging ground which has had an impact on the marsh, deposition of dredging spoil in suitable locations might be one solution.

Re-introduction of *S. alterniflora* is not possible in many of its former sites because the saltmarsh no longer exists. Transplanting *S.alterniflora* into existing sites is unlikely to succeed because of competition from other species. The feasibility of introducing *S. alterniflora* onto any new mudflats that are created in Southampton Water could be investigated. Multiplication of *S. alterniflora* from Marchwood in cultivation would be the logical first step to any introduction programme.

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1. Introduction

On unmodified soft sediment coastlines, of which there are long lengths especially on the English east and south coasts, there would usually be a wide transitional zone between tidal areas and full terrestrial land. The conditions in this zone result in a rich and distinctive range of habitats. However, around much of the English coast past land claims have largely removed this zone. This extensive loss is now being compounded, especially on the south and east coasts, by 'coastal squeeze' where rising sea levels and fixed coastal flood defence banks are leading to further losses of intertidal habitats, including any remaining transitional habitats.

There are two saltmarsh habitats listed in Annex I of the Habitats Directive within this zone (H1420*Mediterranean and thermo-Atlantic halophilous scrubs* and H1320 *Spartina swards, Spartinion maritimae)* reflecting its importance for nature conservation. These Annex 1 habitats, found mainly in England, were assessed in 2007 as in either 'unfavourable, bad and deteriorating' or 'unfavourable, inadequate and deteriorating' conservation status when reported to Europe in 2007. For Article 17 2007 reporting see:

H1320 report 2007: http://jncc.defra.gov.uk/pdf/Article17/FCS2007-H1320-Final.pdf
H1420 report 2007: http://jncc.defra.gov.uk/pdf/Article17/FCS2007-H1420-Final.pdf

This study was established to help provide more detailed information on these scarce habitats for future reporting and to improve confidence in understanding trends in change. In 2013, the conservation status report for both these Annex I habitats concluded for H1320 'unfavourable, bad but stable' and for H1420 'unfavourable, bad but improving', but based on limited data (see JNCC http://jncc.defra.gov.uk/page-6387) and:

UK H1320 report 2013:
http://jncc.defra.gov.uk/pdf/Article17Consult_20131010/H1320_UK.pdf
England H1320 report 2013:
http://jncc.defra.gov.uk/pdf/Article17Consult_20131010/H1320_ENGLAND.pdf

UK H1420 report 2013:
http://jncc.defra.gov.uk/pdf/Article17Consult_20131010/H1420_UK.pdf
England H1420 report 2013:
http://jncc.defra.gov.uk/pdf/Article17Consult_20131010/H1420_ENGLAND.pdf

There have been two key studies that covered the overall saltmarsh resource. The first comprehensive field-based survey was the Saltmarsh Survey of Great Britain (Burd 1989). This described the location of British salt marshes, their extent and described patterns in the distribution of their plant communities. Although the survey included mapping the *Suaeda vera* community (formerly known as *Suaeda fruticosa*) the survey used data from a previous survey for Essex and Suffolk which didn't differentiate this community. While *Spartina maritima* and *Sarcocornia perennis* (formerly *Arthrocnemum perenne*) were recorded they were amalgamated into '*Spartina*' and '*Salicornia*' communities making it difficult to accurately assess their extent.

More recently, the overall extent in England and Wales has been estimated from the use of remotely sensed data. 'The Extent of Saltmarsh in England and Wales: 2006-2009' (Environment Agency 2011) provided an updated baseline of saltmarsh extent using remote sensing and some ground truthing to allow the Environment Agency to fulfil their statutory obligations for reporting under the Water Framework Directive.

Analysis of remotely sensed data, combined with some fieldwork, can be used to derive saltmarsh extent and some elements of quality assessment. However, particularly for the more limited transitional habitats, full field surveys are essential. This project was established to improve understanding of these Annex I habitats in England by:

- Reviewing all existing distributional information for *Spartina maritima* and *Suaeda vera/ Sarcocornia perennis* dominated vegetation;
- Undertaking field surveys of saltmarsh sites with transitional vegetation communities, focusing on those with *Spartina maritima* and *Suaeda vera/Sarcocornia perennis* dominated vegetation.

Intertidal habitat creation is required to compensate for losses from coastal squeeze. Evidence to date suggests that managed realignment has had limited success creating the right conditions for transitional communities to develop. Evidence is limited on optimum topographical and hydrological conditions necessary for the various vegetation communities of the transition zone. In order to fill the evidence gap to enable improved design of future managed realignment projects – that will ensure the saltmarsh transition zone is better catered for – the following key actions also formed part of this project:

- a review to collate the existing sparse information about the vegetation characteristics and habitat requirements;
- A geographically dispersed range of coastal sites with an existing saltmarsh transition zone need to be visited to record details of ground profiles and hydrology across the zone;
- The results of these two pieces of work then need combining to draw up design guidelines to improve future managed realignment projects.

This project builds on an initial review paper presented at an international conference in 2010 jointly by Natural England, CEH and the Sand Dune & Shingle Network - *Transitional habitats & coastal species in England: their conservation value and management* (Rees et al 2010).

2. Review of the distribution and ecology of *Spartina maritima*, *Suaeda vera* and *Sarcocornia perennis*

2.1 Review of distribution and status of *Spartina maritima* (Small cord-grass)

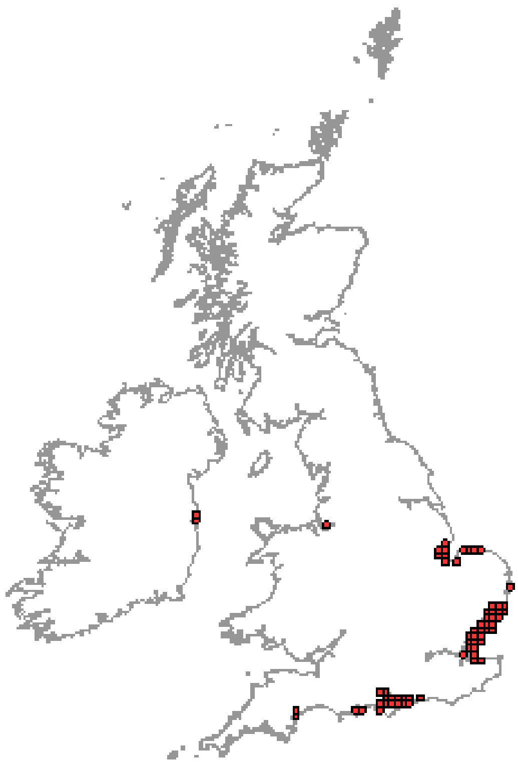
Spartina maritima is the only native UK species of *Spartina*, **(**Marchant & Goodman, 1969). It typically occurs on the higher parts of salt marshes and is commonly associated with *Limonium vulgare*. It is occasionally found in the pioneer zone on bare mud. *S. maritima* is the smallest of the European *Spartina* species. It grows 15-50cm tall forming tufts of very rigid shoots with strong roots and wiry rhizomes. The rhizomes are short (5-20cm) causing secondary clusters to grow close to the parent stock enhancing the tufted appearance. Vegetative spread is usually slow in the UK. Seed production is rare with many spikelets being sterile. As a result reproduction by seed is probably even rarer. Rhizome fragments dispersed by the tide are probably the primary mechanism for colonisation of new tussocks away from the parent stock (Cooper, 1993).

Spartina maritima once extended from the Netherlands to Gibraltar and in to Africa. There were rapid declines in the extent and distribution of *S. maritima* through the first half of the twentieth century coinciding with hybridization with *S. alterniflora* to create *Spartina* x *townsendii. S. townsendii* and subsequently *Spartina anglica* came to occupy a similar ecological niche, outcompeting small cord-grass and restricting it to mid and upper salt marsh where their competitive advantage is weakened. In the UK S. maritima is restricted to the south and east of England, its northern limit roughly corresponding to the mean July isotherm extending from the Wash to the Severn estuary (Fig 2.1).

The earliest recorded *Spartina* species in this country was found at Brigg in South Humberside, where seeds and rhizomes of a plant subsequently identified as a *Spartina* were found under a boat that was being excavated. These were dated at c. 650 BC, and it is assumed that they were remains of *S. maritima* or a close relative (McGrail, 1981; Ranwell, 1981). No other fossil or pollen records have yet been found. The distribution between that record and the next record in 1629 can only be surmised. It is possible that the distribution of the grass changed as the climate altered, slowly moving north as mean temperatures increased, but regressing south rather faster as the climate cooled (Marchant, 1967). *S. maritima* may be killed by extremely cold and frosty weather (Goodman et *al.,* 1969). Stapf (1908) reports the grass as being known since 1629. In 1666 the first samples collected were obtained by Merret from Crixey (now Creeksea) Ferry in Essex and these are definitely the plant we now know as *S. maritima* (Goodman et *al.,* 1969). In 1703 specimens were collected from Frambridge (Fambridge) Ferry in Essex (Hubbard, 1965a). In 1799 specimens were collected near Portsmouth Harbour; the first *S. maritima* was collected from Southampton Water in 1805 (Marchant, 1967). In 1883 Townsend described it as common in South Hampshire and the Isle of Wight in suitable locations (Goodman et *al.,* 1969). The plant was growing below Itchen Ferry in 1836 (Marchant, 1967) and possibly survived until 1910 at Hythe. Some remained in Beaulieu River until 1907. However, Stapf (1908) stated that the distribution was from "Lincolnshire to the Thames in the east, and from Chichester to the Solent in the south". Thereafter decline set in and by 1934 there was only one colony in Hampshire, at Hayling Island (Hall, 1934).

By 1960 Marchant (1967) found that the nearest colony to Southampton Water was at Newtown on the Isle of Wight. There are records of the plant from Dawlish in 1957 (Gillham, 1957) and from Poole Harbour in 1965 and 1966 (Raybould, 1989). Raybould et *al.,* (1991b) surveyed many of the south coast sites from which *S. maritima* had been recorded since 1950 but found the only remaining population was a small one at Hayling Island. On the east coast, the northern limit was formerly Lincolnshire but the last reported population, when the site was resurveyed for *S. maritima* in 1992, no specimens were found. However, in 2007 it was found in a previously unrecorded location on The Wash, Lincolnshire (by Garbutt, author of this report). *S. maritima* is still found on several sites in south Suffolk and north Essex.

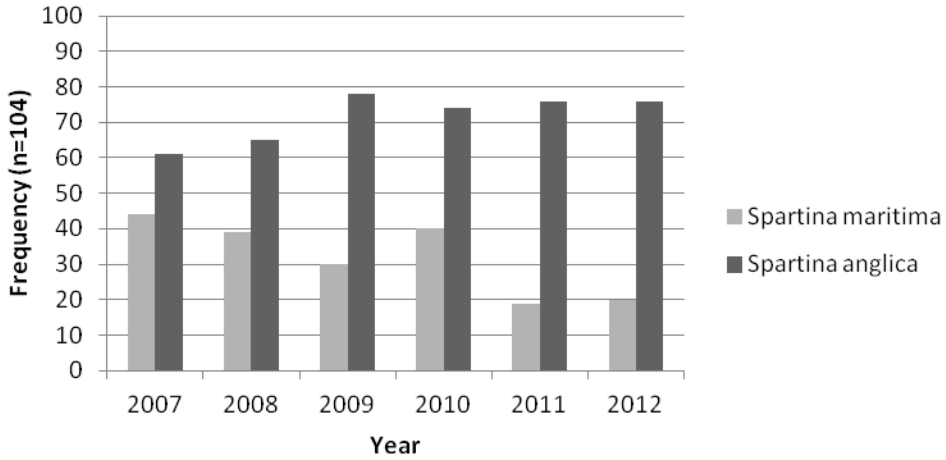
Figure 2.1. UK distribution of *Spartina maritima* (source: NBN gateway)



Whilst the population biology of the related species, *S. anglica* and *S. alterniflora* has been studied extensively in the past (e.g. Hill, 1984, 1987, 1990; Thompson, 1990; Thompson *et al.,* 1991a, 1991b, 1991c for *S. anglica* and Cranford et *al.,* 1989; Hatcher & Mann, 1975; Lana *et al.,* 1991 and Morris & Haskin, 1990 for *S. alterniflora),* little work has been carried out on *S. maritima* except in Spain (Castellanos, 1992). Most research on this plant has been undertaken in the context of establishing its relationship with *S. anglica.* Examples of this are the recent work by Raybould *et al.* (1991a) and earlier work on the origin of *S. anglica* and *S. x townsendii* (Goodman *et al.,* 1959; Hubbard, 1965a; Marchant, 1967).

In 2007, a previously unrecorded population of *Spartina maritima* was discovered on the Lincolnshire side of the Wash near Freiston Shore (by A. Garbutt). The population represents its last known location in Lincolnshire and the northern limit of the species' range in Europe. The *S. maritima* plants are subject to occasional grazing by cattle. On discovery of the plants a recording programme was started to monitor the population and to be able to say something of its viability under livestock grazing. An 8x13m grid was laid over the population and divided into 1x1 m squares; n=104 squares. Presence of both *Spartina maritim*a and *Spartina anglica* were recorded in each 1x1m square (Fig 2.2).

Figure 2.2. Frequency of *Spartina maritima* and *S. anglica* tussocks in 1x1m squares (n=104) at Freiston Shore, Lincolnshire between 2007 and 2012



Frequency of *S. maritima* fluctuated annually as would be expected for an infertile, short lived perennial. The population is located on salt marsh with a low stocking density of cattle introduced for conservation grazing. It is thought that the decline in species frequency in 2011, and similar frequency in 2012, was due to a local increase in grazing intensity where there was considerable poaching and all recorded tussocks were grazed down to 10-15cm. Although some grazing disturbance could benefit the establishment of new *S. maritima* clumps, it is likely that regular overgrazing and poaching would reduce the long term viability of the population.

The PhD thesis by Cooper (1992) presents a comprehensive review of the population ecology of *Spartina maritima* and comparison with *S.anglica* (for the full thesis see: http://ethos.bl.uk/OrderDetails.do?uin=uk.bl.ethos.336180. The project was focussed on the East Anglian populations of both species and described the population status of the species at the time and field sites used for demographic studies on the plants. A 31-month study of the population biology of *S. maritima was undertaken* and compared the results with the behaviour of the plant in Southern Spain. Further work was carried out to describe the population biology of phenotypically distinct clumps *S. anglica,* growing in heterogeneous swards of three marshes. A longer term study described changes in the growth forms of *S. anglica* over time including density, number of tillers and height. A comprehensive description of soil characteristics under swards of *S. maritima* and *S. anglica* was carried out to determine bulk density, soil water content, organic content, soil water retention capacity and particle size distribution. A final component of the thesis was to describe a variety of biological and physical factors influencing the ecology of both *Spartina* species such as dieback, damage by strandline material, responses to erosion and interactions between the two species where they were found growing next to each other. Also included was monitoring of the growth rate of whole clones of *S. maritima* and *S. anglica* over a 30 month period.

The results of the thesis were detailed and wide ranging. Cooper (1992) found that both *Spartina* species will grow between mean high water spring tides (MHWS) and mean high water neap tides (MHWN) although this can be affected by the tidal range. Where both grasses were growing on open mud *S. anglica* tended to grow nearer the MHWS level than *S. maritima*. In mixed high marshes *S. anglica* was often present as small clumps and single tillers whereas when *S. maritima* was found on high level marshes it is nearly always within a pan, or on a lower area of the high marsh where water might be expected to accumulate and remain after flooding by tides or heavy rain. Cooper concluded that the ability of *S. maritima* to grow in pans, low spots or nearer MHWN does not necessarily mean that growth of the grass is better in these conditions, but that it may be a poor competitor in the drier areas of the high marsh. Or alternatively, other salt marsh species growing in these situations may be poor competitors in the waterlogged and often hypersaline conditions of the salt pans.

All sites in the study where *S. maritima was recorded* were loamy sand or sandy loam. The amount of silt in the soil was negatively correlated with the height of *S. maritima,* whilst the amount of sand was positively correlated. In other words, *S. maritima* grew taller in a sandy substrate. Generally the sediments under *S. maritima* were similar in characteristic to the sediments under *S. anglica*.

Cooper (1992) found that *S. anglica* was able to grow earlier in the year than *S. maritima* and it showed great variability of growth, especially in the number of flowering tillers, between and within marshes and between years. *S. maritima* did not show the same degree of variability presumably having some control on its competitive ability. The winter-produced leaves of both species live longer than those produced in the summer. Leaves of *S. anglica* live longer than those of *S. maritima.* Tillers of *S. maritima* produced 13 leaves before flowering, *S. anglica* only 10. Tillers of *S. anglica* that emerge after July, (September for *S. maritima)* do not flower that year. Overwintering tillers are not necessarily the first to flower during the next season.

Dieback (a progressive death of the plant/population) of both species was observed. In *S. maritima* dieback resulted from the non-emergence of tillers during the spring although the reasons for this were not clear. In *S. anglica* dieback effects were exacerbated by physical damage by over-summering Canada geese. Marsh erosion was observed at the study site where the channel edge retreated by over 10 m during the two years of the study. It was also shown that dieback could be caused by deposition of strand-line material.

2.2 Review of distribution and status of *Suaeda vera*

This scrubby vegetation is found at the uppermost levels of saltmarshes, often where there is a transition from saltmarsh to dunes or in some cases where dunes overlie shingle http://jncc.defra.gov.uk/protectedsites/sacselection/habitat.asp?FeatureIntCode=H1420. It is also found in the centre of its range, on and at the foot of flood defences. The form that most closely resembles the scrub vegetation of the Mediterranean is restricted to south and south-east England and is formed predominantly of bushes of shrubby sea-blite *Suaeda vera* and *Atriplex portulacoides*. This most frequently occurs at the upper limit of tidal inundation and is found in association with transitions to sand dunes or shingle structures. In a few localities on the south and east coast of England a similar community develops, but with dense stands of *Sarcocornia perennis* (Fig 2.3).

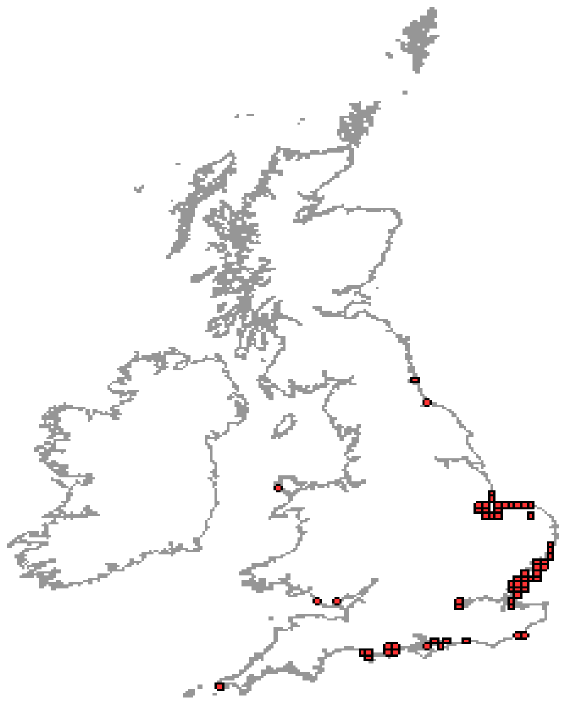
Suaeda vera is a relatively small, deep rooting, evergreen shrub growing up to 1.2m tall (Chapman, 1947). It grows on the drift line of shingle beaches and the upper parts of salt marshes, and is restricted to the south and east of England, with an outlying population in Anglesey, North Wales (Randall, 2004; Rich, T. C.G. & Brown, N. 2000). Large stands are found on the salt marshes of the north Norfolk coast and at the foot of flood embankments in Suffolk and Essex. Individual bushes are also found on the salt marshes of Poole Harbour. *S. vera* flowers from July to September, with fruits appearing from September to November (Leach, 1994).

The Welsh population of *S. vera* was only discovered in 1999 and was thought to have either arisen from long distance dispersal by sea water or wildfowl, or a relic from a previously wider, more continuous distribution (Rich, T. C.G. & Brown, N. 2000). It is a long lived species, with one observation from Poole harbour of a plant at least 40 years old. It probably does not start flowering until several years old but then sets seed every year. The seeds are not able to float in water for long so presumably, unless aided by animals, dispersal is limited. Seeds germinate in spring although viability appears to be low with maximum germination occurring under freshwater conditions (Chapman, 1947). For its successful germination on the drift line some degree of protection from wave action is necessary.

Gardiner (2011) reports that *S. vera* is tolerant of one-off cutting events. As part of a flood defence maintenance scheme, *S.vera* was flailed to a height of 30cm along a 2.8km length of sea wall in Essex to ease inspection. 94% of shrubs showed signs of regrowth after cutting and after eight months mean shrub height was similar to that of plants in control areas. Mean shrub width remained less than that of uncut plants over the same period however; Gardiner (2011) observed the density of bushes growing on the sea defences along the study area was related to the type of construction method used in the embankment design. Smaller sized 'Essex blocks' (0.3 x 0.3m) arranged in grid formation on the seaward side of the sea wall were colonised by high densities of *S. vera* as a result of there being many gaps between the blocks. Larger 'Canewdon blocks' (1.14 x 1.9m) had a lower density of bushes (and gaps between blocks) and Open Stone Asphalt which forms a continuous surface cover on the front of coastal embankments had almost no bushes. Open Stone Asphalt offers the most effective coastal protection of the three methods and is increasingly being used to replace Essex Blocks on sea walls in the county, the implications of which could be detrimental to *S. vera* populations.

The *Suaeda vera* saltmarsh community has been shown to be strongly associated with coastal wintering passerine (song) birds on the North Norfolk coast (Brown & Atkinson, 1996). Across several sites, individuals and flocks of wren, dunnock, blackbird and reed bunting combined, over 90% were from *Suaeda vera* saltmarsh. This habitat accounted for only 5.5% of the study area. Presumably the birds use the *Suaeda* bushes to perch/roost and feed on any available seed. In the same study coastal specialists Twite, shore lark and snow bunting weren't directly associated with *Suaeda vera* saltmarsh, although snow bunting were shown to feed close by on the strand line.

Figure 2.3. UK distribution of *Suaeda vera* (source: NBN gateway)



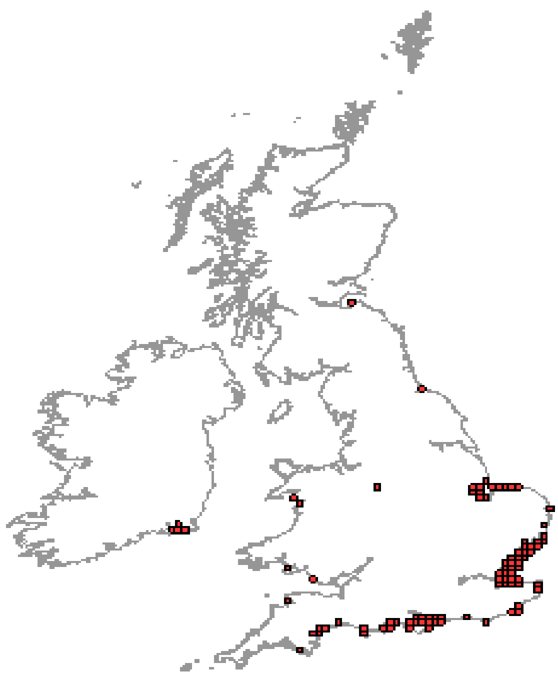
2.3 Review of distribution and status of *Sarcocornia perennis* (perennial glasswort)

Sarcocornia perennis (perennial glasswort) is a small perennial salt tolerant, low growing plant with succulent stems. The stems are often rooted at the nodes to form clumps or mats up to 1m or more in diameter (Davy et al 2006). The perennial habit distinguishes it from all species of *Salicornia*, which are annuals. *S. perennis* has a restricted distribution in Britain. It occurs from the Wash to Poole Harbour, with isolated records from Wales, Teesmouth and the Firth of Forth (Fig 2.4). The species is encountered in a variety of saltmarsh communities and only very locally is an important constituent of the vegetation (Rodwell, 2000). It is associated with *Atriplex portulacoides*, *Puccinellia maritima* and *Suaeda maritima*, and in more diverse marsh with *Limonium vulgare* and *Spergularia media*.

The distribution of *S. perennis* is limited by low temperatures where it reaches its northerly limit in Britain. As with *Suaeda vera* and *Spartina maritima*, its distributional limit correlates closely with the average July temperature isotherm. S*. perennis* is typically found on low to intermediate levels on relatively well drained sediments of salt marshes where local topography or silt overlaying gravels increase drainage. This appears to reflect intolerance for waterlogged saltmarsh sediments. In a survey of 76 English salt marshes *S. perennis* was recorded between +1.8 and +3.2ODN (Ordnance Datum, Newlyn), (Davy et al. 2006). At Scolt Head Island, Norfolk, *S. perennis* had an elevation range equivalent to between 570 and 375 tidal submergences a year (Chapman 1960). *S. perennis* flowers in Britain between August and September with most seeds shed from the succulent segments by November Plants do retain some green segments in winter, with predominantly brown woody stems.

