Improvement Programme for England's Natura 2000 Sites (IPENS) – Planning for the Future IPENS041

Spartina anglica and its management in estuarine Natura 2000 sites: an update of its status and monitoring future change in England

Covers multiple Natura 2000 sites within England

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This project is part of the IPENS programme (LIFE11NAT/UK/000384IPENS) which is financially supported by LIFE, a financial instrument of the European Community.

Foreword

The **Improvement Programme for England's Natura 2000 sites (IPENS)**, supported by European Union LIFE+ funding, is a new strategic approach to managing England's Natura 2000 sites. It is enabling Natural England, the Environment Agency, and other key partners to plan what, how, where and when they will target their efforts on Natura 2000 sites and areas surrounding them.

As part of the IPENS programme, we are identifying gaps in our knowledge and, where possible, addressing these through a range of evidence projects. The project findings are being used to help develop our Theme Plans and Site Improvement Plans. This report is one of the evidence project studies we commissioned.

Common cord-grass *Spartina anglica* is a perennial grass found on mud deposits in the lower intertidal zone and in lower-middle saltmarsh zones across the UK coastline and estuaries. It is of hybrid origin, one of the parent species being non-native, but is now considered to be an endemic native in the UK (Preston et al. 2002). It was widely planted, in the 1920s to 1960s (Ranwell 1967), due to its ability to tolerate periodic flooding by sea-water and support coastal protection and land claim projects. It is also considered to have a detrimental impact on mudflat and saltmarsh biodiversity and processes, but detailed evidence of these impacts is limited.

This study had three main objectives: to update evidence on the presence of *S. anglica* within Natura 2000 sites; to understand under what circumstances its presence may pose a risk to the achievement of favourable condition for other features of Natura 2000 sites; and to update guidance on monitoring and the types and appropriateness of management measures.

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Finally, we thank Sue Rees, Rachael Mills, Graham Weaver, Nikki Hiorns and Stewart Angus for their comments on the draft of this report.

Executive summary

Common cord-grass *Spartina anglica* is a perennial grass found on mud deposits in the lower intertidal zone and in lower-middle saltmarsh zones across the UK coastline and estuaries. It is of hybrid origin, one of the parent species being non-native, but is now considered to be an endemic native in the UK (Preston et al. 2002), but could be considered as non-native locally where it was planted. It was widely planted, in the 1920s to 1960s (Ranwell 1967), due to its ability to tolerate periodic flooding by sea-water and support coastal protection and land claim projects. It is also considered to have a detrimental impact on mudflat and saltmarsh biodiversity and processes, but detailed evidence of these impacts is limited.

This study, part of the EU LIFE+ supported Improvement Programme for England's Natura 2000 Sites, had three main objectives: to update evidence on the presence of *S. anglica* within Natura 2000 sites; to understand under what circumstances its presence may pose a risk to the achievement of favourable condition for other features of Natura 2000 sites; and to update guidance on monitoring and the types and appropriateness of management measures.

S. anglica is known to trap sediments, which can increase the height of saltmarsh and lead to a reduction in mudflat and pioneer saltmarsh habitats, including eelgrass *Zostera* beds and glasswort *Salicornia* communities. There is also evidence of an increase in erosion on the seaward side of *Spartina anglica* and where it is experiencing dieback. Nevertheless, there is evidence of *Spartina anglica* co-dominating with *Salicornia* in mixed communities where only *S. anglica* was known previously, possibly due to a decrease in accretion rates. Whether changes to sediment regimes caused by *S. anglica* have an overall positive or negative effect on saltmarshes is unclear.

S. anglica has been shown to be negatively associated with macro invertebrate numbers and bird-feeding areas, though causal links that suggested *S. anglica* was responsible were not identified. Other factors may have led to reduced invertebrate numbers and subsequent value to birds, whilst at the same time increasing the chances of *S. anglica* establishment.

The previous estimate of the extent of all *Spartina* species was based upon survey data that is now over 25 years old (Burd 1989). A more recent estimate of *S. anglica* that excluded other *Spartina* species was required, but was hampered by the lack of recent survey data. In contrast, data showing the distribution of *S. anglica* were more readily available than previously.