There has been little work done on *S. perennis* in the UK other than the work described above. This is in contrast to in Europe where *S. perennis* has been used to test ecological theory and practise (e.g. Redondo et al. 2004; Palomo and Xavier Niell 2009).

Figure 2.4. UK distribution of *Sarcocornia perennis* (source: NBN gateway)



2.4 Assessing the extent of Spartina maritima, Sarcocornia perennis and Suaeda vera in England

2.4.1 Site selection

In order to assess the current status of salt marsh with *Spartina maritima* and *Suaeda vera/Sarcocornia perennis* dominated vegetation and plan the field survey, a review of existing data was undertaken to inform on sampling strategy. The Botanical Society of Britain and Ireland (BSBI) provided databases with all current and past location records of *Spartina maritima*, *Sarcocornia perennis* and *Suaeda vera*. The databases included in some cases historical records going back more than a century. Species location details varied in accuracy from 1km square level to an eight figure grid reference. In order to refine the survey to make it more time/cost effective, species records were filtered to only include data from 1990 onwards and with a six/eight figure grid reference. Records for *Suaeda vera/Sarcocornia perennis* on shingle were also excluded from the survey. Records were then assigned to a 1km square. Where there were multiple records for any 1km square a single record was selected at random to relocate and survey. Each 1km square with a six/eight figure grid reference was assigned to a Watson Vice Country (see BSBI website http://www.bsbi.org.uk/) with the expectation that 50% of 1km squares were sampled in each VC so sample effort was proportional to population density across each species/vegetation type's range.

There were 124 1km squares in the BSBI data base with records for *Spartina maritima* from 1990 onwards. Records were given from the Wash to Poole Harbour. In the time available it was estimated that 62 1km squares (50%) could be visited. Where *Suaeda vera*/*Sarcocornia perennis* was present within the same 1km square as *S. maritima*, that vegetation was recorded at the same time to increase efficiencies. An additional 12 1km squares were also surveyed for *Suaeda vera*/*Sarcocornia perennis* in North Norfolk and around Poole Harbour.

2.4.2 Plant survey

Grid references in the BSBI database were used to relocate plant populations using a handheld Garmin GPS. Each population was recorded using the BSBI Threatened Plant Project method and associated recording form, including 'null' records (http://www.bsbi.org.uk/tpp.html). Three 1x1m quadrats were used to record the presence and abundance of the target species and associated vegetation community at each location. The presence of all species within the quadrat and abundance using the Domin scale (Kent and Coker 1993) were recorded. At each location, site details, population size and extent, habitat details, any management, sward height and obvious threats to extant populations were also recorded.

2.4.3 Soil sampling

In order to help explain the relative differences in distribution of the target species and associated vegetation community at each location a soil sample was taken from the first of the three quadrats used to record the presence and abundance. A 'control' soil sample was also taken at each location, at random at the same elevation (as estimated by eye) as the target plant population. A single soil core was taken from the centre of the sample and control quadrat. Soil cores were 15cm deep and 4cm in diameter. Each soil sample was stored individually in a sealed tin and stored at 5˚C until processed.

In the laboratory all major roots and stones were removed from the soil samples which were then homogenised by hand for 2 minutes and prepared for analysis. Soil samples were measured for pH, electrical conductivity, moisture, organic matter content (LOI) and bulk density.

Methods used to measure pH and Electrical Conductivity (EC)
A sub sample of 10g of field-moist soil was taken from each sample and mixed with 25 ml of deionised water (1:2.5 dilution factor). After 30 minutes equilibration time a Hanna pH209 pH meter was used to measure pH and a Jenway 4520 Conductivity meter to measure electrical conductivity (mS cm_1) as a proxy for salinity. This method is based upon that employed by the Soil Survey of England and Wales (Avery and Bascomb, 1974).

Methods used to measure moisture, organic matter content (LOI) and bulk density
Soil moisture was determined as the difference between the weight of fresh, field-moist soil at ambient temperature and after 48 hours drying at 105°C. Organic matter content was then determined as the "loss-on-ignition" from the soil after placing in a furnace for 16 hours 375°C. Moisture and organic matter content are expressed as a percentage of dry-weight. This method is based upon that of Ball, 1964. The total dry mass (calculated from percent moisture) was divided by the volume of the core to calculate dry bulk density (g cm^3)

2.5 An assessment of the condition of *Spartina maritima* swards in England

Spartina maritima populations within 48 of the planned 62 1km squares were resurveyed during July 2012 (Table 2.1). An exceptionally wet month slowed progress through the survey. Of the 48 previously recorded populations 37 were refound including outlying populations in the Wash, Lincolnshire and Newtown estuary on the Isle of Wight (Fig 2.5). We can be confident that the survey included an assessment of all habitats within the species range. For logistical reasons the well known stand at Foulness Point was not visited. The extant populations of *S. maritima* were found to be associated with one of three types of plant community. *Puccinellia maritima* salt marsh (SM13) and *Atriplex* (*Atriplex*) *portulacoides* salt marsh (SM14) as described in Rodwell (2000) are both typical of mid-elevation salt marsh in the south east of England and are found as discrete stands adjacent to each other, or as complex mosaics (Tables 2.2; Fig 2.6). One general observation from the field was that where *S. maritima* was associated with SM13 and SM14 it was invariably found within the same plant assemblage or close to *Limonium vulgare* plants. *S. maritima* was also recorded growing on the foreshore of the Orwell estuary, East Suffolk in a monospecific stand (SM4, *Spartina maritima* saltmarsh community; Fig 2.6c). The saltmarsh habitats immediately around extant populations of *S. maritima* were considered to be good examples of their type and no immediate or short term threats were identified.

Table 2.1 Number of location records and 1km squares with six/eight figure grid references visited during the 2012 survey

	Spartina maritima	***Sarcocornia perennis***	***Suaeda vera***
Total number of individual records provided by the BSBI	941	1851	2287
Total number of individual records provided by the BSBI since 1990	501	983	1661
Number of 1km squares visited in 2012	48	38	31
Number of 1km squares visited where species was found	37	38	31
Number of 1km squares visited where species was not found	11	0	0

The primary threat to the mid to long term viability of the species is the loss of extent (i.e. through 'coastal squeeze') and subsequent erosion of the adjacent saltmarsh (see Doody, 2004 for discussion on coastal squeeze). This was especially obvious around the Essex coast and the mainland coast of the Solent where the majority of salt marshes were observed to be cliffed on their seaward edge and suffering from internal erosion through creek expansion. *S. maritima* was not refound at any of the Solent mainland sites where the marshes appear severely eroded. The remaining Solent populations were all recorded on the Isle of Wight growing in the floristically diverse marshes of the Newtown estuary. Even here though, one previously known population was not refound most probably as a result of erosion (see table 2.3).

Figure 2.5. Sample locations with *Spartina maritima* present in 2012 survey

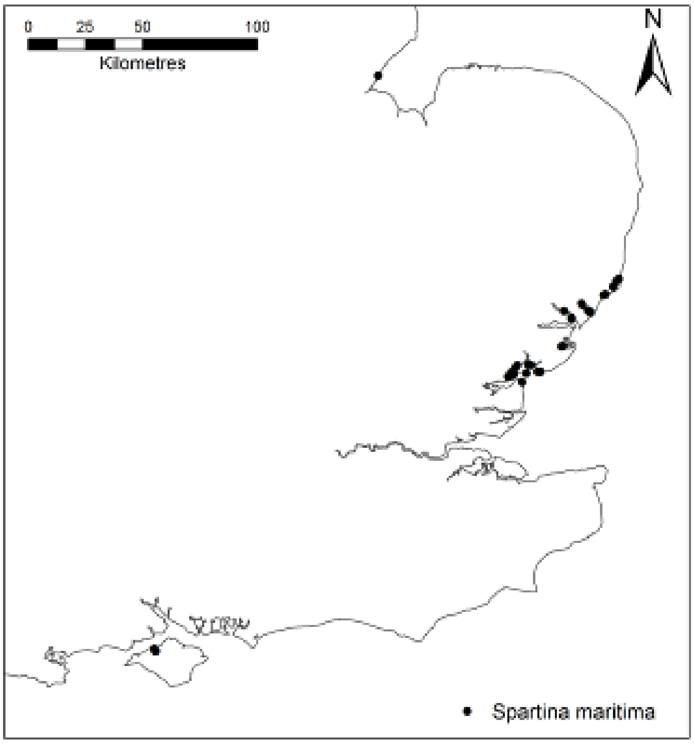


Table 2.2 *Spartina maritima*; location, Vice County, NVC fit, community description and density for samples recorded in 2012.

Sample number	Location	Vice county name	VC code	'Best fit' to NVC code	Community description	Sub community description	Density
1	Bradwell Cockle spit	South Essex	18	SM13	*Puccinellia* saltmarsh		Small clump of around 30 culms
2	Old Hall Point	North Essex	19	SM14a	*Atriplex portulacoides* saltmarsh	*Atriplex portulacoides*	One patch of ~50 culms and scattered plants surroundin g
3	Old Hall/Salcott channel 1	North Essex	19	SM13	*Puccinellia* saltmarsh		Separate clumps
4	Old Hall/Salcott channel 2	North Essex	19	SM13a	*Puccinellia maritima* saltmarsh	*Puccinellia* maritima	Two clumps next to each other
5	Fingringhoe nature reserve	North Essex	19	SM13f	*Puccinellia maritima* saltmarsh	*Spartina* maritima	Several clumps
6	Mersea Stone	North Essex	19	SM14c	*Atriplex portulacoides* saltmarsh	*Puccinellia* maritima	small scattered clumps
7	Mersea North Barn	North Essex	19	SM13a	*Puccinellia maritima* saltmarsh	*Puccinellia maritima*	A few scattered plants
8	Mersea Pyefleet	North Essex	19	SM13a	*Puccinellia maritima* saltmarsh	*Puccinellia maritima*	Dense patch with numerous clumps
9	Bonners saltmarsh	North Essex	19	SM13	*Puccinellia* saltmarsh		A few clumps
10	Ray Island	North Essex	19	SM13	*Puccinellia* saltmarsh		Small scattered clumps
11	Tollesbury Wick 1	North Essex	19	SM13	*Puccinellia* saltmarsh		Several small clumps in close proximity
12	Tollesbury Wick 2	North Essex	19	SM13	*Puccinellia* saltmarsh		~8 plants quite close together
13	Tollesbury Wick 2	North Essex	19	SM14c	*Atriplex portulacoides* saltmarsh	*Puccinellia* maritima	A few plants per clump
14	Lee-over-sands 1	North Essex	19	SM13	*Puccinellia* saltmarsh		Small clumps widely scattered
15	Lee-over-sands 2	North Essex	19	SM13c	*Puccinellia maritima* saltmarsh	*Limonium vulgare - Armeria maritima*	Lots of small clumps widely scattered
16	Colne Point	North Essex	19	SM13c	*Puccinellia maritima* saltmarsh	*Limonium vulgare - Armeria maritima*	Small patches widely spaced

Sample number	Location	Vice county name	VC code	'Best fit' to NVC code	Community description	Sub community description	Density
17	Hamford Water 1	North Essex	19	SM13	*Puccinellia* saltmarsh		Small patch of scattered clumps
18	Hamford Water 2	North Essex	19	SM13	*Puccinellia* saltmarsh		A few scattered clumps
19	Nacton Shore, R. Orwell	East Suffolk	25	SM4	*Spartina maritima* saltmarsh		1 clump
20	Church End, Cranes Hill 1	East Suffolk	25	SM13	*Puccinellia* saltmarsh		A few clumps over a small area
21	Church End, Cranes Hill 2	East Suffolk	25	SM14c	*Atriplex portulacoides* saltmarsh	*Puccinellia* maritima	A few plants
22	Hemly 1	East Suffolk	25	SM13	*Puccinellia* saltmarsh		A few scattered plants
23	Hemly 2	East Suffolk	25	SM13a	*Puccinellia maritima* saltmarsh	*Puccinellia* maritima	Scattered clumps throughout marsh
24	Ramsholt	East Suffolk	25	SM13c	*Puccinellia maritima* saltmarsh	*Limonium vulgare - Armeria maritima*	Common across marsh
25	Felexstow Ferry	East Suffolk	25	SM14c	*Atriplex portulacoides* saltmarsh	*Puccinellia maritima*	3 clumps
26	Bawdsey	East Suffolk	25	SM13	*Puccinellia* saltmarsh		1 clump
27	Falkenham	East Suffolk	25	SM14a	*Atriplex portulacoides* saltmarsh	*Atriplex portulacoides*	A few localised clumps
28	Boyton marshes 1	East Suffolk	25	SM13a	*Puccinellia maritima* saltmarsh	*Puccinellia maritima*	Small clumps scattered throughout area
29	Boyton marshes 2	East Suffolk	25	SM14a	*Atriplex portulacoides* saltmarsh	*Atriplex portulacoides*	Scattered throughout *Atriplex*
30	Sudbourne marshes 1	East Suffolk	25	SM13c	*Puccinellia maritima* saltmarsh	*Limonium vulgare - Armeria maritima*	Scattered clumps throughout marsh
31	Sudbourne marshes 2	East Suffolk	25	SM14c	*Atriplex portulacoides* saltmarsh	*Puccinellia maritima*	Scattered locally
32	Sudbourne marshes 3	East Suffolk	25	SM13a	*Puccinellia maritima* saltmarsh	*Puccinellia maritima*	Scattered throughout area
33	Orford Quay	East Suffolk	25	SM13a	*Puccinellia maritima* saltmarsh	*Puccinellia maritima*	1 dense clump and 2 smaller clumps
34	Newtown estuary 1	Isle of Wight	10	SM14c	*Atriplex portulacoides* saltmarsh	*Puccinellia maritima*	A few scattered plants

Sample number	Location	Vice county name	VC code	'Best fit' to NVC code	Community description	Sub community description	Density
35	Newtown estuary 2	Isle of Wight	10	SM13	*Puccinellia* saltmarsh		A few scattered plants
36	Newtown estuary MoD	Isle of Wight	10	SM13	*Puccinellia* saltmarsh		A few scattered plants
37	Freiston Shore	North Lincs	54	SM13a	*Puccinellia maritima* saltmarsh	*Puccinellia maritima*	A few scattered plants

There was a high degree of certainty that the 11 populations not relocated during the survey were extinct, rather than the survey team just not being able to find the plants (Table 2.3). In most of the 11 sites the marshes appeared to be either in the early phases of erosion (e.g. Maldon, South Essex), or severely eroded (e.g. Great Salterns Lake, South Hampshire). There were several populations of *S. maritima* previously recorded around Trimley docks, South Suffolk last recorded in 1992 which were lost to the expansion of Felixstowe docks. The marshes are now under concrete.

Table 2.3 *Spartina maritima* sites visited 2012 but not re-found

1.	Maldon, South Essex (VC 18). NGR: TL 865 060 The marsh appears to be eroding, with numerous mud mounds with *Salicornia* surrounding on the lower areas. The higher areas of the mounds were dominated by *Puccinellia maritima, Aster tripolium* and *Triglochin maritima*.
2.	Tollesbury Wick, North Essex (VC 19). NGR: TL 980 098 The marsh was dominated by a tall (~25cm tall) sward of *Puccinellia maritima* and *Atriplex portulacoides* with numerous tussocks of *Spartina anglica* and patches of wet ground.
3.	Trimely marshes, South Suffolk (VC 25). NGR: TM 2550 3530 The marsh was dominated by *Atriplex portulacoides* with scattered tussocks of *Spartina anglica*.
4.	Trimely docks, South Suffolk (VC 25). NGR: TM 264 348, TM 258 348, TM 257 349, TM 262 349, TM 259 349. The site has been lost to the expansion of Felixstowe port development. The marshes are now under concrete.
5.	Wherstead, R. Orwell, South Suffolk (VC 25). NGR: TM 1720 4060 The marshes are dominated by *Atriplex portulacoides* with occasional patches of *Limonium humile, Puccinellia maritima* and *Plantago maritima*. The marshes appear to be eroding at the seaward edge and are confined by a road on the landward edge.
6.	Newtown estuary, Isle of Wight (VC10). NGR: SZ 4140 9180 The marshes are dominated by tall *Puccinellia* and abundant *Spartina anglica*. The marshes appear to be eroding.
7.	Great Salterns Lake, South Hampshire (VC11). NGR: SU 676 017 There is now no saltmarsh present at the site, just bare mud fronting a concrete embankment
8.	Hayling Island, South Hampshire (VC11). NGR: SU 7320 0420 There were only occasional patches of *Spartina anglica* and *Salicornia europaea* growing in bare mud at the foot of a concrete embankment in poor condition.
9.	Cobnor Point, South Hampshire (VC11). NGR: SU 792 023 The grid reference is inaccurate and gives a point on land. The nearest marshes look like they are eroding *Puccinellia/Limonium* saltmarsh with abundant *Spartina anglica* and large patches of *Sarcocornia perennis*.
10.	Greenlands Farm, Dorset (VC 9). NGR: SZ 017 847 The marshes were dominated by tall (~35cm) *Atriplex portulacoides* saltmarsh with *Spartina anglica* abundant and occasional *Limonium vulgare, Puccinellia maritima* and *Plantago maritima*.
11.	Brownsea Island, Dorset (VC 9). NGR: SZ 0312 8818 Last recorded in 2006, there was no evidence of *Spartina maritima* present.

Figure 2.6 Photographs showing variation in *Spartina maritima* habitat

a) *Spartina maritima*, in the foreground, is typically found associated with or close to *Limonium vulgare*

b) *Spartina maritima*, in the foreground, in association with *Atriplex portulacoides*

c) A rare example of *Spartina maritima* growing on the foreshore on the Orwell estuary, East Suffolk

d) An eroding saltmarsh cliff near Felixtowe docks, East Suffolk, typical of many of the marshes throughout *Spartina maritima*'s range

2.6 An assessment of *Suaeda vera* swards in England

Suaeda vera populations were recorded within all of the planned 31 1km squares resurveyed during July 2012 (Fig 2.7). Outlying saltmarsh populations from North Norfolk to Poole Harbour were covered, in addition to the populations in the centre of the species range in Essex. As expected, the majority of plants were associated with the *Suaeda vera* driftline plant community (SM25; Table 2.4). There are two subcommunities of SM25; SM25a with *Elytrigia atherica*, and SM25b with *Atriplex portulacoides* both of which were recorded across the range surveyed. Where samples contained only small or scattered bushes of *Suaeda vera*, the samples were associated with *Inula crithmoides* (SM26) or *Puccinellia* saltmarsh (SM13).

The extent of the *Suaeda vera* bushes and habitat type varies across its range. In North Norfolk there were extensive stands across large expanses of saltmarsh (Fig 2.8). In Essex the bushes were mainly confined to the foot of flood defences, with occasional bushes on the better drained edges of saltmarsh creeks. One feature noted on occasion was that older *Suaeda* bushes supported extensive communities of lichens. The lichen *Caloplaca suaedae*, classified as 'near threatened' (Woods, 2012), is restricted to old stems of *Suaeda vera* or rarely *Atriplex portulacoides*.

The populations of *Suaeda vera* growing on salt marsh appeared to be good examples of the vegetation type with no immediate threats recorded. The most likely short to medium term potential threat is probably flood defence maintenance, especially in Essex where the majority of the population is situated on the strand line on, or at the foot of the of the sea wall. Coastal squeeze and rising sea levels are longer term threats.

Figure 2.7 Sample locations for *Suaeda vera* growing on salt marsh visited in 2012 survey

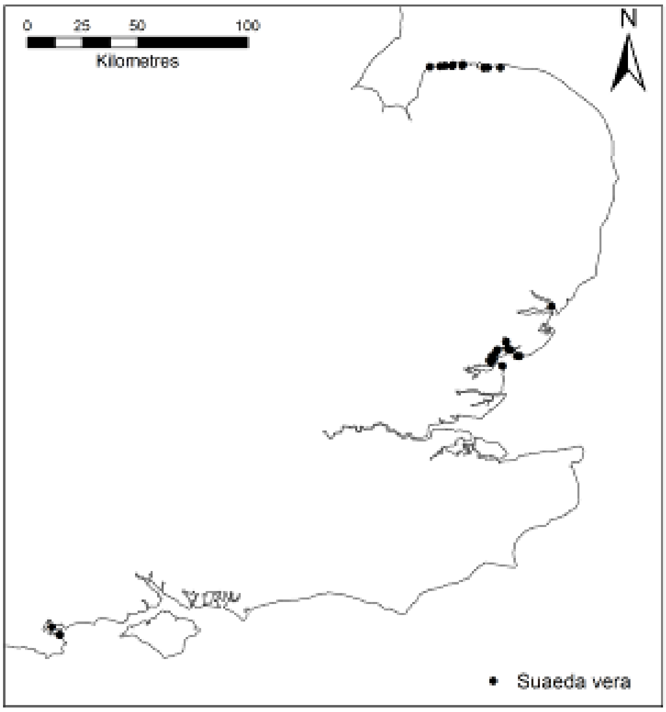


Table 2.4 *Suaeda vera;* location, Vice County, NVC fit, community description and density for samples recorded in 2012.

Sample number	Location	Vice county name	VC code	'Best fit' to NVC code	Community description	Subcommunity description	Density
1	Bradwell Cockle spit 1	South Essex	18	SM13a	*Puccinellia maritima* saltmarsh	*Puccinellia maritima*	1 plant on creek edge
2	Bradwell Cockle spit 2	South Essex	18	SM26/ SM25b	*Inula crithmoides/ Suaeda vera* driftline	*Atriplex portulacoides*	A single large bush
3	Old Hall Point	North Essex	19	SM25a	*Suaeda vera* driftline	*Elytrigia atherica*	Approx. 50 bushes along sea wall
4	Old Hall/Salcott channel 1	North Essex	19	SM25a	*Suaeda vera* driftline	*Elytrigia atherica*	20 - 30 plants along foot of sea wall
5	Old Hall/Salcott channel 2	North Essex	19	SM25a	*Suaeda vera* driftline	*Elytrigia atherica*	A few plants scattered
6	Fingringho e nature reserve	North Essex	19	SM25	*Suaeda vera* driftline		Bushes scattered along edge of lake
7	Mersea Stone	North Essex	19	SM25	*Suaeda vera* driftline		Many plants over a wide area of raised banks
8	Mersea North barn	North Essex	19	SM25	*Suaeda vera* driftline		3 bushes
9	Mersea Pyefleet	North Essex	19	SM25	*Suaeda vera* driftline		A few bushes scattered along seawall
10	Bonners saltmarsh	North Essex	19	SM25a	*Suaeda vera* driftline	*Elytrigia atherica*	A few bushes widely scattered
11	The Strood	North Essex	19	SM25a	*Suaeda vera* driftline	*Elytrigia atherica*	2 bushes
12	Ray Island	North Essex	19	SM25a	*Suaeda vera* driftline	*Elytrigia atherica*	A few scattered bushes
13	Tollesbury Wick 1	North Essex	19	SM24/S M25	*Elytrigia atherica/ Suaeda vera* driftline		1 bush
14	Tollesbury Wick 2	North Essex	19	SM25b	*Suaeda vera* driftline	*Atriplex portulacoides*	1 bush at foot of sea wall
15	Tollesbury Wick 3	North Essex	19	SM25	*Suaeda vera* driftline		A few plants scattered alond sea wall

Sample number	Location	Vice county name	VC code	'Best fit' to NVC code	Community description	Sub-community description	Density
16	Lee-over Sands 1	North Essex	19	SM13	*Puccinellia* saltmarsh		Approx 8 bushes spread along edge of creek
17	Lee-over Sands 2	North Essex	19	SM25a	*Suaeda vera* driftline	*Elytrigia atherica*	Spaced along foot of sea wall
18	Colne Point	North Essex	19	SM25	*Suaeda vera* driftline		Plants spaced along sea wall edge
19	Trimley	East Suffolk	25	SM25	*Suaeda vera* driftline		2 plants 20m apart
20	Arne; Patchings Point	Dorset	9	SM25	*Suaeda vera* driftline		In patches along wall
21	Brands Bay	Dorset	9	SM24/SM25	*Elytrigia atherica* saltmarsh		A single bush
22	Burnham 1	West Norfolk	28	SM25	*Suaeda vera* driftline		Dense sward
23	Burnham 2	West Norfolk	28	SM25b	*Suaeda vera* driftline	*Atriplex portulacoides*	Scattered line along training wall and foot of sea wall
24	Burnham Deepdale 1	West Norfolk	28	SM13a	*Puccinellia* saltmarsh/ *Suaeda vera* driftline		Scattered bushes over high points and creek edges
25	Burnham Deepdale 2	West Norfolk	28	SM25	*Suaeda vera* driftline		Scattered over marsh
26	Brancaster	West Norfolk	28	SM25	*Suaeda vera* driftline		Bushes scattered throughout marsh
27	Titchwell	West Norfolk	28	SM25	*Suaeda vera* driftline		Scattered along creek banks throughout marsh
28	Blackney	East Norfolk	27	SM25a	*Suaeda vera* driftline		Dense and continuous patches next to sea wall/ scattered across marsh
29	Stiffkey	West Norfolk	28	SM25a	*Suaeda vera* driftline	*Elytrigia atherica*	Scattered throughout marsh
30	Wareham	West Norfolk	28	SM25	*Suaeda vera* driftline	*Elytrigia atherica*	A dense line of bushes along coastline
31	Holme	West Norfolk	28	SM25	*Suaeda vera* driftline		Continuous bushes along sea wall

Figure 2.8 Photographes showing variation in *Suaeda vera* habitat

a) Extensive stands of *Suaeda vera* bushes across the salt marsh in North Norfolk

b) *Suaeda vera* bushes growing along the strand line and on the sea defence

c) *Suaeda vera* bushes growing on well drained creek levees

d) An old *Suaeda vera* bush encrusted with lichens

2.7 An assessment of *Sarcocornia perennis* swards in England

Sarcocornia perennis populations were recorded within all of the planned 38 1km squares resurveyed during July 2012 (Fig 2.9). Saltmarsh populations from North Norfolk to Poole Harbour in Dorset were sampled, in addition to the populations in the centre of the species range in Essex. *Sarcocornia perennis* was found to form a distinct and separate community from *Suaeda vera* swards, occurring lower in the shore profile and most commonly associated with species rich SM13 *Puccinellia maritima* and *Atriplex portulacoides* saltmarsh (Table 2.5). Where *S. perennis* was recorded lower in the shore it formed a mosaic with *Spartina anglica* salt marsh (SM6). Occasionally it was recorded in mono specific stands forming SM7 *S. perennis* salt marsh.

There was little variation in the habitat across the range of sites surveyed. *S. perennis* was, in most samples a composite of an associated vegetation type rather than the dominant plant species. Where *S. perennis* did dominate it appeared to be growing in an area of previously bare ground (Fig 2.10).

As with the species above, where *S.perennis* was recorded the salt marshes appeared to be intact and under no short term threat. The primary threat to their mid to long term viability is the loss of extent (i.e. through 'coastal squeeze') and subsequent erosion of the adjacent salt marsh.

Figure 2.9 Sample locations for *Sarcocornia perennis* recorded in 2012 survey

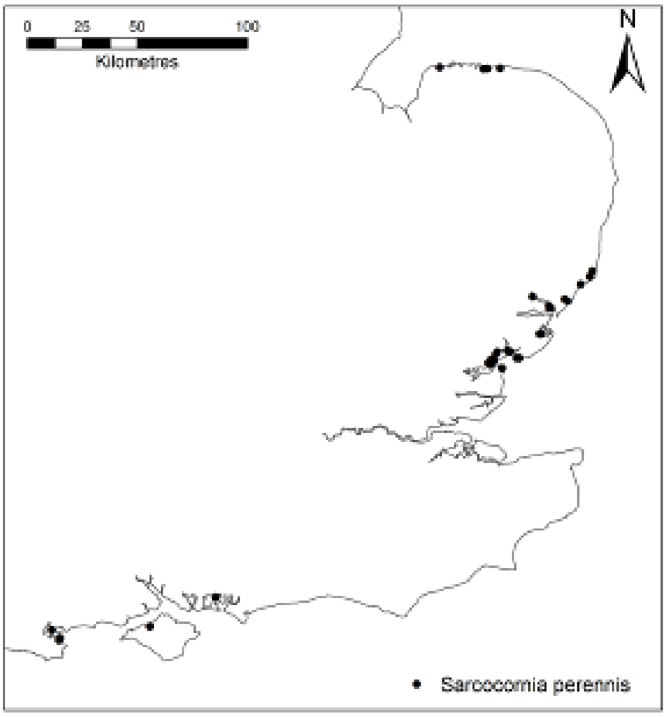


Table 2.5 *Sarcocornia perennis*; location, Vice County, NVC fit, community description and density for samples recorded in 2012.

Sample number	Location	Vice county name	VC code	'Best fit' to NVC code	Community description	Sub-community description	Density
1	Bradwell Cockle Spit 1	South Essex	18	SM14c	*Atriplex portulacoides* saltmarsh	*Puccinellia maritima*	One individual
2	Bradwell Cockle Spit 1	South Essex	18	SM13c	*Puccinellia maritima* saltmarsh	*Limonium vulgare - Armeria maritima*	Single plant
3	Old Hall Point	North Essex	19	SM13a	*Puccinellia maritima* saltmarsh	*Puccinellia maritima*	Plants frequent across marsh
4	Old Hall/Salcot channel 1	North Essex	19	SM13c	*Puccinellia maritima* saltmarsh	*Limonium vulgare - Armeria maritima*	Frequent across marsh
5	Old Hall/Salcot channel 2	North Essex	19	SM13c	*Puccinellia maritima* saltmarsh	*Limonium vulgare - Armeria maritima*	A few plants widely scattered
6	Mersea stone	North Essex	19	SM14c	*Atriplex portulacoides* saltmarsh	*Puccinellia maritima*	Plant sparesely scattered over wide area
7	Mersea North Barn	North Essex	19	SM14c	*Atriplex portulacoides* saltmarsh	*Puccinellia maritima*	Few plants widely scaterred
8	Mersea Pyefleet	North Essex	19	SM13a	*Puccinellia maritima* saltmarsh	*Puccinellia maritima*	Few scattered plants
9	Bonners saltmarsh	North Essex	19	SM13a	Puccinellia maritima saltmarsh	*Puccinellia maritima*	Plants scattered throughout marsh
10	The Strood	North Essex	19	SM13a	*Puccinellia maritima* saltmarsh	*Puccinellia maritima*	A few plants widely scattered
11	Ray Island	North Essex	19	SM13	Puccinellia maritima saltmarsh		Widely scattered all over marsh
12	Tollesbury saltings	North Essex	19	SM13c	*Puccinellia maritima* saltmarsh	*Limonium vulgare - Armeria maritima*	1 clump
13	Tollesbury Wick 1	North Essex	19	SM14c	*Atriplex portulacoides* saltmarsh	*Puccinellia maritima*	A few plants scattered over marsh
14	Tollesbury Wick 2	North Essex	19	SM6	*Spartina anglica* saltmarsh		Scattered plants through whole marsh
15	Tollesbury Wick 3	North Essex	19	SM13	*Puccinellia maritima* saltmarsh		Clumps scattered throughout marsh
16	Lee-over Sands 1	North Essex	19	SM13c	*Puccinellia maritima* saltmarsh	*Limonium vulgare - Armeria maritima*	A couple of very small clumps

Sample number	Location	Vice county name	VC code	'Best fit' to NVC code	Community description	Sub-community description	Density
17	Lee-over Sands 2	North Essex	19	SM13c	*Puccinellia maritima* saltmarsh	*Limonium vulgare - Armeria maritima*	Only 4 patches found
18	Colne Point	North Essex	19	SM13c	*Puccinellia maritima* saltmarsh	*Limonium vulgare - Armeria maritima*	Small patches widely scattered
19	Hamford Water	North Essex	19	SM14c	*Atriplex portulacoides* saltmarsh	*Puccinellia maritima*	1 patch found
20	Hamford Water	North Essex	19	SM13	*Puccinellia maritima* saltmarsh		2 small clumps found within 20cm of each other
21	Whestead, R. Orwell	East Suffolk	25	SM14c	*Atriplex portulacoides* saltmarsh	*Puccinellia maritima*	Aa few large patches
22	Trimley marshes	East Suffolk	25	SM7	*Arthrocnemum perenne*		A few large plants scattered over marsh
23	Church End, Granes Hill 1	East Suffolk	25	SM14c	*Atriplex portulacoides* saltmarsh	*Puccinellia maritima*	A few plants scattered over marsh
24	Church End, Granes Hill 2	East Suffolk	25	SM7	*Arthrocnemum perenne*		Scattered all over marsh
25	Ramsholt	East Suffolk	25	SM13a	*Puccinellia maritima* saltmarsh	*Puccinellia maritima*	Scattered over marsh
26	Falkenham	East Suffolk	25	SM14c	*Atriplex portulacoides* saltmarsh	*Puccinellia maritima*	Distributed in small patches throughout
27	Boyton marshes	East Suffolk	25	SM13c	*Puccinellia maritima* saltmarsh	*Limonium vulgare - Armeria maritima*	Scattered throughout marsh
28	Sudbourne marshes	East Suffolk	25	SM7	*Arthrocnemum perenne*		Clumps, some large (1x1m)
29	Orford Quay 1	East Suffolk	25	SM7	*Arthrocnemum perenne*		Scattered throughout marsh
30	Newtown estuary	Isle of Wight	10	SM13c	*Puccinellia maritima* saltmarsh	*Limonium vulgare - Armeria maritima*	All over marsh
31	Hayling Island	South Hamps hire	11	SM6	*Spartina anglica* saltmarsh		Scattered along bottom of wall
32	Arne; Patching Point	Dorset	9	SM7	*Arthrocnemum perenne*		Scattered thoroughout low, wetter area
33	Greenland s Farm	Dorset	9	SM6	*Spartina anglica* saltmarsh		Occasional clumps throughout marsh

Sample number	Location	Vice county name	VC code	'Best fit' to NVC code	Community description	Sub-community description	Density
34	Brands Bay	Dorset	9	SM6	*Spartina anglica* saltmarsh		A few plants over the marsh
35	Titchwell	West Norfolk	28	SM12a/13a	*Aster tripoloium/Puccinellia* saltmarsh		A few plants in salt pan
36	Stiffkey	West Norfolk	28	SM14c	*Atriplex portulacoides* saltmarsh	*Puccinellia maritima*	A few plants widely scattered
37	Wareham	West Norfolk	28	SM13c	*Puccinellia maritima* saltmarsh	*Limonium vulgare - Armeria maritima*	Scattered throughout marsh
38	Holme	West Norfolk	28	SM13c	*Puccinellia maritima* saltmarsh	*Limonium vulgare - Armeria maritima*	A few scattered patches

Figure 2.10 Photographes showing variation in *Sarcocornia perennis* habitat

a) *Sarcocornia perennis* associated with SM13 *Puccinellia maritima* salt marsh

b) *Sarcocornia perennis* associated with SM14 *Atriplex portulacoides* salt marsh

c) An extensive 'lawn' of SM7 *Sarcocornia perennis* spreading over the saltmarsh, River Orwell, Suffolk

d) *Sarcocornia perennis* spreading over bare ground, Arne, Dorset

2.8 Soil analysis

In order to help explain the relative differences in distribution of the target species and associated vegetation community soil samples were taken at each location surveyed. Soil samples were measured for pH, electrical conductivity, moisture, organic matter content (LOI) and bulk density.

2.8.1 Soil properties by species

Soil results were split by species and quadrat type. Significant differences ($p < 0.05$) between quadrat type (sample or control) were analysed using standard *t*-tests. There were no significant differences observed for any of the five soil properties measured (Table 2.6), all results $p > 0.05$) meaning that the soil directly underneath ('sample') the target plant species was not different to soil ('control') taken within the same plant community and at the same elevation. This meant that all quadrats could be analysed together.

No significant differences were found between *Sarcocornia perennis* and *Spartina maritima* for any of the five soil properties (all results $p > 0.05$). However, *Suaeda vera* was consistently found associated with significantly different soil properties to *Sarcocornia perennis* and *Spartina maritima* ($p \geq 0.002$) apart from organic matter content where no differences were observed. *Suaeda vera* was associated with higher pH and bulk density, and lower conductivity and moisture content.

Table 2.6 Soil properties measured for all 3 species split by quadrat (sample = S and control = C). Differences between quadrat type were evaluated using standard *t*-tests. Significant differences (*p* < 0.05) between quadrat type means are highlighted in bold.

Soil property	Plant	Quadrat	mean	SE	*n*	*p*
pH	*Sarcocornia perennis*	S	7.10	0.10	31	
		C	7.15	0.08	31	0.676
	Spartina maritima	S	7.18	0.06	36	
		C	7.18	0.06	36	0.810
	Suaeda vera	S	7.36	0.08	30	
		C	7.46	0.10	30	0.437
Conductivity (mS)	*Sarcocornia perennis*	S	9.87	0.46	31	
		C	9.57	0.40	31	0.632
	Spartina maritima	S	9.60	0.38	36	
		C	9.60	0.38	36	0.497
	Suaeda vera	S	5.50	0.38	30	
		C	4.69	0.49	30	0.197
Moisture content (% dry weight)	*Sarcocornia perennis*	S	177.35	15.52	31	
		C	185.60	14.18	31	0.696
	Spartina maritima	S	179.60	10.76	36	
		C	179.60	10.76	36	0.792
	Suaeda vera	S	98.92	11.66	30	
		C	98.06	11.70	30	0.959
Organic matter content (%)	*Sarcocornia perennis*	S	13.13	1.13	31	
		C	13.46	1.00	31	0.824
	Spartina maritima	S	12.10	0.69	36	
		C	12.10	0.69	36	0.490
	Suaeda vera	S	12.86	1.37	30	
		C	12.34	1.37	30	0.791
Bulk density (g cm^{-3})	*Sarcocornia perennis*	S	0.46	0.04	31	
		C	0.42	0.03	31	0.428
	Spartina maritima	S	0.41	0.02	36	
		C	0.41	0.02	36	0.790
	Suaeda vera	S	0.59	0.04	27	
		C	0.60	0.04	27	0.767

2.8.2 Soil property correlations by species

All five soil properties were compared against each other to look for correlations and patterns. No relationship was seen between any soil property measured and pH (Figure 2.11) Overall, with increased conductivity (which is a proxy for salinity and therefore in general a proxy for shore elevation, i.e. lower shore being more saline due to increased inundation), moisture content and organic matter content also increased whilst bulk density decreased.

Figure 2.11 Correlations between all soil properties measured for all 3 species. Species means are represented by the black outlined data points.

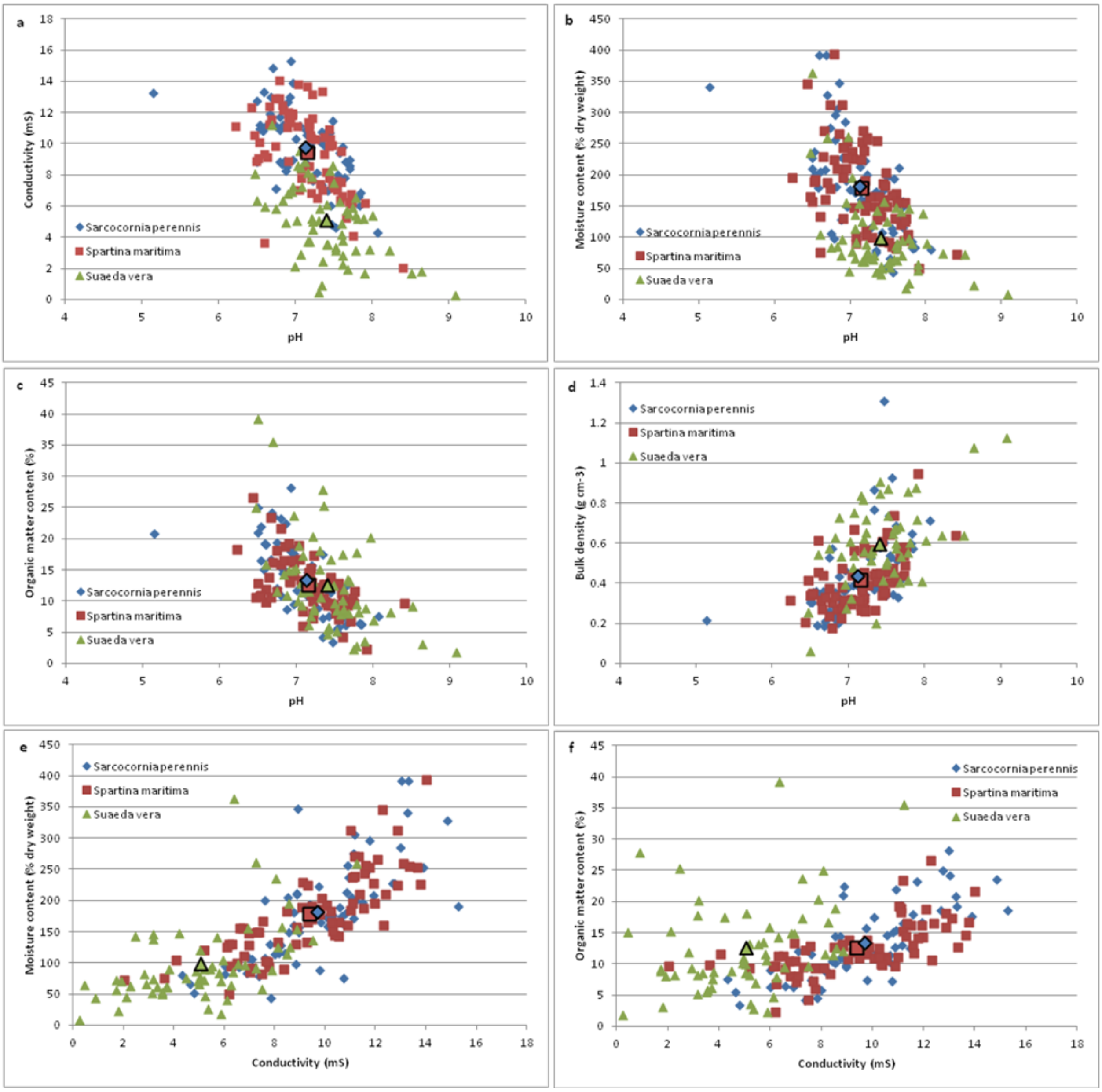


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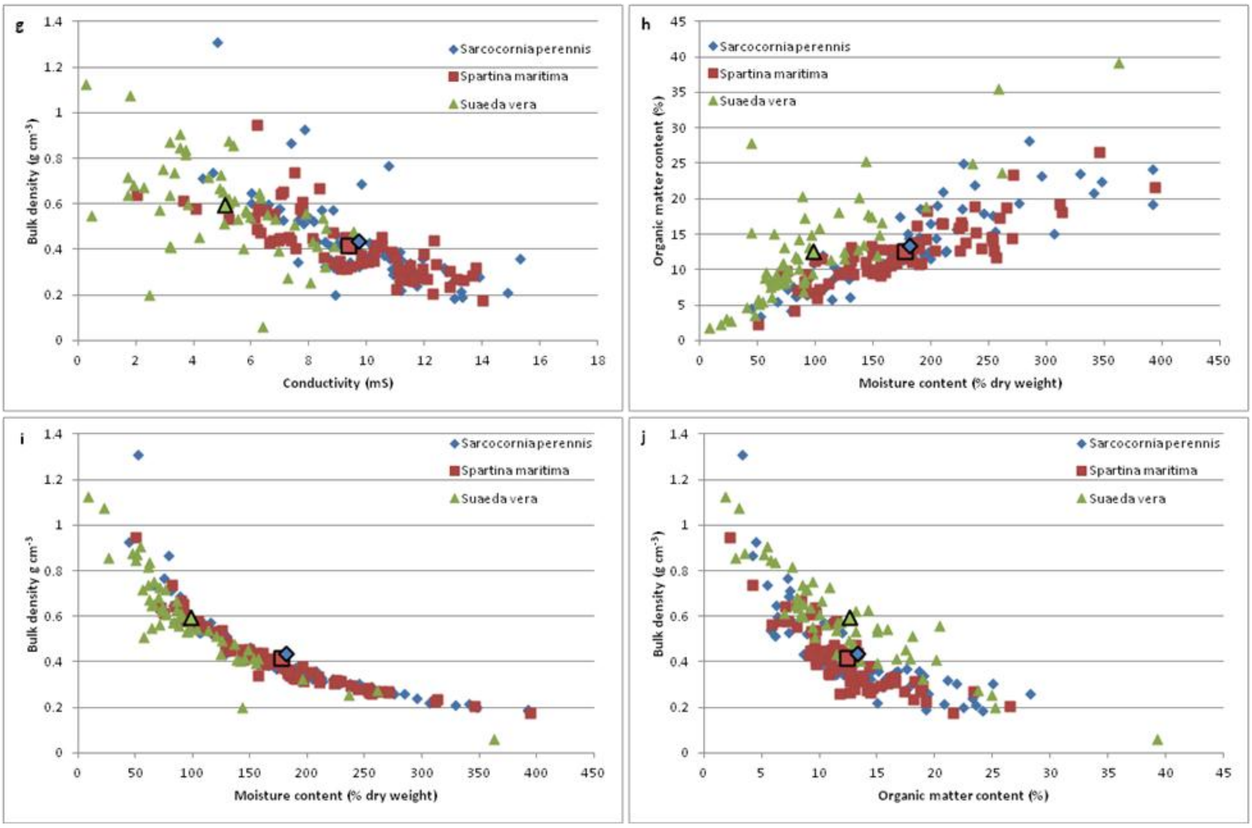
Figure 2.11 continued.



As was also demonstrated by the *t*-test results summarised in Table 2.7, the correlations showed no clear differences in soil properties where *Sarcocornia perennis* and *Spartina maritima* were found. However, *Suaeda vera* is found associated with drier, less saline soils with a greater bulk density which is consistent with conditions expected higher on the shore.

Table 2.7 Results of comparisons between species for all five soil properties. Differences between species were evaluated using standard *t*-tests. Significant differences ($p < 0.05$) are highlighted in bold.

Soil property	Species			*n*	*p*
pH	*Sarcocornia perennis*	v	*Spartina maritima*	134	0.653
	Sarcocornia perennis	v	*Suaeda vera*	122	**0.002**
	Spartina maritima	v	*Suaeda vera*	132	**0.002**
Conductivity (mS)	*Sarcocornia perennis*	v	*Spartina maritima*	134	0.455
	Sarcocornia perennis	v	*Suaeda vera*	122	**< 0.001**
	Spartina maritima	v	*Suaeda vera*	132	**< 0.001**
Moisture content (% dry weight)	*Sarcocornia perennis*	v	*Spartina maritima*	134	0.757
	Sarcocornia perennis	v	*Suaeda vera*	122	**< 0.001**
	Spartina maritima	v	*Suaeda vera*	132	**< 0.001**
Organic matter content (%)	*Sarcocornia perennis*	v	*Spartina maritima*	134	0.331
	Sarcocornia perennis	v	*Suaeda vera*	122	0.566
	Spartina maritima	v	*Suaeda vera*	132	0.882
Bulk density (g cm^{-3})	*Sarcocornia perennis*	v	*Spartina maritima*	134	0.449
	Sarcocornia perennis	v	*Suaeda vera*	116	**< 0.001**
	Spartina maritima	v	*Suaeda vera*	126	**< 0.001**

2.9 Habitat creation potential for Mediterranean and thermo-Atlantic halophilous scrubs and Spartina maritima swards

Results from the soil analysis show that there is a clear separation between the requirements of *Suaeda vera* and that of *Spartina maritima* and *Sarcocornia perennis* reflecting the relative differences in the tidal frame. Although the *Suaeda vera* and *Sarcocornia perennis* communities are both described under the same Annex 1 habitat (*Mediterranean and thermo-Atlantic halophilous scrubs*), with *S. perennis* described as local variant, they clearly occupy different niches in England where they are at the northern edge of their range. Where *S. perennis* occurs in the centre of its range in the Mediterranean, it appears to occur in the upper levels of salt marsh as a scrubby stand of vegetation similar to that of *Suaeda vera* in England (A. Garbutt, pers obs). In England however, *S. perennis* occurs as a low growing herb more often associated with a diverse range of species. Any attempt to re-create 'Mediterranean and thermo-Atlantic halophilous scrubs' in England should consider the requirements of the two species separately.

In re-creating the right conditions for any of the three species or habitat types to establish, frequency of tidal inundation is certain to be the main driver. This is a factor of elevation, so adequate surface levels need to be designed in to have a range of inundations across the site and to landward. The ecological niche of saltmarsh plants has been well described (see Gray, 1992 for overview). *Spartina maritima* and *Sarcocornia perennis* are generally components of SM13 *Puccinellia maritima* and/or SM14 *Atriplex portulacoides* salt marsh, typical of the majority of marshes in the south east of England. *Sarcocornia perennis* has been recorded in several saltmarshes regenerated over agricultural land through managed realignment in the UK (Mossman et al., 2012). *Spartina maritima* has been recorded once in a managed realignment site in the UK (Tollesbury, Essex by Garbutt, A. *pers obs*). The plants grew in the mudflat of the site for three years before being out-competed by *Spartina anglica* and dying. Because it is rare for *S. maritima* to produce viable seed in the UK, if at all, dispersal by propogules from the local species pool would probably be the only way for plants to colonise new sites, other than by translocations. Although *S. maritima* and *S. perennis* core ranges lie in the 'mid marsh' zone at a similar elevation, they are also capable of growing at elevations further down the shore profile in the pioneer zone along side *Spartina anglica.* It is unclear how long *S. perennis* is able to survive at the lower parts of the shore. The extant population in Suffolk shows that *S. maritima* can survive and persist on bare mud.