Data were collated from the National Biodiversity Network (NBN) Gateway and from a variety of Natural England, Environment Agency and third party datasets. These were used to indicate the distribution and extent of *S. anglica* nationally, and within Transitional Waters and Natura 2000 sites. The distribution of *S. anglica* appeared to be relatively stable, having changed little since 1970. Due to lack of suitable survey data, the extent of *S. anglica* in England could best be regarded as being over 751 ha, though we considered this to be a gross underestimate.

The *S. anglica* monitoring protocol was developed based upon existing survey methodologies and aimed to collect information that could be used to determine the extent of *S. anglica*, to help decide whether management was required. Draft survey forms were tested on sites in the Severn Estuary, Essex coast and North Northumberland Coast, resulting in improvements where required. Forms and detailed guidance for the survey protocol are provided.

The review of *S. anglica* control techniques covered physical removal, cutting, grazing, smothering, rotoburying, treatment with herbicides and biological control. Physical measures combined with

use of herbicides could be an effective strategy to control single-species stands. However any control of *S. anglica* should be undertaken cautiously and based upon sound evidence, as its removal was likely to result in sediment discharge and potential impacts on designated features. Most Natural England staff questioned were not aware of management being undertaken to control *S. anglica* on protected sites. A management decision flow chart was created, based upon the literature review undertaken, which aims to help managers of Natura 2000 sites decide where management is most appropriate.

Recommendations were made for further testing and development of the survey protocol, as well as extensive survey based on remote sensing and field survey to determine the extent of *S. anglica*. Further research into the relationship between *S. anglica* and sediment and the effect of climate change was also recommended. Further more comprehensive reviews of the impact of *S. anglica* and its historical spread, both natural and through human introductions, were also recommended.

Contents

1 Introduction

1.1 Background

The subject of this report is common cord-grass *Spartina anglica* CE Hubbard (Figure 1), a large sturdy perennial grass found on mud deposits in the lower intertidal zone and in lower-middle saltmarsh zones across the UK coastline and estuaries (Hubbard 1992).

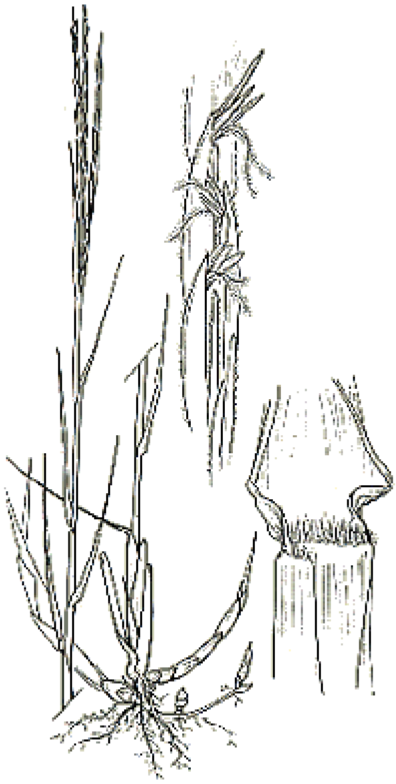


Figure 1 – *Spartina anglica* habit and floret and ligule. From: http://ausgrass2.myspecies.info/content/spartina-anglica. © Australian Biological Resources Study.

S. anglica has had a complicated taxonomic history that is centred on the UK. Until the early nineteenth century small cord-grass *Spartina maritima* was the only species of its genus known in the UK. In 1836 the discovery of the closely related American species, smooth cord-grass *Spartina alterniflora* was reported in the area now known as the Hythe *Spartina* Marsh in Southampton (Bromfield 1836). It is believed that *S. alterniflora* was carried across the Atlantic in ships' ballast water (Eno et al. 1997). In 1879 an infertile hybrid of *S. maritima* and *S. alterniflora* was discovered and later named Townsend's cord-grass *Spartina* × *townsendii* (Groves and Groves 1881). The hybrid undertook wild amphidiploidy, which doubled its chromosome count and restored its meiotic regularity and fertility. This amphidiploid, *S. anglica*, was first collected in the 1890s (Gray et al. 1991), but was not formally recognised as distinct from *S.* x *townsendii* and fertile until much later (Hubbard 1968). In the intervening period between the first record of *S. anglica* and its description, the species aggressively expanded across the south coast of England (Eno et al. 1997). All four species are still present within the UK and much research is available relating to the exceptional evolutionary leap discussed above (e.g. Renny-Byfield et al. 2010; Ayres and Strong 2001; Gray et al. 1991; Raybould et al. 1991; Gray and Raybould 1997), but comparatively little work has been undertaken to assess the impact of the species on UK habitats.