Sueada vera plants appear to readily colonise new or abandoned sea walls within managed realignment sites and on embankments of primary defences so seed limitation does not appear to be a confining factor. The higher transitional strand line or creek side vegetation of *Suaeda vera* salt marsh was better drained and less saline than soils for the other two species, reflecting less tidal inundations. While this report focuses on saltmarsh communities, *S. vera* is also a plant of shingle and sand dune transitional habitats. Its ability to colonise the upper parts of salt marsh with lower salinity and soil moisture content should be considered when creating new intertidal habitat. There may be opportunities to create the right conditions for *S. vera* to colonise by relatively small scale interventions through elevating areas of land surface, or by introducing coarser grained, free draining sediment types.

Because of the influence of tidal flooding salt marshes are 'open' systems exposed to high levels of organic input and nutrient loading (Boorman & Hazelden, 2012). High soil nutrient status is not thought to be significant in controlling plant assemblages for communities exposed to regular tidal inundation where tolerance to the physical environment has greater baring; i.e. in the zone occupied by *S. perennis* and *S. maritima*. At the upper edge of salt marshes interspecific competition has greater control on plant community composition. The nutrient status of soils in this zone is likely to have a significant role in determining species' ability to colonise and compete for space. Whilst this report did not measure soil nutrient content it is likely to have a some effect on the ability of *S. vera* to colonise and grow. In any habitat creation project where upper salt marsh or transitional habitats are a target soil nutrient status should be considered and may influence the speed and direction of plant community reassembly.

Although it is potentially possible for the target species and habitats to colonise new ground if available, newly created habitats rarely represent all the species or functions of the target community. Every effort should be made to conserve extant functioning examples of *Mediterranean and thermo-Atlantic halophilous scrubs* and *Spartina maritima swards* in England where possible.

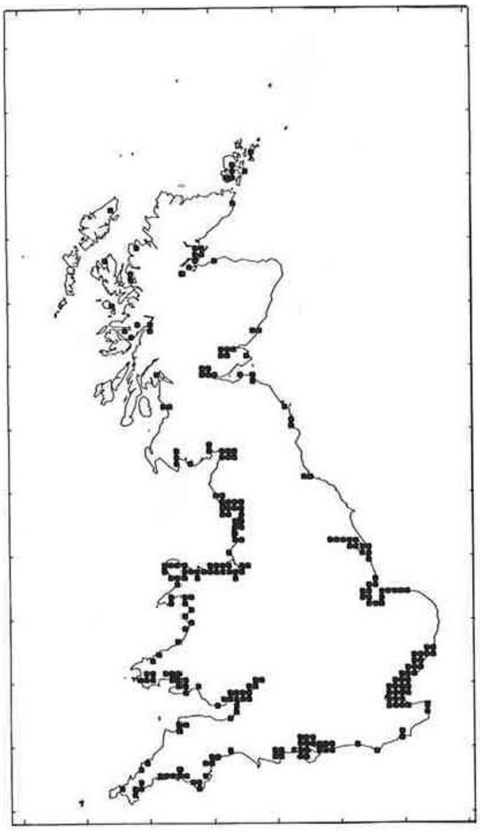
3. A review of saltmarsh to grassland transition zones

3.1 Review of requirements and characteristics

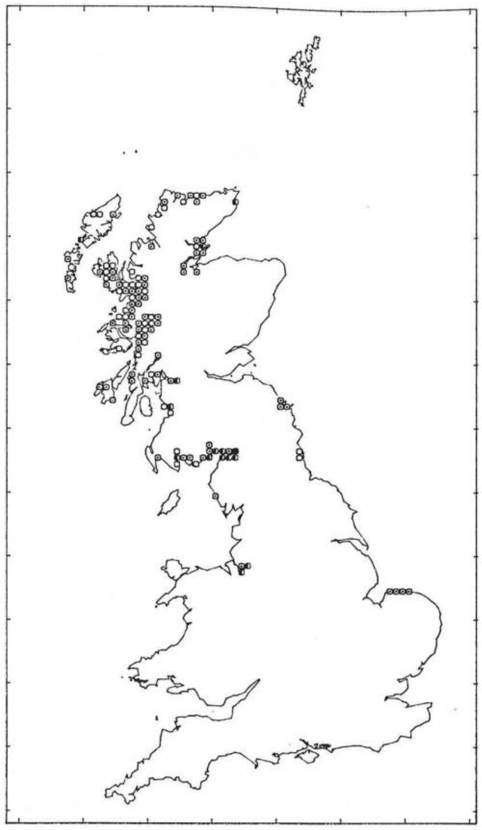
Transitions between salt marsh and several other habitats are present throughout the British Isles; salt marsh to: shingle, sand dune, reed swamp and fen, bog, woodland, terrestrial grassland and coastal embankments. Transitions occur across salinity gradients along estuaries and across elevational gradients from intertidal to terrestrial environments. Transitional zones across both type of gradient are uncommon in England as a result of channel modification and embankment for flood defence. Burd (1989) identified saltmarsh to grassland, sand dune and freshwater transition communities in Great Britain and truncated transition zones (Fig 3.1). The maps show that the majority of the 'soft coast' in Great Britain is embanked and that areas with transition zones are rare or confined to the 'hard coast'.

Figure 3.1 Comparison of the distribution of transition communities with the distribution of truncated transition zones (taken from Burd, 1989)

a) Truncated transition zones



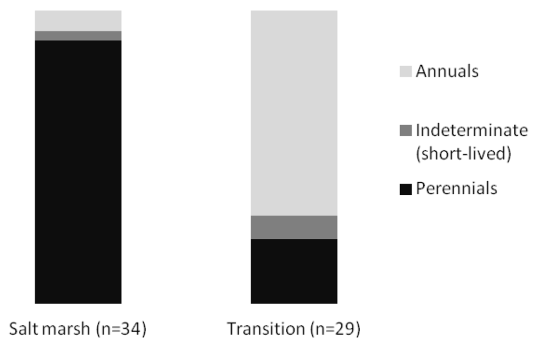
b) Grassland transitions



Intertidal ecosystems are subject to periodic disturbance. For mudflats and salt marshes the major 'disturbance event' is tidal flooding which is regular and predictable and creates a characteristic zonation of plant assemblages (Adam 1990). Towards the upper edge of salt marshes disturbance by tidal flooding is infrequent and unpredictable, usually driven by storm events and coinciding with high tides. Disturbance in this transitional zone between the intertidal and terrestrial or freshwater environment creates gaps, or niches, in what would otherwise be a closed vegetation community. Gaps are created by either physical disturbance such as the erosion of soil or vegetation, the deposition of sediment or tidal litter, or by an increase in salinity which kills off non-salt tolerant plants or creates hyper-saline conditions in marginal pools (Gray 1989). Left undisturbed, these transition zones would become dominated by perennial grasses and shrubs. In order to gain an understanding of the maintenance of saltmarsh to grassland transition zones, Gray (1989) categorised saltmarsh 'coastal fringe' plant species by their life history characteristics (Figure 3.2). In contrast to the saltmarsh, where 90% of species had perennial life histories, 70 % of coastal fringe species were annuals or of an indeterminate or short lived life history. The only widespread and commonly occurring annual species in saltmarsh are *Salicornia* species and *Suaeda maritima*. These species are characteristic of the mudflat transition zone where tolerance to high inundation frequency and salinity are required for recruitment and survival.

Many species characteristic of the upper saltmarsh transition zone also have annual life histories (Fig. 3.2). Species such as *Puccinellia rupestris (*stiff saltmarsh-grass*), Bupleurum tenuissimum (*slender hare's-ear*), Trifolium squamosum (*sea clover*), Peucedanum officinale* (hogs fennel), *Hordeum marinum (*sea barley*)* all occur in a narrow zone between the upper limits of salt marsh and neutral grassland, or in areas of saline seepage behind coastal defences (Table 3.1).

Figure 3.2. Life history characteristics of flowering plants from British salt marshes and transition zones (between mean high water spring tides and extreme high water). Adapted from Gray 1998.



This is a suite of nationally and locally scarce species which are found on upper saltmarsh transitions to damp grassland and on coastal grazing marsh (grazing land created from salt marsh by excluding tidal incursion by building sea walls). In coastal grazing marsh habitat, the presence of these species may indicate the past existence of a more natural transition or of a continuing seepage or occasional overtopping. However, as most of the enclosure of low-lying areas has been carried out historically, there are few natural examples remaining of extensive salt marsh-grassland transitions. Many of the sites which retained elements of this transition have since been modified by agricultural intensification. Unmodified systems can still retain the topography of old saltmarsh creeks, and in some places the ditches can still have a brackish character.

A 1970's vegetation study of the North Kent Marshes (Macey 1974) attempted to understand the changes following saltmarsh reclamation and the factors that influenced it. At that time, most of the reclaimed marshes were still unimproved and still supported a wide range of these plant species, several of which are nationally scarce.

Table 3.1 Species associated with saltmarsh and coastal grazing marsh transitions

Data source: [1]Maplin grazing marsh study (Macey 1974); [2] Severn Estuary saltmarsh survey (Dargie 1998); [3]Ramsar interest feature of Colne and/or Blackwater Estuaries, Essex; [4] Section 41 (S41) species listed in the 2006 Natural Environment and Rural Communities (NERC) Act linked to saltmarsh habitat.
Rarity status: Present= not rare or scarce; Scarce=occurs in16-100 10km squares in Britain; Rare =1-15 10km squares in Britain.

Species	Rarity status	Life history	Habitat preference
Puccinellia rupestris [1,2]	Scarce	annual	Upper salt marsh, bare ground, vehicle tracks, cattle poached mud behind sea walls
Puccinellia distans[1]	Present	perennial	Upper salt marsh
Puccinellia fasciculata [1,2,3,4]	Scarce	perennial	Bare ground cattle poached mud
Bupleurum tenuissimum [1,2,4]	Scarce	annual	Disturbed ground on sea walls, upper salt marshes
Trifolium squamosum [1,2]	Scarce	annual	Upper salt marshes and brackish meadows, behind sea walls in areas of saline seepage
Peucedanum officinale[1]	Rare	perennial	Coastal grassland on, or behind sea walls and brackish marsh
Hordeum marinum [1,2,3,4]	Scarce	annual	Upper salt marsh, bare ground near the sea
Bolboschoenus maritimus [1]	Present	perennial	Brackish upper reaches of estuaries or ditches behind sea walls
Polypogon monspeliensis[1]	Scarce	annual	Bare or sparsely grassy ground by the coast
Ranunculus baudotii [1,3]	Present	annual	Brackish ditches by the sea
Parapholis strigosa[1]	Present	annual	Upper salt marshes and bare ground near the sea

Key factors influencing species presence identified in the 1974 study were soil moisture, salinity and management. Different combinations of factors altered the combinations of species present. Overall, the reclaimed marsh habitat was considered to include both the landward and seaward areas of the sea wall. High species density was recorded on the landward sides of the sea wall, which would have had some commonalities with the high level saltmarsh habitat, and may be influenced by grazing. Joint Nature Conservation Committee (http://jncc.defra.gov.uk/page-5171) has developed generic management recommendations for BAP priority species. For *Bupleurum tenuissimum* (http://jncc.defra.gov.uk/_speciespages/2108.pdf) this includes two key elements that are linked to coastal management:

- 'ensure appropriate habitat condition at sites including maintaining open areas and increasing grazing and poaching by cattle or sheep to help control main competitors e.g. *Elytrigia atherica'* and;
- 'Ensure needs of this species are taken into account when devising coastal defence strategies, including managed retreat/re-alignment (including Shoreline Management Plans). Ensure measures are incorporated into Local Plans and Structure Plans to prevent further losses of its saline/brackish habitats (saltmarsh and grazing marsh), either to development or agricultural intensification (e.g. conversion to arable).'

For the first action, there is potential conflict with the management of the sward to maintain the overall vegetation community, where extensive bare ground is typically considered detrimental. In order to be considered to be in 'favourable condition' (JNCC, 2004), saltmarsh habitat should have less than 25% bare ground as a result of poaching damage by livestock, whereas condition assessment for the vascular plants listed in Table 3.1 requires more than 20% bare ground within the zone they are associated with. However, recent work to advise on integration of species with habitat management has resulted in the development of the 'Mosaic Approach' by Natural England http://publications.naturalengland.org.uk/publication/6415972705501184?category=5856835374415872 . This will help to inform management advice and setting of bare ground targets where rare species are likely to be present; action targeted at creating appropriate niches should be integrated with habitat management. This will help to meet Outcome 3 of the Government's Biodiversity 2020 strategy which contains an ambition to ensure that *'By 2020, we will see an overall improvement in the status of our wildlife and will have prevented further human-induced extinctions of known threatened species.'* Futher information is provided at http://publications.naturalengland.org.uk/publication/4958719460769792

4. Survey of potential locations for freshwater-saltmarsh transition zones in Morecambe Bay

4.1 Introduction

A total of 13 locations were visited through July to September 2012 around Morecambe Bay extending from Bolton-Le-Sands in the south (SD460660) to Roudsea Woods in the north (SD320820). The aim was to carry out a rapid vegetation survey, targeting areas at the upper saltmarsh boundary where vegetation assemblages were transitional in character reflecting brackish conditions, often where freshwater flow from streams and ditches appeared to interface with salt water. In addition, the data collected could be used to contrast and compare with any transition zones observed in the south and east of England as part of the Annex 1 habitat survey.

4.2 Methods

Transect locations were taken from those that were first set up as part of the proposed Morecambe Bay barrage environmental assessment in 1969 (Gray, 1972) and resurveyed in 1994 (Adam, 2000) and Garbutt in 2011 (unpublished). The location of each transect was visited and the area in the immediate vicinity described using one or more 2x2m quadrat samples placed in homogenous vegetation in the upper saltmarsh and then a DAFOR list made of all species present above the saltmarsh and in vegetation that appeared to characterise the upper marsh-freshwater transition. In some cases there was no obvious evidence of freshwater inputs but a description was provided anyway in case the location had changed or degraded from previous visits and to enable rapid assessment of future change against a rapidly assessed baseline.

Units of separate vegetation were delimited based on differences in location and species composition. DAFOR scores were translated into constancy values (D,A = 5, F=4, O=3, R=1) and the lists analysed in terms of fit to the National Vegetation Classification using the MAVIS software (http://www.ceh.ac.uk/products/software/cehsoftware-mavis.htm). The top five fits were displayed for each vegetation unit using radar diagrams (Smart 2000).

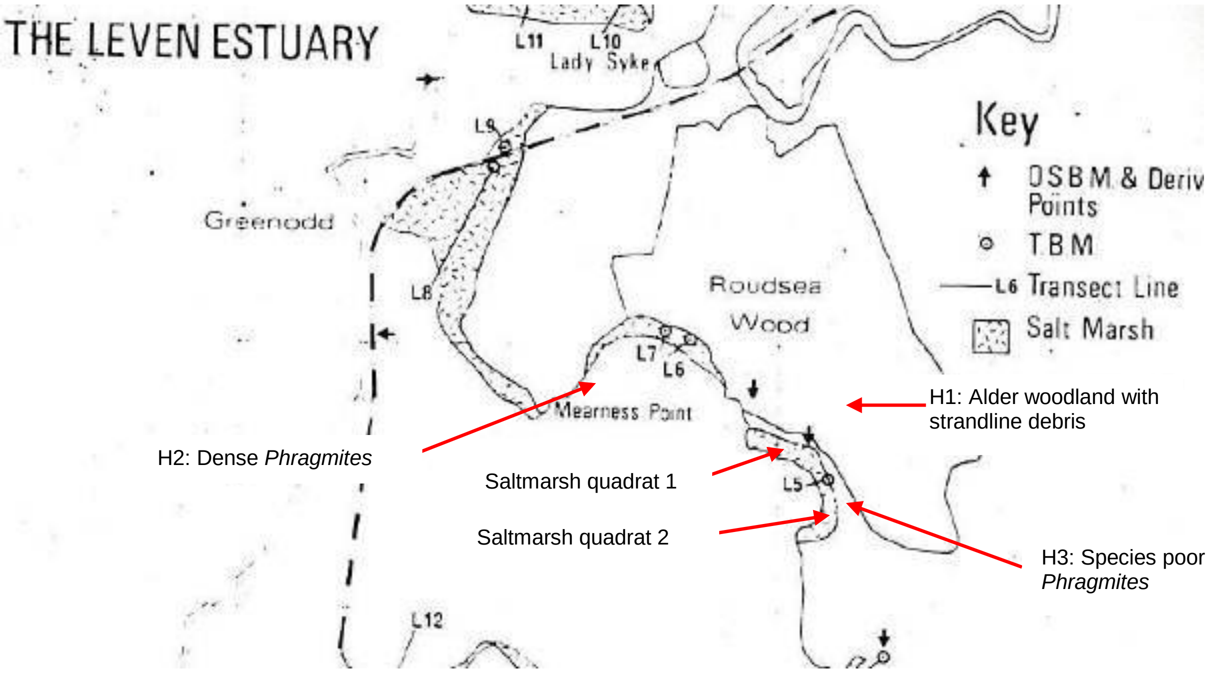
In each site particular care was taken not to miss species especially characteristic of the upper marsh transition. These species included *Trifolium fragiferum, Apium graveolens, Samolus valerandi, Potamogeton pectinatus*, *Juncus compressus, Ruppia maritima, Ranunculus sceleratus, Blysmus rufus* and *Carex punctata*. Only *P.pectinatus, A.graveolens, R.sceleratus* and *R.maritima* were found.

4.3 Results

N.B. Maps of the area of search are scans of the original maps used in the proposed Morecambe Bay barrage Environmental Assessment in 1969.The transect lines (e.g.L6) were used to describe the elevation and plant communities of the salt marshes.

Roudsea Woods – transects L5, L6 and L7

Figure 4.1: Map of the area of search.

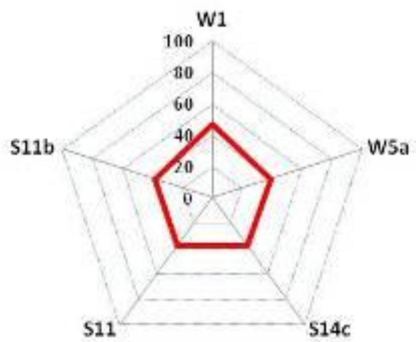


Vegetation types present

H1: Alder woodland with strandline debris

Clearly inundated at extremely high tides but no obvious brackish assemblages nor obvious ground or surface water seepage.

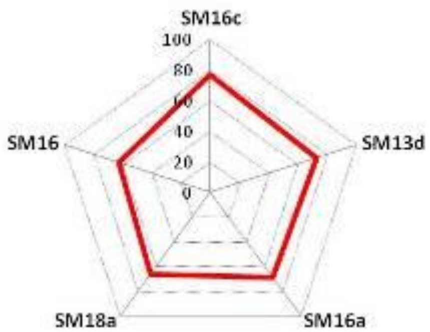
Species	Constancy
Alnus glutinosa	5
Juncus effusus	4
Carex remota	4
Dryopteris dilatata	4
Lycopus europaeus	4
Carex vesicaria	3
Iris pseudacorus	3
Phalaris arundinacea	3
Scutellaria galericulata	3
Valeriana officinalis	1
Rumex sanguineus	3
Apium graveolens	1
Deschampsia	1



cespitosa	
Solanum dulcamara	4
Lysichiton americanus	1
Urtica dioica	3
Molinia caerulea	1
Glyceria fluitans	3
Mentha aquatica	3
Ranunculus flammula	1
Ranunculus repens	3
Galium palustre	3

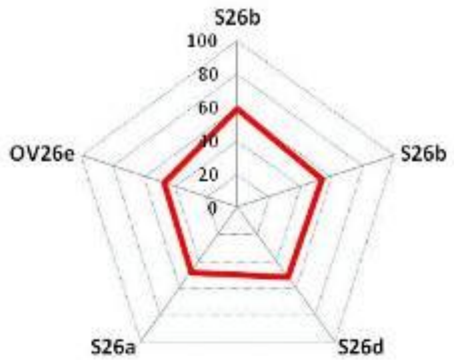
Q1 and Q2: Saltmarsh quadrat samples

Species	**Q1**	**Q2**
Aster tripolium	10	1
Armeria maritima	1	1
Plantago maritima	40	10
Agrostis stolonifera	40	40
Glaux maritima	1	10
Triglochin maritimum	10	40
Cochlearia officinalis		1
Festuca rubra		10



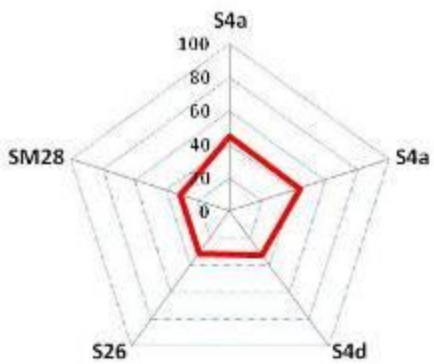
H2: Dense *Phragmites*

Species	**Constancy**
Urtica dioica	5
Phragmites australis	5
Elytrigia repens	4
Arrhenatherum elatius	4
Lythrum salicaria	3
Galium aparine	3
Cirsium arvense	3
Lotus pedunculatus	3
Lathyrus pratensis	3
Salix cinerea	3
Typha latifolia	3
Lemna minor	1



H3: Dense *Phragmites*

Species	**Constancy**
Phragmites australis	5
Elytrigia repens	4
Festuca arundinacea	3
Oenanthe lachenalii	3



H1: Alder woodland with strandline debris

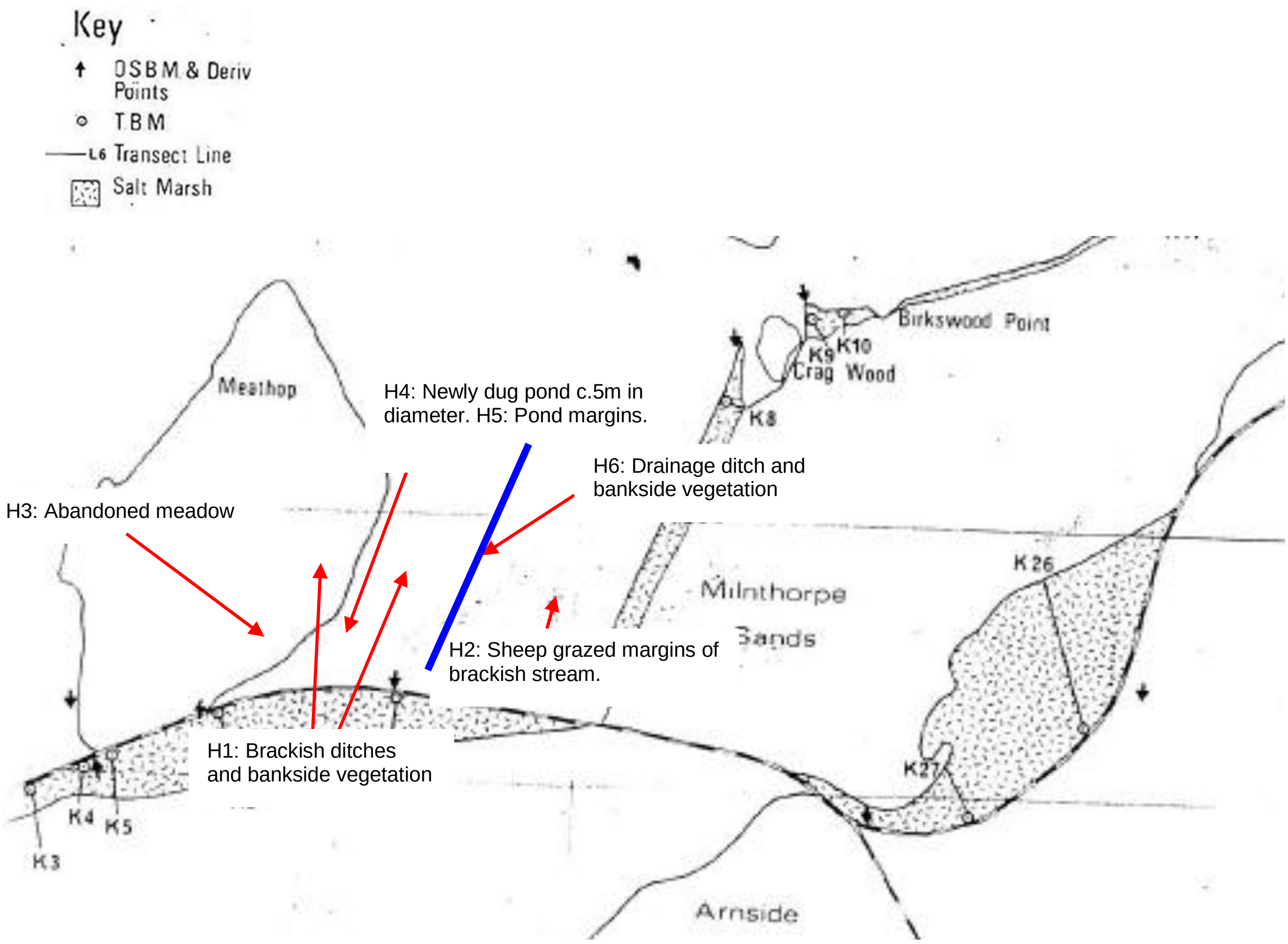
Q1 and Q2: Saltmarsh quadrat samples

H2 & H3: Dense *Phragmites* adjoining broadleaved woodland

H2 & H3: Dense *Phragmites*

Meathop – transects K3 - K7

Figure 4.2: Map of the area of search.



No sign of any transitional saltmarsh/freshwater zones were seen in the vicinity of K3-K5. This area on the seaward side of the railway is saltmarsh on the lower slopes and dry grassland or bare rock on the railway embankment. The River Winster drains into the bay via a culvert under the railway at K4 with no natural vegetation or transition zones present.

The area on the landward side of the railway at K6 to K7 does have brackish vegetation. This is confined to ditches that flow between the agricultural fields that extend up to the landward side of the railway embankment (H1, H6). Three additional areas of vegetation were also described; an old abandoned meadow in the south west corner at K6 (H3), a newly dug pond currently colonising with plants (H4,H5) and a very heavily sheep grazed area of grassland on the level banks of the brackish ditch in the south east (H2). The abandoned meadow is extremely variable in its species composition. Lack of management has led to patchy dominance by *Schoenoplectus tabernaemontani, Scirpus maritimus, Carex otrubae, C.paniculata, Juncus effusus, J.inflexus* and *J.acutiflorus*. The result is that species richness is low but herbs that were previously probably more common persist as rare individuals. They comprise a very odd mix of calcicoles and calcifuges that might have been associated with a wet meadow. NVC assignment is problematic given the confusing mix of affinities present and the low frequency of most species other than the dominants.

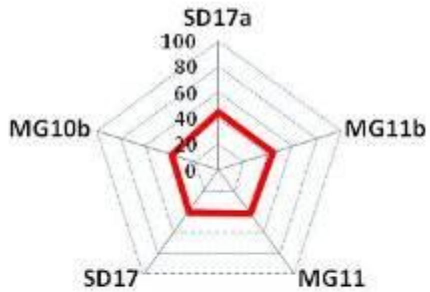
Vegetation types present

H1: Brackish ditches and bankside vegetation. On average 1.5m wide. Banks are steep and generally narrow and unmanaged and so generally have little in the way of short, open inundation communities present.

Species	Constancy
Glyceria fluitans	5
Potentilla anserina	4
Carex otrubae	4
Festuca arundinacea	4
Juncus inflexus	3
Rumex conglomeratus	3
Juncus articulatus	3
Juncus bufonius	3
Equisetum palustre	3
Veronica beccabunga	1
Rorippa nasturtium-aquaticum	1
Sparganium erectum	1
Ranunculus aquatilis	1
Carex flacca	1

H2: Heavily sheep grazed margins of brackish stream

Species	Constancy
Trifolium repens	5
Equisetum palustre	5
Agrostis stolonifera	5
Juncus articulatus	4
Cardamine pratensis	4
Potentilla anserina	4
Ranunculus repens	4
Stellaria media	4
Cirsium arvense	4
Cynosurus cristatus	4
Plantago maritima	3
Ranunculus acris	3
Rumex crispus	3
Triglochin palustre	3
Sagina procumbens	3
Juncus bufonius	3
Poa annua	3
Veronica anagallis-aquatica	1
Carex otrubae	1
Ranunculus sceleratus	1
Spergularia marina	1



H3: Abandoned meadow. Presumably not succeeded to scrub or woodland because of the inimical effects of saline influence on possible tree and shrub colonists, in addition to strong dominance by herbaceous species.

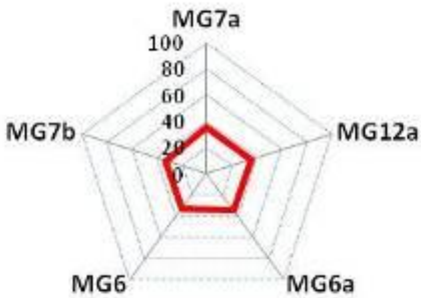
Species	Constancy
Carex nigra	5
Bolboschoenus maritimus	4
Potentilla anserina	4
Juncus effusus	4
Carex otrubae	4
Holcus lanatus	4
Anthoxanthum odoratum	4
Rumex conglomeratus	4
Arrhenatherum elatius	3
Juncus articulatus	3
Cirsium palustre	3
Rumex acetosa	3
Galium palustre	3
Festuca arundinacea	3
Poa trivialis	3
Filipendula ulmaria	3
Agrostis gigantea	3
Centaurea nigra	3
Agrostis stolonifera	3
Juncus inflexus	3
Juncus acutiflorus	3
Lotus pedunculatus	3
Schoenoplectus tabernaemontani	3
Hydrocotyle vulgaris	1
Equisetum palustre	1
Rhinanthus minor	1
Carex ovalis	1
Rumex crispus	1
Carex flacca	1
Briza media	1
Nardus stricta	1
Eleocharis palustris	1
Lychnis flos-cuculi	1
Eleocharis uniglumis	1

H4: Recently established pond now colonising with plants.

Species	Constancy
Glyceria fluitans	5
Rorippa nasturtium-aquaticum	4
Juncus articulatus	3
Juncus inflexus	3
Potentilla anserina	3
Carex otrubae	3
Sparganium erectum	3
Agrostis stolonifera	3

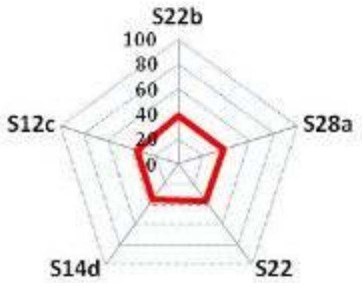
H5: Neutral grassland around pond.

Species	Constancy
Lolium perenne	5
Odontites vernus	4
Potentilla anserina	4
Trifolium pratense	4
Holcus lanatus	4
Cynosurus cristatus	4
Phleum pratense	4
Carex otrubae	3



H6: Farmland ditches.

Species	Constancy
Phalaris arundinacea	5
Sparganium erectum	3
Bolboschoenus maritimus	3
Typha latifolia	3
Glyceria fluitans	3
Rorippa nasturtium-aquaticum	1
Impatiens glandulifera	1



River Winster draining into Morecambe Bay at K4

H4: Recently established pond now colonising with plants.

H3: Abandoned meadow

H1: Brackish ditches and bankside vegetation.

H1: Brackish ditches and bankside vegetation.

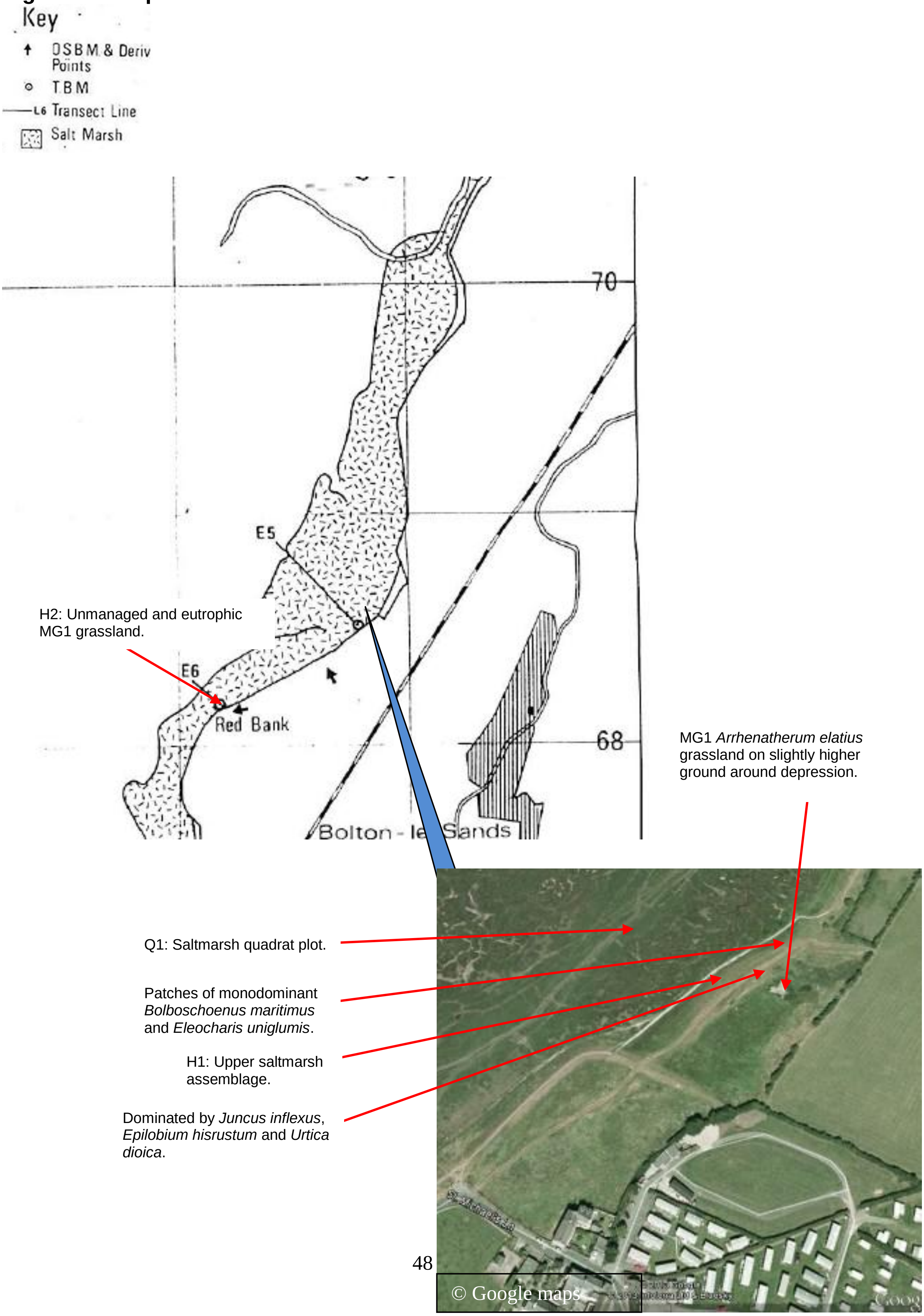
H2: Heavily sheep grazed margins of brackish stream

H2: Heavily sheep grazed margins of brackish stream

H2: Heavily sheep grazed margins of brackish stream

Bolton-le-Sands – transects E5 and E6

Figure 4.3 Map of the area of search.

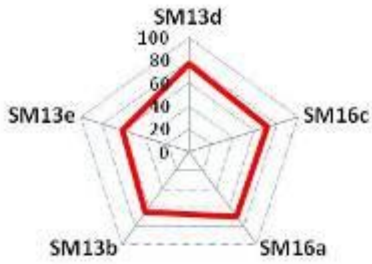


Vegetation types present

No obvious saltmarsh-freshwater transition zones seen in or around E5 or E6. Indeed at E6 the saltmarsh ends inland at the road and behind this either housing, agricultural fields or the camping and caravan site at Red Bank farm (see photographs).

Q1: Saltmarsh quadrat

Species	Cover
Plantago maritima	40
Glaux maritima	25
Festuca rubra	25
Aster tripolium	20
Triglochin maritimum	5
Salicornia europaea	1
Armeria maritima	1
Spergularia media	1



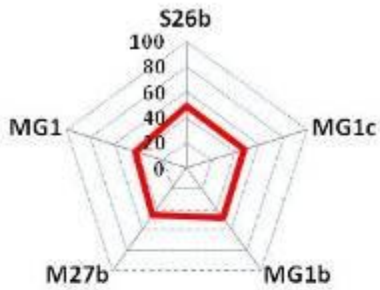
H1: Upper saltmarsh assemblage

Species	Constancy
Festuca rubra	5
Agrostis stolonifera	5
Potentilla anserina	5
Juncus gerardii	4
Carex otrubae	3
Oenanthe lachenalii	3
Triglochin maritimum	3
Festuca arundinacea	3

H2: Unmanaged, eutrophic grassland at transect E6

No obvious saltmarsh-freshwater transition zones were noted in the area. The patch described here occupies around 40m by 15m between the road and car park at Red Farm and adjacent agricultural land and the caravan park. The presence of rare *Carex nigra* and *Potentilla anserina* hint at a pre-existing inundation grassland or dune slack community but these vestiges are overwhelmed by a eutrophic assemblage of common herbs with dominant *Arrhenatherum elatius*. Note that no *Phragmites* was present despite the top match below to S26b.

Species	Constancy
Arrhenatherum elatius	5
Urtica dioica	4
Festuca rubra	4
Elytrigia repens	4
Cirsium arvense	4
Holcus lanatus	4
Calystegia sepium	3
Heracleum mantegazzianum	3



Vicia cracca	3
Galium aparine	3
Potentilla argentea	3
Festuca pratensis	3
Lathyrus pratensis	3
Centaurea nigra	3
Persicaria amphibia	1
Juncus inflexus	1
Lythrum salicaria	1
Epilobium hirsutum	1
Carex nigra	1

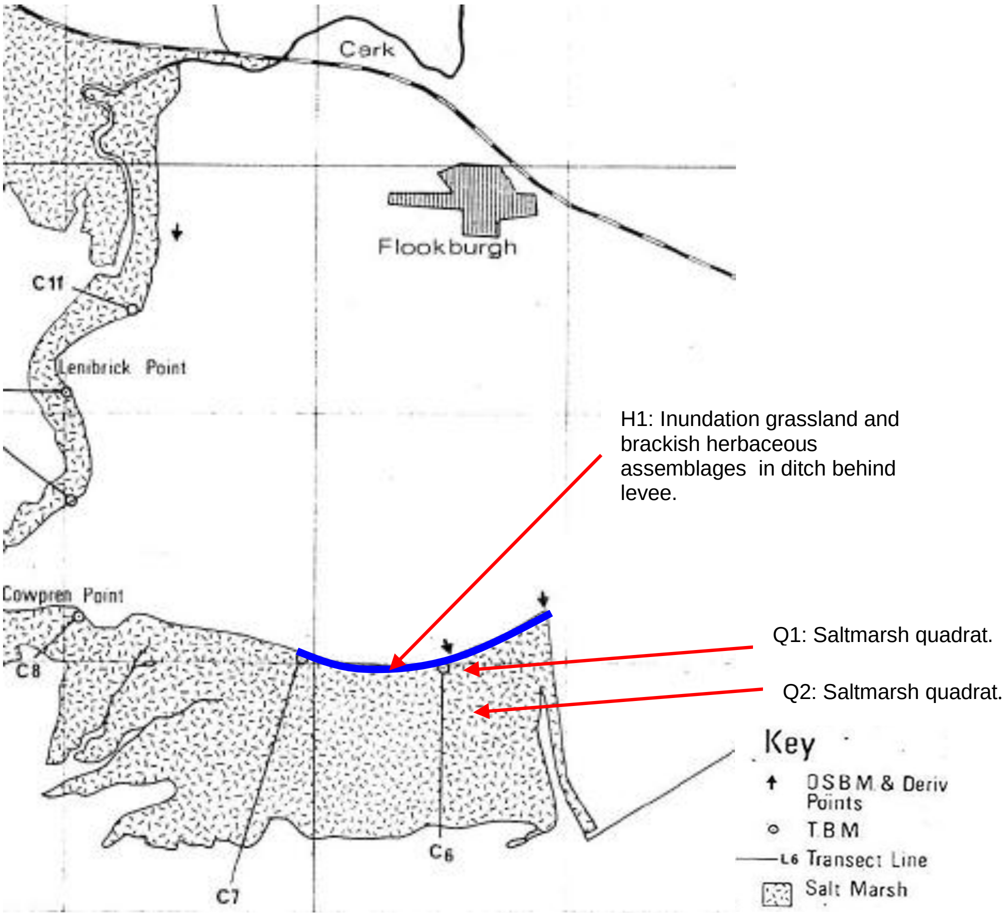
Looking south from footpath between saltmarsh and enclosed upper marsh and MG1 at E5

Mown enclosure of upper marsh and MG1 at E5

Unmown low lying upper marsh at E5 dominated by *Bolboschoenus maritimus* and *Eleocharis uniglumis* and *E.palustris* at E5

Flookburgh – transects C6 and C7

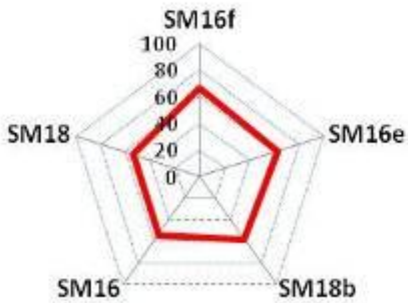
Figure 4.4: Map of the area of search.



Vegetation types present
The most obvious saltmarsh-freshwater transitional assemblages occupy the landward ditch behind the levee bank at the top of the saltmarsh. This continued west beyond the area of search around C7 and C6. No seepage zones or streams draining over land and onto the saltmarsh were noted.
Two reference quadrats representing the upper saltmarsh (Q1,Q2) were recorded. The upper marsh includes scattered lagoons (c.15x10m maximum size) with little except abundant *Potamogeton pectinatus* and local *Enteromorpha* spp suggesting brackish and freshwater influence in places. *Juncus maritimus* was also locally dominant throughout.

Q1 & 2: Upper saltmarsh

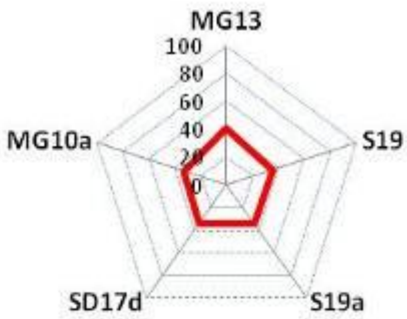
Species	Constancy
Glaux maritima	5
Festuca rubra	5
Alopecurus geniculatus	5
Leontodon autumnalis	5
Juncus gerardii	5
Trifolium repens	5



Carex distans	5
Triglochin maritimum	5
Plantago maritima	5
Potentilla anserina	3
Agrostis stolonifera	3
Juncus bufonius	3
Cirsium arvense	3
Plantago major	3
Rumex crispus	3
Carex flacca	3
Juncus articulatus	3
Oenanthe lachenalii	3
Sagina maritima	3

H1: Levee ditch assemblage

Species	**Constancy**
Juncus effusus	5
Salix cinerea	5
Agrostis stolonifera	5
Carex otrubae	4
Galium palustre	4
Potentilla anserina	4
Ranunculus flammula	3
Urtica dioica	3
Glyceria fluitans	3
Eleocharis palustris	3
Persicaria amphibia	3
Juncus acutiflorus	3
Alopecurus geniculatus	3
Rumex conglomeratus	3
Stellaria uliginosa	1
Oenanthe lachenalii	1
Lotus pedunculatus	1
Callitriche seedling/sp	1
Apium nodiflorum	1
Carex hirta	1
Carex ovalis	1



H1: Levee ditch

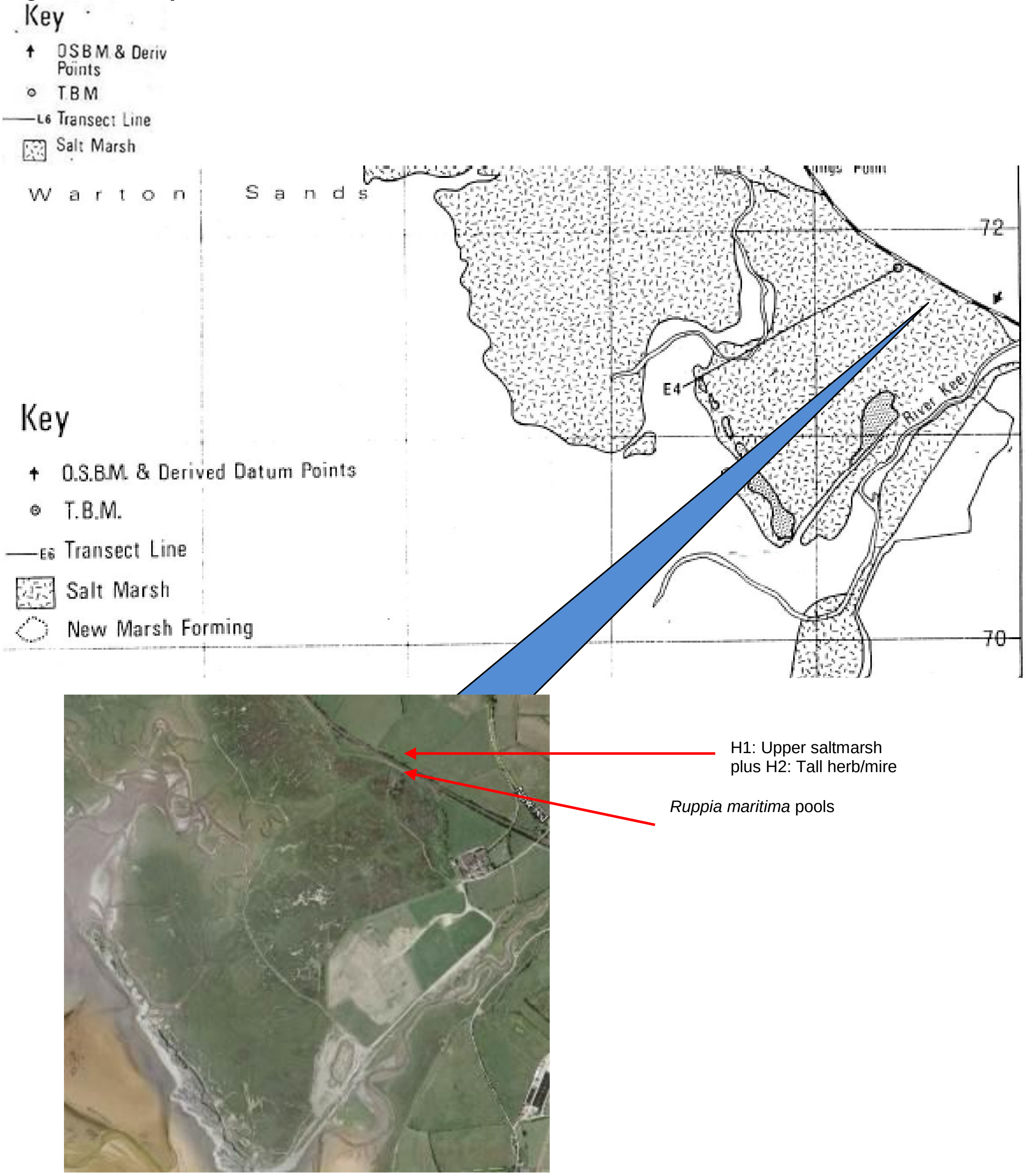
H1: Levee ditch

H1: Levee ditch

Q1 & Q2: Upper saltmarsh

Warton – transect E4

Figure 4.5: Map of the area of search.



Vegetation types present

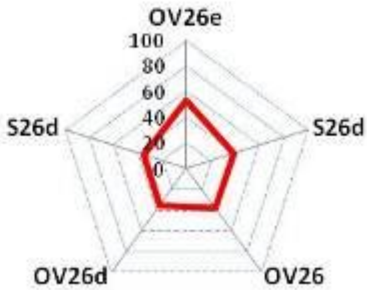
No sign of any obvious saltmarsh-freshwater seepage zones or brackish stream assemblages. The ecotone between the upper saltmarsh and improved grassland on dry ground is typified by rank, dense patches (c.10x10m) patches of tall herb (H2). Small pools (c.1x4m) dominated by *Ruppia maritima* are a rare and notable presence on the upper marsh.

H1: Upper saltmarsh

Species	Constancy
Juncus maritimus	5
Agrostis canina	5
Festuca rubra	5
Carex distans	4
Oenanthe lachenalii	4
Juncus gerardii	4
Potentilla anserina	4
Triglochin maritimum	3
Glaux maritima	3

H2: Tall herb/mire patches (c.10x10m) scattered through the landward edge of the upper marsh.

Species	Constancy
Iris pseudacorus	5
Epilobium hirsutum	5
Urtica dioica	4
Lycopus europaeus	4
Elytrigia repens	4
Apium graveolens	3
Galeopsis tetrahit	1



Ruppia maritima in the vicinity of E4

4.4 Recreation of saltmarsh transitional communities

In the United Kingdom, coastal flood risk management has been the primary objective of intertidal habitat restoration (Wolters et al 2005). Rising sea levels, coupled with the high cost of maintaining coastal defences, have led coastal managers to look for more cost effective and sustainable methods of coastal protection coupled with a statutory requirement for compensatory intertidal habitat to be created due to flood risk management schemes. Managed realignment, the landward retreat of coastal defences and subsequent tidal inundation of reclaimed land has, since the early 1990's, been increasingly used to fulfil these requirements. Broadly speaking managed realignment schemes in the UK have shown that with relatively minimal pre-treatment and/or management of the area, allowing tidal ingress through a simple, relatively small breach of the existing sea wall, onto low-lying agricultural land will quickly produce intertidal mudflats which are colonised by salt marsh plants (Garbutt et al 2006). Evidence to date has shown that managed realignment sites are sinks of sediment and, given time and the appropriate elevation, recognisable plant communities similar to existing saltmarsh can develop. At sites where the land surface rises up to, or beyond, highest astronomical tide (HAT) saltmarsh to grassland transition communities have developed.