Spartina anglica is a hardy species able to tolerate periodic flooding by sea-water. Its ability to trap sediment and promote the accretion of mud deposits on intertidal flats resulted in large scale plantings outside their natural range, along with some other members of the genus, to support coastal protection and land claim projects worldwide between the 1920s and 1960s (Ranwell 1967). Subsequently *S. anglica* is now present on many temperate coastlines globally (Minchin 2008). These stabilising properties and the expansion of *S. anglica* across the UK coastline needs to be addressed when setting conservation objectives for protected sites.

Until relatively recently *S. anglica* was treated as a non-native species in the UK, but Preston et al. (2002) considered it to be an endemic native in the latest Atlas of the British Flora. This assessment was subsequently repeated by Stace (2010). The Water Framework Directive recognises it as a 'high impact' alien species affecting water bodies. However, at a local level its native status remains unclear, as there is limited information defining where it spread naturally and where it was planted.

S. anglica may be considered to be invasive both within and outside its native range, as it can form dense stands that exclude all but a few species. Research implicates *S. anglica* as a cause for decline in glasswort *Salicornia* and eelgrass *Zostera* (Gray et al. 1997; Doody 1990; Le Goff et al. 1989), both key components of habitats protected under Annex I of the Habitats Directive (Joint Nature Conservation Committee 2014a). Nevertheless, the interaction of *S. anglica* and *Salicornia* may not be simple and there are suggestions that it may equally lead to direct competition, facilitation and expansion of the Annex I *Salicornia* habitat (Huckle et al. 2004). To complicate matters, *Spartina* swards are also protected under Annex I of the Habitats Directive but only formerly recognised within the UK where *S. maritima* or *S. alterniflora* occurred (European Environment Agency 2014; Joint Nature Conservation Committee 2014b). It has also been suggested that *S. anglica* may reduce the ecological value of tidal flats as habitats for wading birds (Davis and Moss 1984; Millard and Evans 1984; Evans 1986; Davidson and Evans 1987).

The mixed understanding of the impacts of *S. anglica* on designated features, and implications for the Water Framework Directive, has led to a range of conservation management objectives focused on contradicting interpretations of the species' status, ranging from actively promoting *S. anglica* to seeking to control or eradicate the species. In extreme cases, eradication strategies have been developed for whole regions and countries including Northern Ireland and Tasmania (Hammond 2001; Kriwoken and Hedge 2000, Lacambra 2004).

1.2 The IPENS programme

The Improvement Programme for England's Natura 2000 Sites (IPENS), supported by EU LIFE+, is a new strategic approach to managing England's Natura 2000 sites. It will enable Natural England, the Environment Agency, and other key partners to plan what, how, where and when they will target their efforts on Natura 2000 sites and areas surrounding them.

This project is part of the IPENS programme (LIFE11NAT/UK/000384IPENS) which is financially supported by LIFE, a financial instrument of the European Community.

1.3 Objectives

An understanding of the extent of *S. anglica* dominated swards was required to assess the significant repercussions for related habitats of the expansion and decline of the species. Further research was also needed to understand and, where possible, to quantify the positive and negative impacts of *S. anglica*, particularly on Natura 2000 sites where regular monitoring and reporting of Annex I habitat types is required under Article 17 of the Habitats Directive.

Natural England required an investigation into *S. anglica* on Natura 2000 sites in England and an update to the information in the previous Natural England review (Lacambra et al. 2004). This required an assessment of the available data on *S. anglica* distribution and extent, as well as a review of recently published literature. They also required a survey methodology to be developed that could be used for future monitoring and mapping of *S. anglica* and collect information to help determine its impact on protected sites.

The specific objectives for this work were to:

- Investigate the positive and negative effects of *S. anglica* on other biota, focusing specifically upon those species and habitats relevant to the Natura 2000 network in England.
- Estimate the extent and distribution of *S. anglica* dominated habitat in England based on recent data, detailing any limitations of this estimate.
- Develop a *S. anglica* monitoring methodology that enables the identification and mapping of mixed *S. anglica* stands
- Test the methodology on a small number of case study sites with different stages of *S. anglica* development.
- Review recent information and guidance on *S. anglica* management.