There are several managed realignment sites in England that have areas of unimpeded transition zones to terrestrial grassland (e.g. Hesketh Outmarsh in Lancashire, Paull Holme Strays on the Humber in East Yorkshire, Orplands and Abbotts Hall, both in Essex). The site at Abbotts Hall on the Blackwater Estuary in Essex has the longest restored tidal/terrestrial transition zone in the UK. Created in 2002, the coastal defences at the site were breached in five places along a 3km length of coastline allowing tidal flooding of 50ha of reclaimed farmland. At the upper limits of tidal inundation, 35ha of terrestrial grassland were created on formerly cultivated arable fields. The intertidal areas and intervening transition zone were allowed to colonise naturally by plants and animals. Saltmarsh plants rapidly colonised the lower areas of the site. The transition zone developed a ruderal plant community dominated by *Cirsium arvense*, *Brassica nigra*, *Sisymbrium officianle* and *Picris echioides*. In addition to the natural colonisation of the transition zone, *Peucedanum officinale* seeds and plug plants were introduced from 2003/04 (Essex Biodiversity Project 2004). The plant is rare to Britain, occurring in three isolated coastal populations, locally to the Abbotts Hall site. The plant also supports two rare moth species (*Agonopterix putridella* and Annex II species *Gortyna borelii lunata* (see http://jncc.defra.gov.uk/protectedsites/sacselection/species.asp?FeatureIntCode=S4035). While the establishment of *Peucedanum officinale* by plug plant at this site proved relatively successful (Essex Wildlife Tust), the plant community of the transition zone continues to be dominated by ruderal species rather than a more grass dominated sward typical of the region.

The plant community of the Abbotts Hall transition zone contrasts with that of two other managed realignment sites in the region; Orplands (created in 1995), also on the Blackwater estuary and Brandy Hole (created in 2002) on the Croach estuary in Essex just to the south. The plant communities of these sites have developed characteristic, grass dominated transition zones. At the Orplands site, upper salt marsh merges into *Elytrigia atherica* and *Agrostis stolonifera* dominated grassland with chartecterisic species of coastal inundation grassland such as *Festuca arundinacea*, *Potentilla anserina*, *Trifolium repens*, *Carex otrubae*, *Odontites verna* and discrete stands of *Atriplex portulacoides*. A similar community and one dominated by *Elytrigia atherica* is represented at the Brandy Hole site. Why the communities of the Orplands and Brandy Hole sites differ to Abbotts Hall is unclear. Pre-inundation land use was agricultural in each case, although the time scales differ. One obvious difference is the gradient of the slope through the transition zone, which is far greater at Abbotts Hall than the other two sites. The steepness of the slope reduced the transition zone at Abbotts Hall to a few meters in width compared to a much more extensive zone at the other sites. On the small amount of evidence available it appears that restoration time is less important than slope in plant community reassembly at these sites. Orplands and Brandy Hole were created seven years apart and both have distinctive transitional communities on shallow slopes; whereas Abbotts Hall created at the same time as Brandy Hole and has a transition zone dominated by ruderal species. Moreover, the angle of slope will have an impact on the extent of occasional, extreme flooding events with shallower slopes exposing more land surface to salt water inundation and resulting in greater niche availability for new coloniser and weaker competitors.

More attention needs to be given to the requirements of transition zones in the design of managed realignment schemes by identifying relevant physical elements, suitable populations nearby for transfer of propagules as well as artificial introduction of species. Understanding how habitats develop naturally, and the types of timescales involved, could help with designing and managing habitat creation projects that promote development of transitions.

The overriding attribute for the recreation of grassland transitional habitats is to have the space to realign the coastline to higher, naturally rising ground that is subject to occasional saltwater flooding. Shallow sloping ground maximises the potential area for inundation and therefore niches available for coastal transitional specialists and reduces the chance of more vigorous ruderal species and mat forming grasses to colonise. Where naturally rising ground is not present engineering options to build areas at the right elevation suitable for the creation of transitional communities could be an option, whether by a wider berm or 'staircase' of berms, but this option needs a feasibility study. As this study did not collect data on soil types, it is unclear whether this is critical to the establishment of transitional grassland species. As with true halophytes, transitional species are likely to be weak competitors if growing against terrestrial species, so salinity and an available niche for establishment are probably crucial to establishment.

The majority of transitional plant communities in the south east of England are impeded by coastal defences and were rarely encountered during the Annex 1 habitat field survey. On the rare occasion they were encountered, they were generally on sloping ground towards neutral grassland. In contrast, the majority of transitional communities encountered in Morecambe Bay tended to be brackish in nature. This appeared to be an artefact of the wetter climate, salt marshes backed by other semi-natural habitats where run-off was frequent or, where there were coastal defences, a network of wet ditches in a pasture dominated landscape.

Results from the Morecambe Bay study suggest that saline intrusion through over-topping or underground seepage of sea water has an important role to play in the development of salt to freshwater transition habitats. In each site particular care was taken not to miss species especially characteristic of the upper marsh transition. Even so, following extensive searches only four species typical of these habitats (*Apium graveolens, Potamogeton pectinatus*, *Ruppia maritima, and Ranunculus sceleratus*) were recorded during the survey emphasising the relative scarceness of the habitat. The recreation of freshwater habitats with the right biogeochemical conditions to host coastal specialist species is likely to be locally dependant on the right physical environment and results are likely to be highly variable. Pools situated in the higher marsh, subject to occasional tidal flooding and freshwater inputs from rain water are important habitats for *Ruppia maritima*. Around Morecambe Bay there were pools that looked physically very similar, both with and without *R. maritima*. Where the recreation of both grassland and freshwater transitions are likely to be limited by availability of raising ground and angle of slope, transitions to freshwater are likely to have suitable water chemistry as an added consideration for successful restoration.

5. An assessment of *Spartina* species in the Solent Maritime SAC

5.1 The history and importance of the *Spartina alterniflora* population at Marchwood

5.1.1 Introduction

Within the Solent Maritime SAC http://jncc.defra.gov.uk/protectedsites/sacselection/sac.asp?EUCode=UK0030059 the Annex I habitat '*Spartina swards'* is one of the features for which the SAC is selected http://jncc.defra.gov.uk/protectedsites/sacselection/sac.asp?EUcode=UK0030059. This is only one of two SACs in the UK designated for this habitat, the other being Essex estuaries SAC; see:- http://jncc.defra.gov.uk/protectedsites/sacselection/habitat.asp?FeatureIntCode=H1320 The conservation objectives and advice on operations for the Solent European Marine Site is available at http://publications.naturalengland.org.uk/publication/3194402. This advice will be updated and this element of the project will inform this. The Status of *Spartina maritima* swards is included elsewhere in this report. This section reports on the status of other *Spartina* species.

Spartina alterniflora is a perennial grass native to saltmarshes of the eastern seaboard of North America. In about 1820 it was unintentionally introduced onto mudflats on the River Itchen, from where it spread throughout Southampton Water. In some areas, *S. alterniflora* grew beside *Spartina maritima*, a plant of Old World saltmarshes, which is now extinct in Southampton Water. Fertilisation of *S. alterniflora* by *S. maritima* pollen (Ferris *et al*., 1997) produced a sterile species now named *Spartina x townsendii*. The first record of this plant is from Hythe in 1870. Chromosome doubling in *S. x townsendii* formed *Spartina anglica* (Marchant 1968; Raybould *et al*., 1991a), a fertile amphidiploid species (see below). *S. anglica* spread naturally along the south coast of England and the north coast of France by seed and by rhizome fragments. It was also deliberately introduced to saltmarshes throughout the British Isles and world-wide to reclaim land and for coastal defence (Ranwell, 1967). *S. anglica* has greatly altered the ecology of many intertidal areas, although it is debatable whether it is a 'friend or foe' of nature conservation (Doody 1984; Lacambra et al. 2004).

In addition to economic and nature conservation relevance, *S. anglica* has immense scientific importance. Because the species formed so recently, and because both its parental species are extant, it provides a superb opportunity to study the ecological and genetic consequences of polyploid speciation and so understand one of the key processes driving plant evolution (see below). The Marchwood population is the last remnant of the *S. alterniflora* material involved in the origin of *S. anglica* (Maskell, L.C. & Raybould, A.F. 2001) and is therefore a unique resource to evolutionary biologists.

5.1.2 Polyploid evolution in plants

Polyploids are organisms 'that combine three or more basic genomes of the taxonomic group to which they belong' (de Wet 1980). Estimates of the proportion of plants that are polyploid vary as definitions and techniques for detecting genome duplication have changed. The most recent estimates, based on fossil and molecular data, are that 70% of angiosperms are polyploids (Soltis & Soltis 1999).

The most common type of polyploid is the amphidiploid (Grant 1981). Although amphidiploids have more than two genomes they behave like diploids by forming bivalents at meiosis. Amphidiploids are formed by hybridisation between species or between varieties of the same species whose chromosomes are sufficiently differentiated to prevent regular chromosome pairing at meiosis. Amphidiploids can be formed in a single step by the fusion of unreduced gametes, or by chromosome doubling in a hybrid formed from reduced gametes. These processes result in immediate speciation: the new amphidiploid is reproductively isolated from its parents because backcross hybrids are triploid and hence sterile due to irregular meiosis.

Amphidiploids have been synthesised in the laboratory and some have arisen spontaneously in cultivation (e.g. *Primula kewensis*). However, to understand why polyploidy is such a common process in plant evolution we need to study natural amphidiploids. Although most flowering plants are polyploid, most formed thousands or millions of years ago. Advanced molecular methods can determine the parentage polyploid plants that evolved relatively recently, although this is not always possible if, for example, the parental species are extinct.

Understanding the success of polyploids requires more than a determination of the mechanism of their formation. We need to investigate the comparative ecology of polyploids and their parents, to determine why polyploids often persist while their parents become extinct. In addition, studies of gene expression and genome rearrangements will help us learn how polyploid plants evolve to behave as diploids. Ideal material for these types of study is a newly formed allopolyploid that grows alongside its parental species. *S. anglica* is such a species, but its value as a tool for evolutionary biologists is threatened. *S. maritima* has already been lost from the Southampton Water as its habitats have been destroyed by development, erosion or succession (Marchant, 1967; Raybould *et al*., 1991b; Gray *et al*., 1999). The careful management of the Marchwood site to preserve *S. alterniflora* is essential if a unique scientific opportunity is to be exploited fully. Given that the the origins of *Spartina townsendii* are in the Solent the speceis persistance in the region is also of value.

5.1.3 The history of *Spartina alterniflora* in the British Isles

The earliest confirmed record of *S. alterniflora* is a herbarium specimen collected by Borrer from the Itchen in 1829. Bromfield (1836) discovered large patches of the plant growing near the Itchen ferry, particularly near the Belvidere shipyard. Anecdotal accounts in Bromfield's paper suggest that *S. alterniflora* was introduced sometime between 1810 and 1820 at a site upstream of the Itchen Ferry. By 1836, it had spread downstream of the Ferry onto what were previously bare mudflats.

Marchant (1967) gives a detailed account of the spread of *S. alterniflora*. At the height of its distribution, *S. alterniflora* grew as a more or less continuous sward on the east shore of the Itchen from just below the railway bridge at St. Denys to the mouth of the river at Woolston, and from here to about ½ a mile north of Netley. There were also two smaller patches on the west shore of the Itchen.

In Southampton Water/River Test upstream of the Itchen, *S. alterniflora* occurred as several discontinuous swards from Hythe Marina to Cracknore Hard, and as a large sward on the Bury Farm marshes as far upstream as Eling Churchyard. The species also occurred on the eastern shore of the Test from Redbridge to Millbrook. Downstream of the Itchen, *S. alterniflora* grew at Hythe in a large patch about ½ a mile south of the pier. *S. alterniflora* was also common in the Hamble at Burlesdon, Lincegrove, Hamble-le-Rice and Warsash and occurred as far downstream as Hillhead at the mouth of the Meon. *S. alterniflora* may also have spread as far as Lymington in the west and Thorney Island (Chichester Harbour) in the east. However, Marchant & Goodman (1969) cast doubt on the accuracy of these records.

It is likely that *S. alterniflora* spread through Southampton Water by vegetative reproduction only. Bromfield (1836) commented that *S. alterniflora* in the Itchen 'seldom perfects its fruit' and Marchant (1968) states that 'British' '*S. alterniflora* always fails to set seed'. Failure of seed production is probably due to low pollen fertility (Marchant, 1968). It is also possible that the introduced *S. alterniflora* is a single clone (Raybould *et al*., 1991b) and because some clones of *S. alterniflora* are self-incompatible (Daehler, 1998) even if viable pollen is produced, self-incompatibility may prevent any seed set in 'British' *S. alterniflora*.

Recession of *S. alterniflora* began in about 1920 (Marchant & Goodman, 1969) and by the 1930s it was extinct in the Hamble and at Hythe. By 1924 the populations at Eling and Redbridge to Millbrook were extinct. A small population at Dibden was destroyed by reclamation in 1963; this left the Bury Farm marshes at Marchwood as probably the final site for the *S. alterniflora* material involved in the evolution of *S. anglica*.

It is possible that *S. alterniflora* occurs elsewhere in Southampton Water. There is a *S. alterniflora*-like clone within a *S. anglica/S. x townsendii* sward at Sylvan Villa (SU 434070) (for example see Brewis *et al*., 1996). The taxonomic status of this plant is uncertain as its isozyme phenotype is identical to those of *S. alterniflora* at Marchwood and *S. glabra* at Eling (see Gray *et al*., 1999). There are also plants with *S. alterniflora*-like morphology at Fawley. It is possible that these are *S. alterniflora* X *S. anglica* backcross clones introduced from Hythe during saltmarsh restoration (Gray *et al*., 1999). DNA fingerprinting methods, such as amplified fragment length polymorphism (AFLP), could determine the status of the Sylvan Villa and Fawley plants.

5.1.4 Objectives

The main objectives of the work were to repeat the exercise carried out in 1999 (Maskell and Raybould 2000) which mapped the distribution of *S. alterniflora* on the Bury Farm marshes and surveyed areas in Southampton Water and the Rivers Test, Itchen and Hamble where *S. alterniflora* once occurred. Also to repeat the study in 2000 (Maskell and Raybould 2000) which assessed the populations of other *Spartina* (*Spartina x townsendii, S. glabra and S. anglica*) species at Hythe marsh. The specific objectives of the current study were:

- To produce a map of the distribution of *S. alterniflora* on the Bury Farm marshes and compare this to the previous map from 1999.
- To assess physical niche and associated species of *S. alterniflora* at Marchwood.
- To explain changes in distribution of *S.alterniflora*.
- To recommend management procedures for the conservation of *S. alterniflora*, including possible reintroductions.
- To map the current distribution of *S. glabra* at Hythe marsh
- To determine whether there have been any significant changes in the distribution of *S x townsendii* at Hythe

5.2 Spartina alterniflora at Marchwood

5.2.1 Identification

Spartina alterniflora is a robust perennial approximately 40-100cm high (Figures 1a and 1b). Leaves are green, sheaths smooth and the ligule is a dense fringe of hairs. It flowers from July to November, producing panicles with 3-13 spikes. In contrast to *S.maritima, S x townsendii*, and *S.anglica*, *S. alterniflora* has almost hairless spikelets and flag leaves that overtop the inflorescences. It is much larger than *S. maritima* and has smaller spikelets and anthers than *S. x townsendii* and *S. anglica*. The angle between the leaves and the culm is also more acute than that in the latter two species. *S. alterniflora* differs from *S. glabra* in having shorter and narrower leaf blades (Hubbard, 1984; Marchant, 1967; see Table 5.1 for a summary).

Table 5.1. Morphology of *Spartina* species found in Britain (adapted from Marchant, 1967)

	S. alterniflora	**S. glabra**	**S. maritima**	**S. x townsendii**	**S. anglica**
Stem height (cm)	53-80	107-118	30-42	42-133	48-107
Leaf length (cm)	21-40	42-48	7-12	14-28	17-40
Leaf width (mm)	6-12	9-10	5-6	6-11	7-14
Ligule length (mm)	1.25-1.50	1.50	0.25	1.00-1.75	2.00-3.00
Leaf angle ^{o}	15-18	10-15	12-20	30-40	30-60
Overtopping	Yes	??	No	No	No
Spikes/ stem	3-8	8-12	2-5	2-8	2-10
Spike length (cm)	6-10	5.4 (mean)	6-8	8-15	9-20
Spikelet length (mm)	11-18	13-14	12-15	15-18	17-21
Glume hairiness (Sides)	0-1S	0	3L	1S-2M	1S-2L
Glume hairiness (Keel)	2S-2M	1S	2S-2M	1S-3S	1M-3L
Anther length	5.0-7.0	5.0-5.5	5-6.5	5.0-5.8	8.0-13.0

Notes:
Stem height – mature flowering culms at anthesis, measured from soil level to tip of spikes.
Leaf morphology – 3rd from top (flag leaf).
Leaf angle – angle between stem and upper surface of leaf.
Overtopping – whether flag leaf extends past the tip of the longest spike.
Glume hairiness – arbitrary scale: 0 = hairless, 1 = sparsely hairy, 2 = moderately hairy, 3 = thickly hairy; S = short hairs, M = medium hairs, L = long hairs.
Anther length does not include the filament.

5.2.2 Distribution

Mapping *Spartina alterniflora*

Patches of *Spartina alterniflora* identified in 1999 were re-surveyed to determine the current extent. Identification was more challenging than in 1999 as the previous survey was carried out later in the season when flowering was more advanced. Morphological characters listed above were used to identify *S. alterniflora* and selected individuals were sampled and measurements taken to support identification. The marsh was also surveyed for new patches of *S. alterniflora*. At each patch, the location was roughly mapped onto a base map and GPS readings taken using a Trimble Geoexplorer hand held GPS unit. When the patch was of a sufficient size GPS readings were taken by traversing the edge of the patch, when the patch was too small to map point readings were taken. These readings were downloaded and corrected for maximum accuracy which was approximately sub-metre and exported to Arcmap and added to the Ordnance Survey digital map of the area. The surrounding vegetation at each patch was also recorded. The Ordnance Survey maps for grid squares SU3711, SU3712 and SU3811 were imported from MapInfo and transformed to shape files in Arcmap.

Figure 5.1 is the aerial photograph of Bury marsh, Marchwood in 1991 and the mid-2000's from Google Maps. The marsh itself has changed, with erosion at the front of the marsh, formation of new creeks and loss in other parts of the marsh. Figure 5.2 shows the distribution of *Spartina alterniflora* on the Bury Farm Marsh, Marchwood in 1999 and the distribution of *S. alterniflora* in 2012 superimposed onto the past distribution. There is still overlap between populations of *S. alterniflora* recorded in 1999 and in 2012. Some of the slight discrepancies in location may be due to sampling method, different GPS units were used and possibly the 2012 sample is more spatially accurate.

On the whole the distribution of *S. alterniflora* in 2012 is quite similar to 1999. There have undoubtedly been some changes in distribution; patch 12 from Figure 5.3 has now mostly gone with only a few plants left. When surveyed in 1999 this was on an eroding area of marsh that has since disappeared completely. Patch 7 is also much smaller now; just a few small patches of plants are left. Most plants are still in the western part of the marsh. In the eastern part some new patches have been recorded but these are scattered plants rather than dense patches and there has probably little change in density overall in this area.

Figure 5.1a: Aerial photograph of marsh from 1991 © NERC

Figure 5.1b: Aerial photograph of marsh from mid-2000's © Google Earth

Most of the remaining patches are pure stands of *S.alterniflora (*or scattered *S. alterniflora* amongst other vegetation but these are marked separately*)*. The surrounding vegetation was a mixture of typical species typical of the 'mid-marsh' of the region with *Atriplex portulacoides, Limonium vulgare, Aster tripolium* and *Triglochin maritima* all present in the patches. *Atriplex portulacoides* and *Puccinellia maritima* are particularly abundant.

The salt marsh at Marchwood is a mature marsh with relatively high species diversity. There are patches of *S.alterniflora* growing in pure stands at the seaward of the marsh (e.g. patch 17) adjacent to an eroding section. There were a few tillers on the eroded section, but there is very little colonisation seaward of the erosion front. A few patches of *S. anglica* were recorded on the eroded mud. Most patches of *S. alterniflora* are on high parts of the marsh in areas with high species diversity and the species tends not to occur right on the edges of deep creeks.

Figure 5.2. Marchwood saltmarsh showing *S. alterniflora* populations in 1999 and 2012

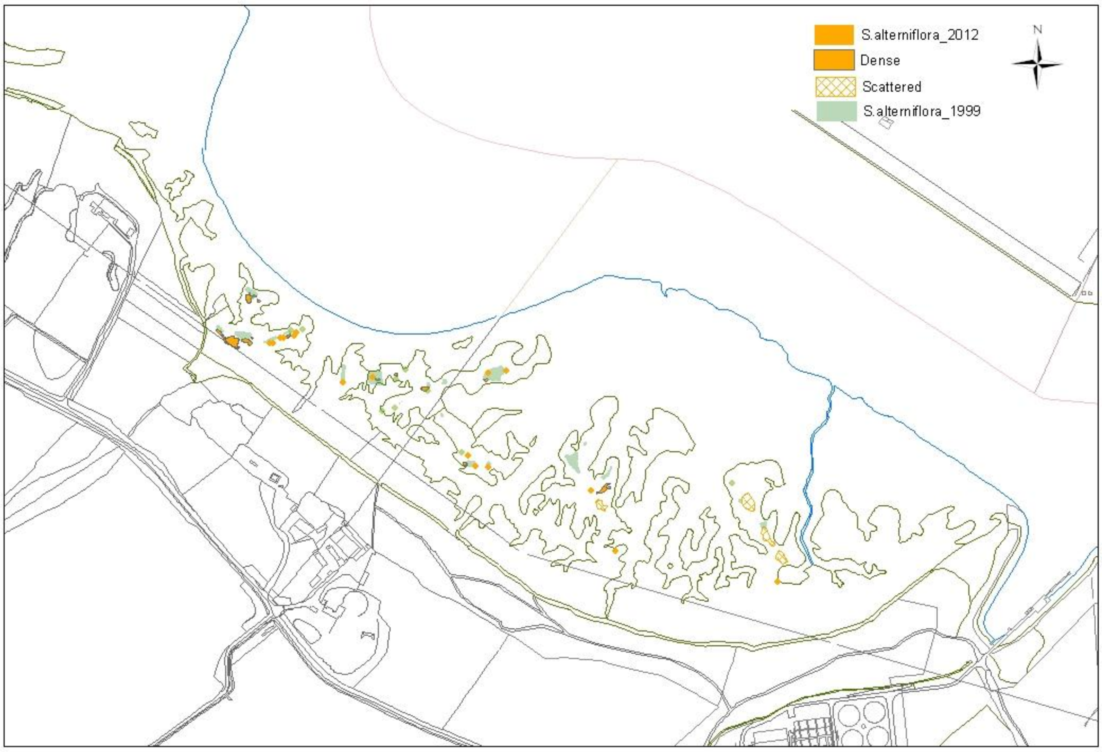
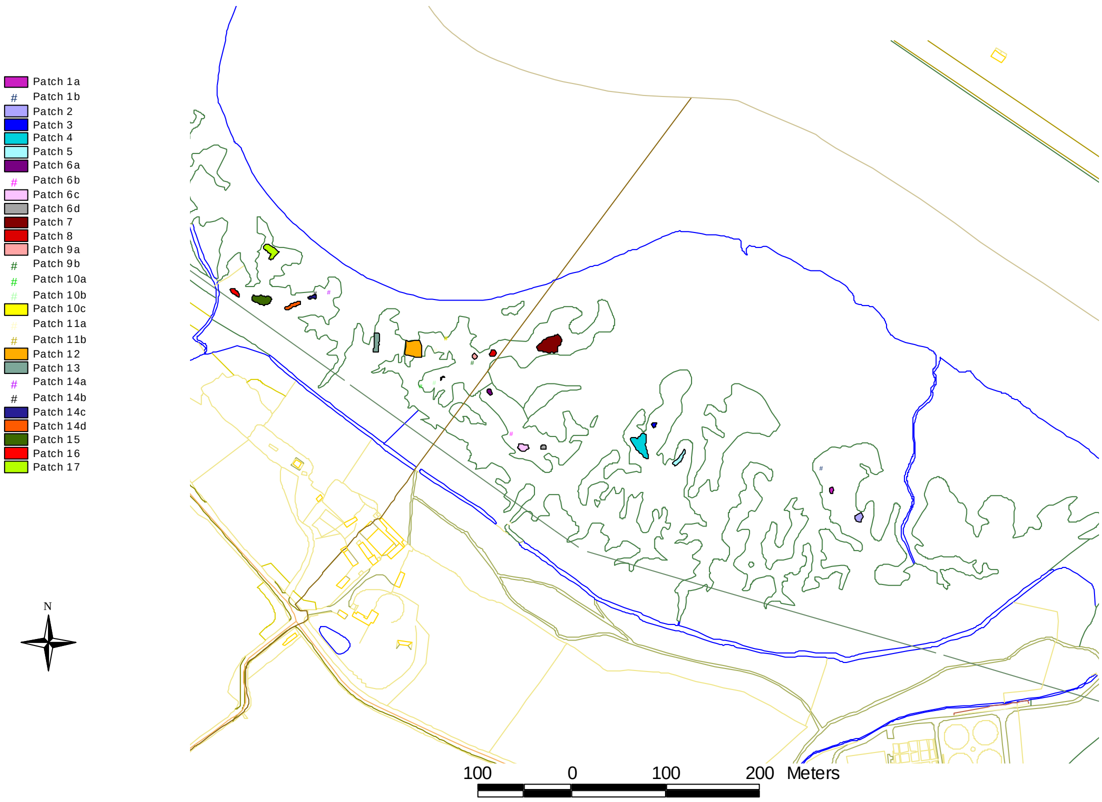
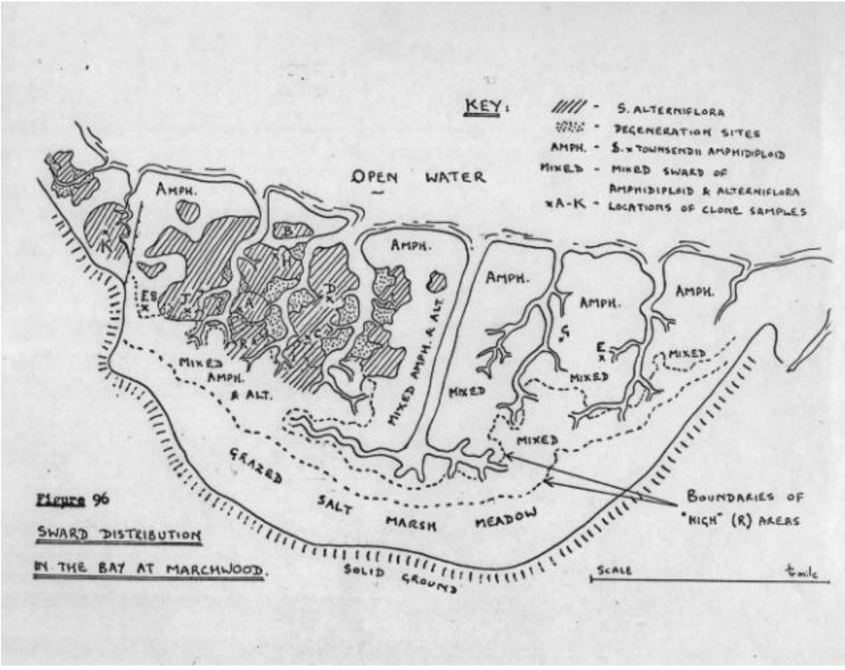