2 *Spartina anglica* within Natura 2000 sites in England

Spartina anglica is identified as a component of the Annex I Habitat type 'H1320 - *Spartina* swards (Spartinion maritimae)', which is described as 'Perennial pioneer grasslands of coastal salt muds, formed by *Spartina* or similar grasses' (European Environment Agency 2014). The Annex I habitat types are used in the selection of Special Areas of Conservation (SACs). As with many Annex I habitats, different EU member states categorise and describe the habitat type differently. Some member states include any *Spartina* species found in coastal areas, while others stipulate the presence of *Spartina* species other than *S. anglica*.

In the UK, the Joint Nature Conservation Committee (JNCC) has only selected SACs for H1320 that have stands of *Spartina maritima* or *Spartina alterniflora,* or if they include the rare and local hybrid *Spartina* × *townsendii* (JNCC 2014). Only the Essex Estuaries and Solent Maritime SACs are selected on the basis of *S. maritima*, *S. alterniflora* or *S.* × *townsendii*, although they are also present in Suffolk and The Wash (Joint Nature Conservation Committee 2007; 2013 and Garbutt, A. (in preparation)). However, *Spartina anglica* dominated swards are included and reported within European assessments of H1320, with all *Spartina* swards assessed together. The UK assessments currently indicate that the status of H1320 is 'Bad-Stable' (JNCC 2013) while the wider European assessment indicates the status as 'Unfavourable bad', due to the presence and/or dieback of *Spartina anglica* (European Environment Agency 2009). The varying approaches to H1320 reporting indicate that it is not clear how to appraise the presence of *S. anglica.* For example, in the UK it is highly unlikely that *Spartina* swards dominated by *S. maritima* would have ever reached the abundance and range that *S. anglica* now occupies, so to ascribe all locations of *S. anglica* as a cause for loss of *S. maritima*, where it is outside of its range, is inappropriate. Distribution maps from the European Environment Agency (2009) reporting show that H1320 is recorded from all across the UK, while the UK reporting indicates a limited distribution around south-east England (Joint Nature Conservation Committee 2007; 2013). *S. anglica* can also be recorded in a number of other Annex I habitats (Table 1).

S. anglica may also be present in other habitats, but is unlikely to cover large areas and require monitoring and management unless these habitats are undergoing a habitat phase shift, where an ecosystem switches into a new regime which may impact on its resilience (Beisner et al. 2003). *S. anglica* usually acts as a pioneer species on intertidal mud and sand flats, creating a narrow to wide band of *S. anglica* dominated or mixed species vegetation at the front of saltmarshes; but it can also occur in other parts of a saltmarsh where there are elevated salinity levels such as some salt pans and lagoons; as a pioneer species at the front of dune or shingle features where there is a substantial increase in muddy sediments; and as a non-dominant part of a mosaic within Atlantic salt meadow vegetation.

Marine angiosperms (saltmarsh and seagrass) are used as one of the biological quality elements for assessing the ecological status of coastal and transitional waters under the Water Framework Directive (European Commission 2000). Data required include vegetation samples, area estimates and vegetation classification. Although the presence of *S. anglica* in vegetation swards will be recorded and dominated areas mapped, no further data about *S. anglica* is provided through Water Framework Directive assessments to appraise management requirements. However, *S. anglica* is considered as an aquatic alien species with a 'high impact' by the UK's technical advisors for the WFD (UK Technical Advisory Group on the Water Framework Directive 2014).

The following sections investigate both the positive and negative effects of *S. anglica* on key features of Natura 2000 sites and habitats.

Table 1 - Annex I habitats identified within the Habitats Directive that can support and *Spartina anglica* occur within.

Annex I Code	Habitat Description
H1110	Sandbanks which are slightly covered by sea water all the time
H1130	Estuaries*
H1140	Mudflats and sandflats not covered by seawater at low tide*
H1150	Coastal lagoons
H1210	Annual vegetation of drift lines
H1310	*Salicornia* and other annuals colonizing mud and sand*
H1320	*Spartina* swards (Spartinion maritimae)*
H1330	Atlantic salt meadows (Glauco-Puccinellietalia maritimae)*
H1420	Mediterranean and thermo-Atlantic halophilous scrubs (Sarcocornetea fruticosi)

The habitats identified with a '*' are the habitats where *Spartina anglica* can be common and become an ecosystem engineer, modifying the dynamics of the habitat.