Figure 5.3. The distribution of *Spartina alterniflora* differentiated into individual patches in the 1999 survey



The map in Figure 5.4 shows the distribution of *S. alterniflora* at the site in 1964 (Marchant 1964). This map is only a sketch map so it is difficult to accurately compare the two; however it appeared in the 1999 survey that the abundance of *S. alterniflora* has decreased. In 1964 the eastern side of the marsh contained only mixed stands of *S. anglica* and *S. alterniflora*. These were restricted to the back of the marsh whilst the front of the marsh was dominated by *S.anglica*. Now there are only a few small patches of *S.alterniflora* on the eastern side of the marsh. The *S. alterniflora* is concentrated on the west side of the marsh. In 1964 it was distributed all over this part but has definitely contracted. Marchant (1964) describes some of the stands as degenerate. He noted that although the largest pure stands of *S.alterniflora* grow in the low-lying areas, that these swards are less vigorous and have lower pollen fertility. On the higher sites although other plant species are present the *S.alterniflora* individuals appear to be much healthier.

Figure 5.4 Map of *Spartina* species at Marchwood in 1964



5.2.3 Physical niche and associated vegetation

The degree of tidal inundation has been considered to be a dominant factor influencing plants in the intertidal zone, it affects a number of factors including, degree of anoxia, salinity and build up of chemicals. Determination of the level above Ordnance Datum at which a species occurs should give some idea of the ecological conditions that it prefers or can tolerate and suggest factors that limit its distribution.

In 1999 the topography of the marsh was surveyed using a Pentax Total Station electronic theodolyte. Three transects were established (Appendix 1, Figure 1). The current survey re-surveyed the transect lines, a theodolyte was not used to establish height, instead the Trimble geoexplorer digital GPS was used to record height. Height is not recorded as accurately as spatial location but is still reasonably accurate and does give a good indication of relative height and physical niche. Transect 1 is in the middle of the marsh and encompasses several patches of *Spartina alterniflora*, Transect 2 is to the western side of the marsh and incorporates a particularly low-lying patch of *S.alterniflora* which lies at the back of the marsh near to an equally low-lying patch of *S.anglica*. Transect 3 is found to the eastern side of the marsh where there is far less *Spartina alterniflora* present. Measurements were recorded at each point where the vegetation or topography changed significantly and these have been plotted onto profile diagrams. The plant species found have been related to the height (Ordnance Datum) at which they were found.

5.2.4 Results

The topographic profiles and vegetation from 1999 and 2012 can be seen Appendix 1, Figures 2, 3 and 4. The vegetation found growing at each height has been given an alphabetical code, which is explained in the accompanying tables.

The height at the top of the marsh was slightly lower than in the 1999 survey instead of being between 2m and 2.5m OD it is now under 2m. This could be a methodological issue, however, the profiles in transects 1 and 2 are otherwise quite similar to the previous ones. Transect 3 is different, less creeks have been recorded, possibly there was an issue with re-location. The raised parts of the marsh are all around 1.5m and the creeks around 0.5-1 m. There appears to be no particular pattern for *S. alterniflora* distribution. There is a large patch in a relatively low-lying area near transect 2 which means that it is found at the front and back of the marsh. On transect 1 S*. alterniflora* is found around 1.5m. It occurs on transect 2 from 1.32m to 1.68m with S.*anglica* and at 1.76m on transect 3*. Spartina anglica* is found at 0.9m on transect 1 and from 1.5m OD to 1.6m OD on transect 2.

5.2.5 Conclusions

Spartina alterniflora has declined in abundance slightly at Marchwood since the stands were last mapped in 1999 (and abundance was less then than in 1964 when they were first mapped). Despite this the population remaining appears to be stable in areas where the marsh is not eroding, and the plants appear healthy and vigorous. The time of year in which the survey took place made it difficult to fully assess the vigour of the plants or to examine reproductive success. *S.alterniflora* is found throughout the marsh in both low-lying and elevated areas (vertical limits range from 1.3mOD to 1.8mOD). The only obvious difference between the environmental characteristics and limits to growth required by *S. anglica* and *S. alterniflora* was that *S. anglica* was found to extend slightly higher than *S. alterniflora* (1.88m OD) in its upper limit.

Although not many of the swards contain both *Spartina* species the *S.alterniflora* patches do contain other species such as *Atriplex portulacoides, Limonium vulgare* and *Plantago maritima*. There may be some competitive interactions between species but it is difficult to predict what the outcome of such interactions might be.

6. Reasons for the extinction of *Spartina alterniflora*

6.1 Introduction

A review by McKee and Patrick (1988) looked at a number of studies in the USA where the mean upper and lower limits of occurrence of *S. alterniflora* above Ordnance Datum had been measured using standard surveying equipment. These studies were distributed across a wide geographical area from Portland Maine (latitude 43° 40') to Cedar Key, Florida (29° 09'). The latitude is important because it does appear to play a role in the performance of a species; none of the studies were in as high a latitude as Southampton (50° 55'). In northern marshes the upper limit of *S. alterniflora* was lower than in southern marshes. *S. anglica* appears to perform better than *S. alterniflora* at high latitudes (Daehler and Strong 1996) and has failed to succeed at lower latitudes. The successful invasion of New Zealand suggests that *S.anglica* requires a cool temperate climate rather than high latitudes.

McKee and Patrick (1988) found that the elevational limits of growth of *S.alterniflora* do not correspond to a consistent height above Ordnance Datum but that they did correlate with mean tidal range. *S. alterniflora* extended its elevational range in response to greater tidal amplitudes by extending both the upper and lower boundaries. Tidal range represents the complex interaction of factors, which determine the limits of species distribution such as variation in turbidity and mechanical factors such as water depth and current speed.

6.1.1 Ecology of Spartina alterniflora

One hypothesis concerning the upper and lower limits of growth of *S.alterniflora* is that *S.alterniflora* is restricted to low lying habitats because it is competitively displaced in higher marsh, it copes better with anoxia by production of aerenchyma and the ability to oxygenate roots than its competitors, at higher elevations it is competitively displaced by *Spartina patens* in the USA (Bertness 1991). The plants do not develop the ability to aerate until they have reached a certain size so its success is size dependent. Apparently *S.alterniflora* grows best at salinities of 20 ppt or less, the upper limit for salt tolerance is 60ppt (Morris and Haskin 1990) and the growth of *S.alterniflora* is adversely affected by hypersalinity (Naidoo, McKee and Mendelssohn 1992). Reed (1947) observed that salinity levels in the upper intertidal zone where growth of *S.alterniflora* is reduced were twice as high as low elevations.

S. alterniflora does not appear to set seed successfully in Britain; this is also the case in New Zealand (Partridge 1987). This may relate to climatic differences such as requirement of low winter temperatures for vernalisation. It may be a factor in the decline of *S.alterniflora* populations that only vegetative reproduction is possible. Clones of *S. anglica* decline in vigour with age (e.g. Thompson *et al*., 1991) and it is likely that a similar process occurs in *S. alterniflora*. Marchant (1967) noted that herbarium specimens of *S. alterniflora* collected in the 19th Century are larger than plants growing at Marchwood in the 1960s.

6.1.2 Competition between *Spartina anglica* and *Spartina alterniflora*

There is very little information about competition between *S. anglica* and *S. alterniflora*. *S. anglica* has invaded sites where *S. alterniflora* once occurred. However, it is not known whether this has been responsible for the decline of *S.alterniflora*. Marchant (1964) notes that pure stands of *S.alterniflora* are showing signs of decline even though *S. anglica* is not present, so there are factors responsible other than competition.

Gray *et al.* (1991) described a simple regression model of physical tide-related variables and *S. anglica* distribution. The limits of *Spartina* on south and west coast saltmarshes are predicted well by tidal range. The limits of *S. alterniflora* from the Marchwood site fall within the limits of *S. anglica* suggesting that there is little distinction in niche and vertical limits to growth between the two.

6.2 Sites on the River Hamble

We did not visit sites where it was apparent in the 1999 survey that the salt marsh no longer existed or that the site would be completely unsuitable for *S. alterniflora* (the Hamble at Burlesdon, Lincegrove, Hamble-le-Rice and Warsash where previously *S. alterniflora* was common). There has been less development of the river Hamble than the river Itchen and there are still areas of marsh at Burlesdon (Lincegrove and Hacketts) that are mature marshes, which are within designated sites. *Spartina alterniflora* was last recorded at these marshes pre-1910.

The reasons for decline of *Spartina alterniflora* here are unclear. Unlike the river Itchen it is not due to loss of habitat through development. A transect was established at Hacketts marsh in 1999. That transect was not re-visited in this survey but could be re-visited in the future. The marsh at Lincegrove was visited (photos can be seen in (Figure 6.1). Lincegrove is a mature mixed species marsh. *A. portulacoides* can be found fringing the creeks.

Figure 6.1 Saltmarsh vegetation at Lincegrove marsh, Hampshire

Further down the Hamble on the east side is Bunny Meadows (grid squares 4806 and 4807). There is still some salt marsh here, although *S.alterniflora* has never been recorded here. There is an area enclosed by a seawall at Bunny Meadows that experiences a tidal regime with delayed inundation through culverts. Inside the seawall is a large area of *Spartina anglica*. There was some obvious erosion of the marsh here (Figure 6.2).

Figure 6.2 Saltmarsh vegetation at Bunny Meadows, Hampshire

6.3 Southampton Water

The *S. alterniflora* swards between Hythe and Cracknore Hard have been lost to development. The last population became extinct in 1963 following reclamation at Dibden. South of Hythe, *S. alterniflora* grew on saltmarshes dominated by *S. x townsendii* and *S. anglica.* It is possible that invasion by these species may have played a role in the disappearance of *S. alterniflora* here, although it is not known how extensive *S. alterniflora* was at Hythe. *S. anglica* and *S. alterniflora* must have occurred together because Marchant (1968) discovered backcross plants at Hythe. It is not known whether these plants are still extant.

Between Hythe and Calshot, the shore of Southampton Water is predominantly *S. anglica* dominated saltmarsh, with numerous creeks and mudflats. This part of the coast is within the Hythe to Calshot marshes SSSI. *S. alterniflora* has not been recorded from this area, probably because the marshes are too low-lying. However, in 1986 there were plants with *S. alterniflora*-like morphology at Fawley (A.J. Gray pers. comm. & A.F.Raybold pers. obs.). These plants were taken from sites further upstream and used to restore saltmarsh damaged by effluent from the oil refinery. It is possible that they could be backcrosses between *S. alterniflora* and *S. anglica*.

6.4 River Itchen

The loss of *S. alterniflora* from the River Itchen was explored in 1999 and is due to the loss of marsh habitat and the industrial development of the coastline. There are some small patches of salt marsh vegetation remaining. At the mouth of the Itchen (Weston Point) the shoreline consists of bare shingle and sand with no mud and no vegetation. *S. alterniflora* used to be found all along this stretch of Southampton Water (going East from Weston Point). However, the lack of mud and predominance of shingle make this an unsuitable site to consider re-introduction. Although *S. anglica* swards grow across a wide range of sediments from clays, fine silts, organic muds to more sandy substrates and even shingle, it grows best on clay (Gray *et al*. 1991). It is likely that this is the same for *S. alterniflora*.

6.5 River Test

The river Test has also been developed. The eastern shore now consists of docks and port facilities. The Marchwood site on the western shore is quite isolated now. The next saltmarsh vegetation downstream is at Hythe in Southampton Water. Upstream there is mostly bare mud with a few fragments of *S. anglica*. *S. alterniflora* occurred upstream of Marchwood at Eling, and was present there when Mangham introduced *S. glabra* there in the early 1920s, but according to Goodman and Marchant (1969) the remaining plants were lost to invasion by *Scirpus maritimus* and *S. anglica* in 1960.

6.6 Conclusions

It was established in the 1999 survey of *S. alterniflora* that many of the sites where this species was recorded in the past (before 1910) had already been developed for docks and port facilities. As well as the direct impacts of such developments by loss of saltmarsh habitat there are indirect impacts such as changes in wave action and tidal currents, changes in sediment deposition and pollution which have implications for the whole of the estuary system including the existing site at Marchwood. There has been much erosion of saltmarshes and many areas where *S. alterniflora* used to grow are now low-lying mud or shingle, the saltmarsh having completely disappeared.

At Marchwood the *S. alterniflora* population has declined slightly since 1999. Before this, over a thirty year period (since 1964) there appeared to be a much greater decline although this was based on less quantitative methods (comparison with a rough sketch map made in 1964). Nevertheless, it is reassuring that the changes in the population have been slight. They mostly appear to be related to changes in the marsh structure, erosion and loss of sediment although there may be some effect from competitive interaction with *S. anglica*. The size of the marsh has reduced with increases in the number and size of channels. This may be the result of changes elsewhere in the estuary that have altered tidal movement and scour. Regular dredging of the deep-water channel may be a factor, possibly resulting in an increase in wave energy transfer, or the wakes from the increased shipping movement. There is a container ship facility directly opposite the marsh with regular visits of large container ships. The soft mud at the surface of the marsh may have crept laterally into the deep channel and lowered the level of the overlying marsh. The lowering of the marsh increases waterlogging and tidal immersion of sites. In low-lying waterlogged sites the sediment that is deposited is also more easily removed by re-suspension than sites of higher elevation where it may have a chance to dry out and become part of the marsh surface so the process is cyclical and self-enforcing (Reed and Cahoon 1992).

Two reasons proposed in the 1999 survey that pollution may have affected vegetation generally by weakening the plants and that there may be an age-related decline in vigour because there is no sexual reproduction of *S. alterniflora* in Britain seem less likely in the current time period given that changes have been relatively minor and associated with changes in marsh structure.

7. Recommendations for the conservation of *Spartina alterniflora* in Hampshire

7.1 Conservation and monitoring at Marchwood

There has been a slight reduction in the amount of *S. alterniflora* at Marchwood since the survey in 1999. Much of this appears to be due to saltmarsh erosion. We recommend continued monitoring of the Marchwood site to estimate the rate of change. The information collected from the 1999 survey provided a good baseline with which to monitor future changes at the marsh and compare with the results from the 2012 survey

The methods developed in the 1999 survey were employed for this recent survey and it will be possible to re-survey using these methods in the future and assess changes in distribution to a high degree of accuracy. It would be desirable to survey the populations in the summer, when plants are at their most vigorous, perhaps slightly later than this survey (July) as some plants were only just flowering.

Linking vegetation distribution and change to intertidal height is important and it was useful to repeat this activity, although slightly different methods were used. Given that the major changes on the marsh were associated with marsh erosion and changes in structure it might be useful to set up methods to look at changes in marsh sediment level on a finer scale to try to determine what is causing changes in the marsh area.

The dieback of salt marsh areas due to vertical accretion rate being less than required is a problem experienced in Louisiana salt marshes. In an experiment looking at *S. alterniflora* transplant success, Wilsey *et al.* (1992) found that increasing elevation by only 30cm, by depositing dredging spoil onto saltmarsh prior to transplanting *Spartina,* resulted in successful transplantation. If the dieback of *S. alterniflora* on the remaining sections of marsh since 1964 is due to the loss of sediment, it would perhaps be appropriate to transplant tillers of *S. alterniflora* to areas that have been artificially elevated at selected locations within the site. The low-lying areas at the western end of the marsh might be most suitable for this purpose. However, control of *S. anglica* would be a problem.

7.2 Reintroductions

Re-introduction of *S. alterniflora* is not possible in many of its former sites because the saltmarsh no longer exists due to reclamation or erosion. Hacketts and Lincegrove marshes are the only realistic possibilities. An attempt to introduce *S. alterniflora* into Poole Harbour failed, although the site at Keysworth has a very different topography from Marchwood (Maskell et al 1996) and may not give an indication of the probability of successful reintroduction in the Hamble.

The experiments by Wilsey *et al*. (1992) suggest that the best way to re-introduce *S. alterniflora* is by transplanting tillers into dredging spoil. The chances of success of a re-introduction are unknown and any attempt might damage the nature conservation value of these sites. An additional problem is the source of material for re-introduction. Extensive removal of plants from Marchwood might endanger *S. alterniflora* at that site. If re-introduction was attempted, we recommend that a few plants are removed from Marchwood and bulked up in cultivation before transplantation.

7.3 Creation of new habitat

Transplantation of *S. alterniflora* into existing saltmarshes is unlikely to succeed as competition from other species, particularly *S. anglica*, will probably overwhelm the introduction before it can become established (as probably happened at Poole). The original introduction from the USA invaded bare mud, rather than existing saltmarsh vegetation. It might be possible to recreate these conditions if new mudflats were created from dredging spoil. If new mudflats are being created, then they could be considered as possible new habitats for *S. alterniflora*. Even if the ecological conditions were suitable for the introduction of *S. alterniflora*, there would still be the problem of obtaining sufficient material for transplantation without significant damage to the Marchwood site.

7.4 Conclusions

Based on the findings of this study and the literature review, it is recommended that the best strategy for conservation of *S. alterniflora* to be conservation of its habitat at Marchwood. We recommend periodic monitoring of the site to determine whether erosion at the front of the marsh is continuing and whether *S. alterniflora* populations are being invaded by other species. If erosion is occurring, it will be necessary to consider whether the marsh can be protected. Since dredging already occurs at the Bury swinging ground which has had an impact on the marsh, deposition of dredging spoil at the front of the marsh might be one solution. The marsh may benefit by reducing the amount of dredging within the swinging ground if this were possible.

We do not recommend re-introduction of *S. alterniflora* into the saltmarshes of the Hamble. The chances of success are too uncertain to justify disruption of some of the few remaining species-rich saltmarshes in Southampton Water. We believe it is worth investigating the feasibility of introducing *S. alterniflora* onto any new mudflats that are created in Southampton Water. Multiplication of *S. alterniflora* from Marchwood in cultivation would be the logical first step to any introduction programme.

8. Other *Spartina* species at Hythe

8.1 Introduction

As mentioned previously the *Spartina* taxa in Southampton Water are internationally important because they allow us to study the early stages of polyploid evolution. Polyploids are organisms 'that combine three or more basic genomes of the taxonomic group to which they belong' (de Wet 1980). The saltmarsh between Hythe and the Fawley oil refinery is extremely interesting botanically, as it was here that the hybrid *S.* x *townsendii* was first recorded in 1870 (Groves and Groves, 1882). It is now well known that this species is the result of a cross between *S. maritima* and *S. alterniflora*. During the 1870s the species spread slowly along the south-west shore of Southampton Water. As a result of chromosome doubling in *S. x townsendii*, the fertile amphidiploid species *S. anglica* (C.E. Hubbard 1984) was produced. This plant is seed-bearing and is the form that spread rapidly and colonised large areas of our coastline (Marchant 1964). *S. x townsendii* still grows at Hythe, it is very similar morphologically to *S. anglica*. In 2000 the area was surveyed and a map of *S x townsendii* populations and *S.anglica* was created. The identity and extent of a potentially different species; a *S. glabra* like plant found on the salt marsh at Hythe was investigated in a survey in 2000 (Maskell and Raybould 2000).

S. glabra is a North American species very closely related to *S. alterniflora*. In fact, there is some debate as to whether *S. glabra* is a separate species or a variety of *S. alterniflora*; Stace (1991) describes it as a variety while Hubbard (1984) describes it as a species. F.W. Oliver introduced *S. glabra* into Southampton Water in 1922 (independently of the Marchwood introduction by Mangham) and material from the same source was introduced into Blakeney Point, Norfolk in 1924. The Norfolk material is now extinct. A separate introduction of the species was made into Goldhanger Creek in the River Blackwater (Essex) by J. Bryce in 1935, and material from here was introduced to Udale Bay in the Cromarty Firth in 1947 and 1948 (Raybould *et al*., 1991).

8.2 Identification; Differentiating between *S. townsendii* and *S.anglica*

S. x townsendii and *S. anglica* are very difficult to distinguish in the field particularly at certain seasonal times (i.e. when flowers are not available for examining anthers and leaves have deteriorated). Appendix 1: Table 1 includes characteristics and measurements taken from Hubbard (1984) and Marchant (1964), there are slight differences between the two which is why both sources have been included.

S. x townsendii leaves are distinctly joined to the sheaths making an angle of 30-40° with the stem. High culm density and high tiller density usually distinguish swards of *S. x townsendii*. The usually narrow leaves are also distinctive.

There are a few gross morphological characteristics that unambiguously differentiate *S. x townsendii* and *S. anglica*. The ligule is longer in *S. anglica*, 2-3mm rather than 1-2mm, obviously there is still an overlap in this characteristic. The blade width in *S. anglica* is slightly larger than *S. x townsendii* (between 11-14mm it is more likely to be *S. anglica)*. The anthers are larger in *S. anglica*, 8-13mm rather than 5.5-8mm and exserted under normal circumstances. The sward is less dense in terms of tillers; the leaves are distinctly joined to the sheath and stand at a wide angle with the culm.

Spartina glabra
S. glabra is quite distinctive morphologically, it is closest in form to *S. alterniflora* but is a much larger plant with longer less stiffly held leaves – the leaves have a more drooping habit. The ligule is the same length. The spikelets are slightly shorter than in S. alterniflora

and entirely glabrous except for a few short hairs on the keel. In the 1999 survey two patches were identified where the S. glabra plants were found and an additional patch currently coded as *S. glabra* where the plants appear morphologically intermediate between *S. glabra* and *S.anglica*.

Flow cytometry data on the *S. glabra* plants gave a DNA content very similar to S. x townsendii. The plants with morphology intermediate between *S. glabra* and *S. anglica* had DNA content that was indistinguishable from S. glabra. The most likely explanation of these conflicting data is that the plants are advanced generation backcrosses between S. glabra and S. anglica, with S. glabra as the recurrent parent.

8.3 Methodology

The same methods employed at Marchwood were used to map the distribution of *S. glabra* at Hythe (using a Trimble Geoexplorer digital GPS unit to map patches). Populations of *S. townsendii* and *S.anglica* were not re-mapped. A sample of plants was measured from the northern part of the marsh to check identity (Appendix 1; Table 1). These populations could be re-mapped if required.

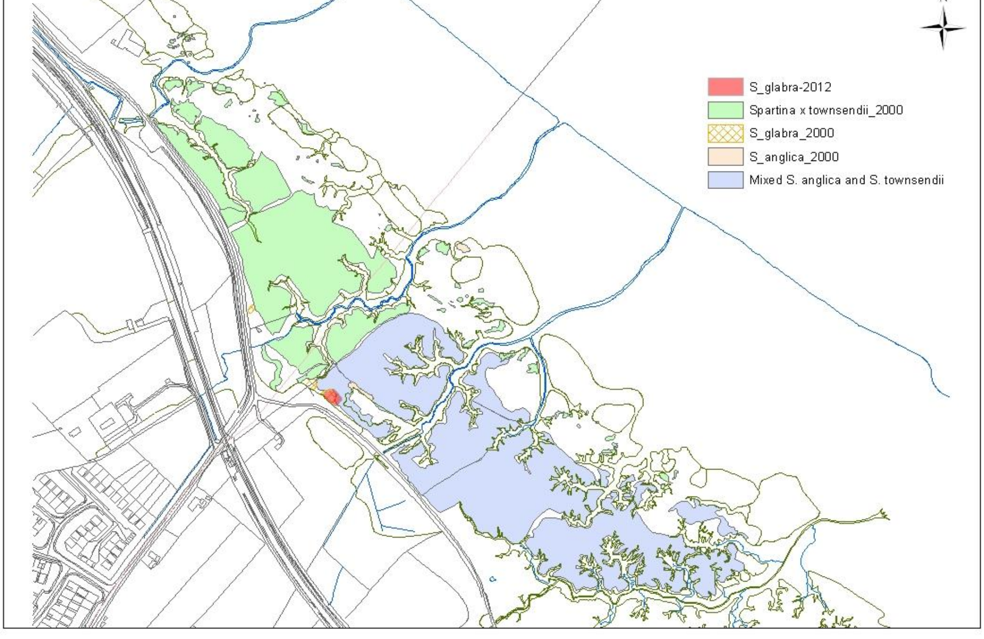
8.4 Results

The distribution of *S. glabra* at Hythe in 2012 can be seen in Figure 8.1 along with the distribution (mapped in 1999) of *S. anglica* and *S x townsendii*. The small patch mapped as potential *S. glabra* is no longer there. One of the other two patches is slightly smaller but the other patch is still present at similar extent and condition. The plant measurements confirmed that the distribution of S x townsendii found in 2000 in the northern part of the marsh was still correct.

8.5 Conclusion

The plants identified as *S. glabra* in 2000 are still present at Hythe. The patches are only small and they are more representative as a source material for genetic study rather than a thriving population. The populations of *S. x townsendii* and *S. anglica* seemed to be in similar positions but a thorough survey was not done. The plant measurements confirmed that *S x townsendii* was present in the northern part of the marsh. A more detailed survey could be carried out here extending along the marsh to Fawley refinery where species of dubious genetic heritage have been found previously.

Figure 8.1 The distribution of *Spartina x townsendii*, *Spartina anglica* and *Spartina glabra* at Hythe. *Spartina glabra* was re-surveyed in 2012.



9. Overall conclusions on the status of saltmarsh transitional habitats and *Spartina maritima* populations in England

This report provides a review of the key species associated with scarce communities of the saltmarsh transition zone at a range of sites in England, including the Annex I habitat H1420*Mediterranean and thermo-Atlantic halophilous scrubs*. The rare Annex 1 habitat H1320 *Spartina swards, Spartinion maritimae* is also included in the review, as are remaining populations of *Spartina alterniflora* in The Solent.

The approach included assessment of presence against previous records and thus provides an indication of changes in recent decades. The data will contribute to site condition monitoring and overall reporting on the status of these habitat types. Some species found in those locations are listed in Section 41 of the 2006 NERC Act, and action to improve their status is an objective of current biodiversity policy in England. In particular the data on *Spartina maritima* helps to take forward an action outlined in recommendations to the Terrestrial Biodiversity Group. This study confirms the value of transition zones for a range of species which are rare. The information presented in this report will contribute to the evidence base needed to implement conservation action, particularly recognising the importance of life history characteristics and dynamics of the environment.

The study concludes that these habitats and the species they support are vulnerable to factors such as coastal squeeze, flood defence maintenance and development. Due to the restricited niches of the species and their limited range and extent, it is important that this new information is considered in advice on operations and in habitat management and restoration or creation.

Repeat surveys of saltmarsh transects in Morecambe Bay enabled an assessment of the quality and scarcity of the upper marsh to freshwater transitions in that area. This aspect of the work confirmed the importance of saline intrusion (by overtopping or seepage where sea defences are present) and water chemistry in maintaining some element of transitional vegetation. Many transitions also showed a limited 'fit' to the NVC.

The priority should be to maintain functioning habitats in situ wherever possible. Where habitat creation takes place within the range of the key species, efforts should be made to create the appropriate niches and take account of soil properties (drainage, pH etc.) and the influence of elevation on tidal inundation. Understanding the degree of sea wall overtopping or seepage of saline water is also important for existing locations or in the design of creation projects.

A repeat survey of *Spartina alterniflora* and other *Spartina* species in the Solent Maritime SAC showed how individual stands had changed since 1999. Losses have occurred due to development and although some locations remain, these remain vulnerable to degradation. Due to the importance of this species in the scientific understanding of evolutionary biology, it is recommended that management of the main site is re-assessed, together with actions to carry out a recovery programme.

10. Data archiving

Data collected as part of this project are held with the Environmental Information Data Centre (EIDC) http://eidchub.ceh.ac.uk/. EIDC coordinates Centre for Ecology & Hydrology data activities and is the Natural Environment Research Council's data centre for terrestrial and freshwater sciences. Species records will be sent to Botanical Society of Britain and Ireland http://www.bsbi.org.uk/ and added to the plant Distribution Data Base and available via the National Biodiversity Network gateway.

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Appendix 1

Figure 1. Map showing *S. alterniflora* populations at Marchwood in 2012 and 1990. Map also includes transects that were re-surveyed.

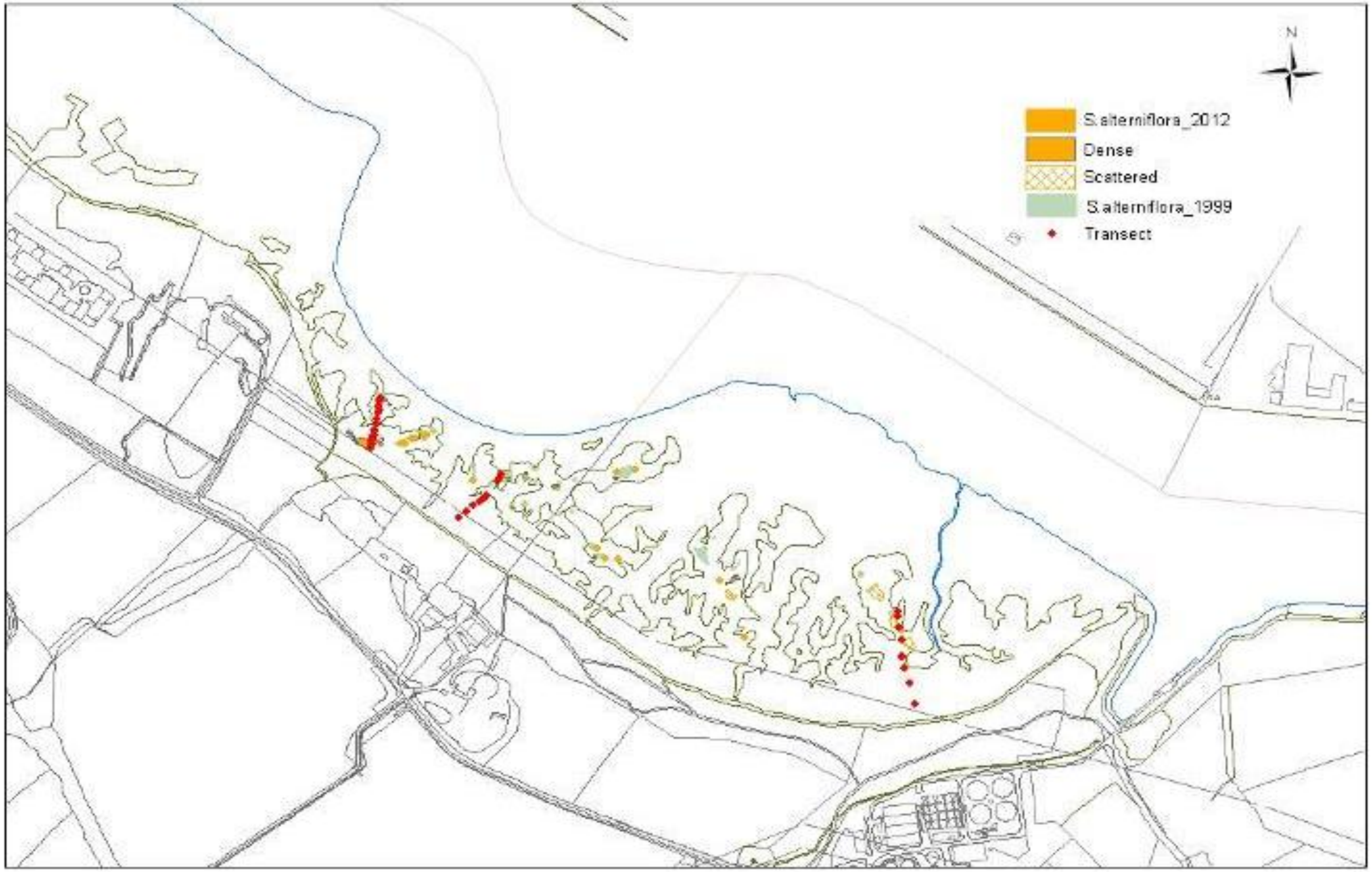
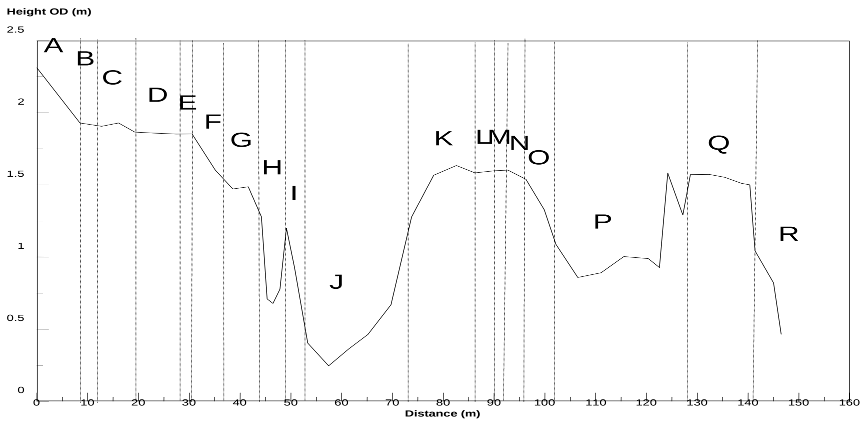
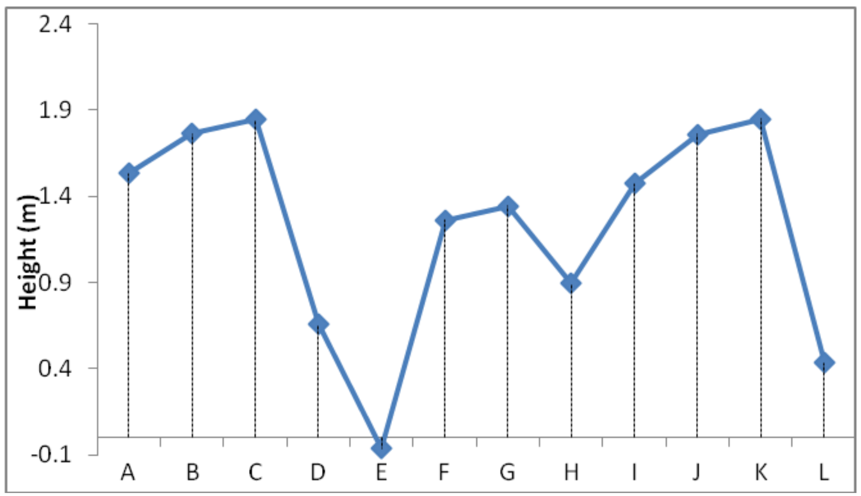


Figure 2. Transect 1



Zone	Vegetation
A	*Festuca rubra, Aster tripolium*
B	*Puccinellia maritima, Spergularia media, Aster tripolium*
C	*Puccinellia maritima, Spergularia media, Aster tripolium, Atriplex portulacoides, Triglochin maritimum*
D	*Puccinellia maritima, Spergularia media, Aster tripolium, Plantago maritima, Spartina anglica*
E	*Puccinellia maritima, Spergularia media, Aster tripolium, Limonium vulgare*
F	*Puccinellia maritima, Aster tripolium, Spartina anglica, Atriplex portulacoides*
G	Top edge of creek, *Spartina anglica, Atriplex portulacoides*
H	Mud, bottom of creek
I	*Spartina anglica, Atriplex portulacoides*, top of bank
J	Mud, bottom of creek
K	*Atriplex portulacoides*, top of creek
L	*Aster tripolium, Atriplex portulacoides, Spartina alterniflora*
M	*Atriplex portulacoides*
N	*Puccinellia maritima, Aster tripolium, Atriplex portulacoides, Plantago maritima*
O	Aster tripolium, Atriplex portulacoides
P	Mud, bottom of creek
Q	*Aster tripolium, Atriplex portulacoides*
R	Mud

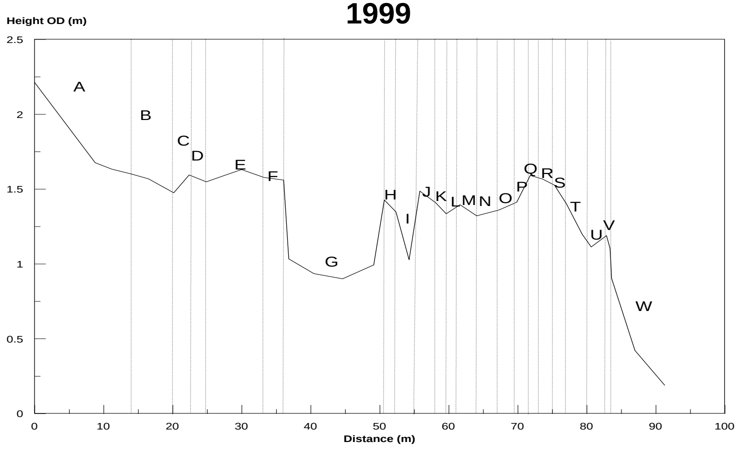
2012



Zone	Notes
A	*Spartina alterniflora* and *Atriplex portucaloides*
B	*Atriplex portucaloides*
C	*Atriplex portucaloides* dominated marsh on top of mud mound
D	mud at foot of cliff
E	mud at foot of cliff (20-30cm mud in between 4 and 5).
F	on top of cliff, *A.portucaloides* dominated
G	*A.portucaloides, Trig, Plantago, Lim.*
H	*Aster, J. gerardii, Plantago, Trig, A. Portucaloides, Spartina anglica*
I	*Plantago, Lim, Festuca, Aster* (old stake)
J	
K	*Plantago, J. gerardii, Aster* (old stake)
L	*Spartina anglica*, bare mound around foot of pylon

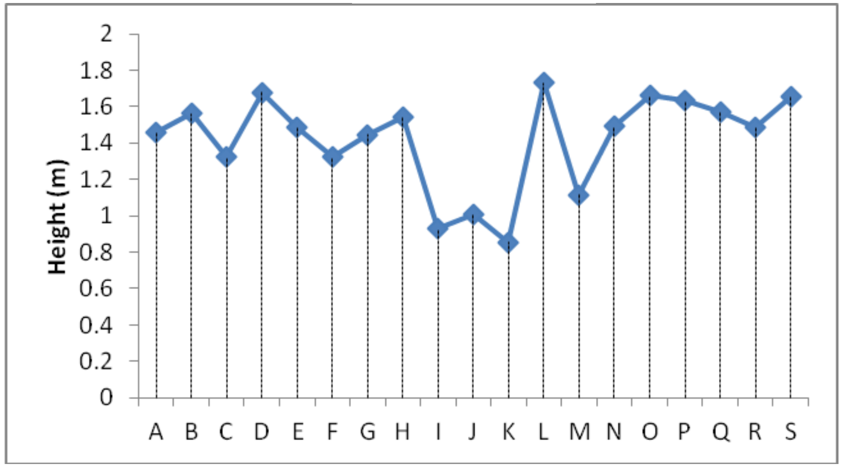
Figure 3. Transect 2

1999



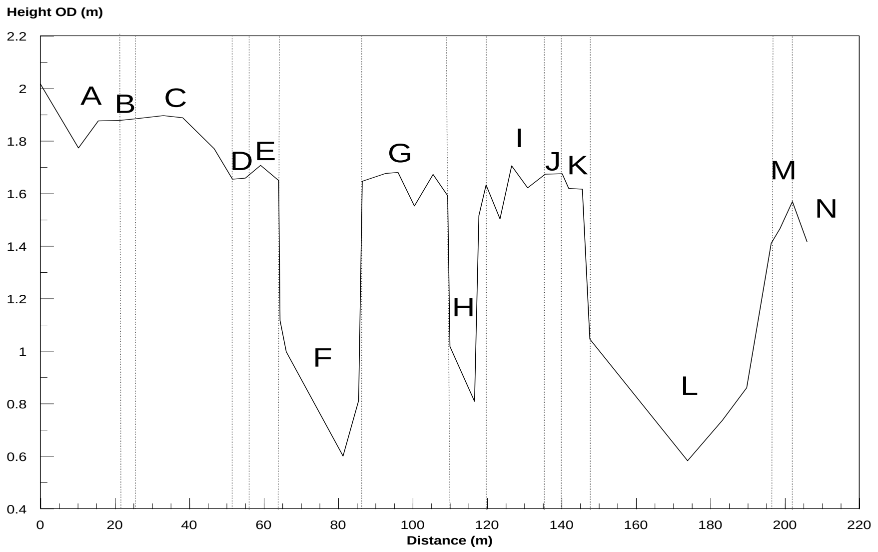
Zone	Vegetation
A	*Spartina anglica, Puccinellia maritima, Limonium vulgare, Aster* tripolium, Plantago maritima, Triglochin maritimum
B	*Puccinellia maritima, Spartina anglica*
C	*Puccinellia maritima, Spartina anglica, Spartina alterniflora, Atriplex portulacoides*
D	*Puccinellia maritima, Spartina alterniflora, Atriplex portulacoides*
E	Puccinellia maritima, Spartina anglica, Atriplex portulacoides
F	*Atriplex portulacoides*
G	Mud
H	Atriplex portulacoides
I	Mud
J	Atriplex portulacoides
K	*Atriplex portulacoides, Spartina anglica*
L	*Spartina anglica*
M	*Atriplex portulacoides, Spartina anglica*
N	Mud
O	*Spartina anglica*
P	*Atriplex portulacoides, Spartina anglica*
Q	*Spartina anglica, Spartina alterniflora*
R	*Spartina alterniflora, Puccinellia maritima, Atriplex portulacoides*
S	*Puccinellia maritima, Spartina alterniflora, Atriplex portulacoides, Spartina anglica*
T	*Spartina alterniflora*
U	Mud
V	*Spartina alterniflora*
W	Mud

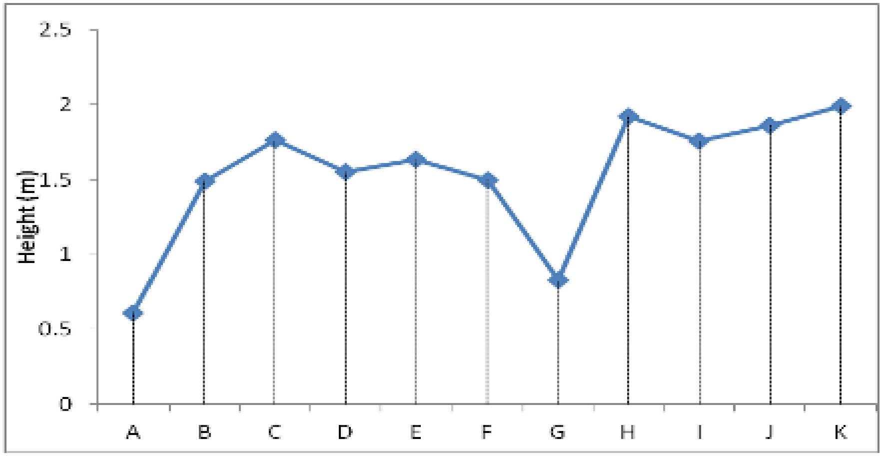
2012



Zone	Notes
A	*S. alterniflora* only
B	*S. alterniflora* only
C	*S. alterniflora* only
D	*S. alterniflora* and *A. portulacoides*
E	*S. alterniflora* only at edge of patch
F	mud
G	*A.portulacoides* only
H	*A.portulacoides* only
I	*A.portulacoides* only
J	mud
K	Cane
L	Top of marsh, bare mud
M	mud
N	small clumps of *S. alterniflora* in bare mud, *A. portucaloides* dominated vegetation on mud cliff with occasional *Limonium* and *Plantago*
O	Start of consistent cover of *A. Portucaloides* to higher marsh
P	*A. portulacoides, Limonium, Plantago*
Q	Prob *S. anglica* with *A. portucaloides*, poss *S. alterniflora* nearby
R	*S anglica* in *A. portucaloides* dominated veg
S	Top edge of *A. portucaloides* zone, start of *J gerardii*, *Trig, Plantago* area

1999 **Figure 4. Transect 3** 2012





Zone	Vegetation
A	*Puccinellia maritima, Aster tripolium, Triglochin maritimum, Spergularia media*
B	*Puccinellia maritima, Aster tripolium, Triglochin maritimum, Limonium vulgare, Spartina anglica*
C	*Puccinellia maritima, Aster tripolium, Limonium vulgare, Triglochin maritimum*
D	*Puccinellia maritima, Aster tripolium, Spartina anglica, Atriplex portulacoides*
E	*Puccinellia maritima, Aster tripolium, Spartina anglica, Atriplex portulacoides,* Limonium vulgare
F	Mud
G	*Puccinellia maritima, Aster tripolium, Spartina anglica, Atriplex portulacoides*
H	Mud (in creek)
I	*Puccinellia maritima, Spartina anglica, Atriplex portulacoides*
J	*Puccinellia maritima, Aster tripolium, Spartina anglica, Spartina alterniflora*
K	*Puccinellia maritima, Aster tripolium, Spartina anglica, Spartina alterniflora, Atriplex portulacoides*
L	Mud, creek
M	Edge of creek, *Atriplex portulacoides*
N	*Puccinellia maritima, Aster tripolium, Spartina anglica, Atriplex portulacoides*

Zone	Notes
A	Mudflat
B	Top of cliff a in dense *A. portucaloides*
C	Dense *A. portucaloides* with scattered *S. alterniflora*
D	Dense (100% cover) of *A.portucaloides* with scattered *S. alterniflora*
E	*Trigonium, Aster, A. portucaloides*
F	Creek edge dominated by *Puccinellia maritima, A. portucaloides*
G	Creek bottom
H	Creek edge dominated by *A. portucaloides, Aster, trigonium*
I	*Festuca rubra, Cochlearia anglica, A.portucaloides*
J	Tall plant, *Aster, J. gerardii*
K	*Festuca dom*. With *Aster*

Table 1. Measurements of *Spartina* plants taken from Hythe

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Stem height	76	58	50	57	48	41	48	64	55	50	32	40	46	44	46
Culms	Robust	moderate	Slender	Moderate	Moderate	Slender	Slender	Slender	Slender	very slender	Slender	Slender	Slender	Slender	Slender
Leaf length	22, 23.5	20, 23	15, 12	17, 16	16, 18	13, 15	12, 12	16, 18.5	7, 13.5	14, 18	10.5, 9.5	11	18, 13	17.5, 19	18, 17
Leaf width (cm)	1, 1.1	1, 1	0.7, 0.6	1, 0.6	0.6, 0.8	0.6, 0.7	0.5, 0.6	0.6	0.4	0.7	0.5	0.6	0.5	0.6	0.6
Ligule (mm)	1	1	1.5	1.5	1.5	1	1	1	2	1	1	1	1	1	1
Leaf Angle (degrees)	40	40	30	45	30	45	40	45	45	40	45	30	40	45	40
Number of spikes	5	4	3	3	3	3	3	3	2	2	2	3	3	3	3
Spike length (cm)	20, 15	13, 14	9, 12	11, 10	13.5	10, 10	8, 7	12.5, 13, 11	12, 14.5	12, 9	7, 6	7, 10	6, 14	10, 12, 11	10, 11, 12
Anther length (cm)	1	1	1.3	1	0.8	0.6	0.6	1	1.5	1	0.5	0.7	0.8		