2.1 Effects on bird-feeding areas

Previous studies have highlighted the risk of *S. anglica* invading wildfowl and wader feeding areas and the possible impact on bird populations (Madden et al. 1993; Gray et al. 1991). Waders are likely to be affected by *S. anglica* invasion, as dense stands physically prevent their access to invertebrate prey species inhabiting the sediments of *S. anglica* swards (Hammond and Cooper 2003).

Some of the first studies to investigate the negative effects of *S. anglica* on wildfowl and waders were on dunlin, *Calidris alpina*. One of the most significant studies was undertaken by Goss-Custard and Moser (1988; 1990), where the rate of dunlin decline across different estuaries was compared with changes in the abundance of *S. anglica* from 1971-1986. They found that dunlin numbers declined at the highest rates in estuaries where *S. anglica* had expanded the most significantly throughout that study period, while dunlin populations remained stable in other estuaries. Although this study identified a direct association between increases in *S. anglica* extent and decline in dunlin populations, it does not identify a causal effect. It is possible that an external factor changed conditions within the estuary to allow *S. anglica* to expand and Dunlins to decline (Gray et al. 1991), or that the expansion took place in the areas most favoured by Dunlin (Doody 2001). Conversely, common redshank, *Tringa totanus*, are reported to be able to feed within *S. anglica* stands (Gray et al. 1991).

No further studies on the effects of *S. anglica* on birds (post-2000) were located in this literature review, but most papers reference the studies from the 1980s. Bird observations from Anderson Inlet in Victoria, Australia have shown that the majority of wading birds avoid *S. anglica* dominated mudflats (Simpson 1995) with similar patterns observed in Tasmania (Hedge and Kriwoken 2000).

2.2 Effects on macro-benthos

Studies of benthic macro-invertebrate communities in the River Stour found species richness to be higher in mudflat communities than in adjacent *S. anglica* marsh (Long and Mason 1983). The inverse was found in studies undertaken in Tasmania where higher species richness and total abundance of invertebrates on *S. anglica* stands compared with mudflats (Hedge and Kriwoken 2000). Other studies have shown that some burrowing invertebrate species are negatively associated with the density of *S. anglica* roots and rhizomes (Capehart and Hackney 1989).

Management treatments on *S. anglica* using uprooting and removal treatments have been assessed as having a low risk of affecting macro-invertebrates, but this seems to be related to the low numbers of invertebrate species in areas that are dominated by *S. anglica* (Cottet et al. 2007).

A decrease in species richness and/or abundance in macro-invertebrate species (such as gastropods, bivalves, annelids and anthozoa) within *S. anglica* stands would have a direct negative effect on wading birds that require macro-invertebrate food sources. The risk of overall reductions in macro-invertebrate abundance and diversity due to *S. anglica* establishment across UK intertidal habitats requires further consideration.

A direct link between *S. anglica* root and rhizome density and burrowing invertebrates is suggested, which might explain a decrease in macro-invertebrate numbers in *S. anglica* areas. The ability of *S. anglica* to modify sedimentation regimes across mudflats and saltmarshes could also be responsible for decreasing macro-invertebrate numbers.

Hughes and Paramor (2001) proposed the abundance of the ragworm *Hediste diversicolor* as a possible driver of erosion on mudflats and saltmarshes in south-east England. This hypothesis references damage and change in benthic communities caused by *H. diversicolor* through bioturbation. In addition, laboratory experiments demonstrated *H. diversicolor* has the ability to bury seeds of key saltmarsh plants. While there is some over-simplification of the overall processes as a driver of widespread erosion on the south-east coast (Morris et al. 2004), further research by Paramor and Hughes (2007) showed that *S. anglica* was able to establish quickly across hessian mats laid across the surface of mudflats to exclude herbivory by *H. diversicolor*. Other authors have concluded that physical factors are more significant drivers of erosion than bioturbation (Wolters et al. 2005) and have highlighted the need for further research into the interaction between benthic species and their interaction with sedimentation processes, including *S. anglica* colonisation.

2.3 Effects on sedimentation regimes

S. anglica has long been utilised as an ecosystem engineer[1] by land managers, due to its ability to modify physical environmental parameters of mudflats. Its ability to trap sediment is well documented (Adam 1990). The trapping of sediment tends to change the structure of mudflats and is observed to create ‘hummocks’ of mud behind the seaward border of *S. anglica* (Gray et al. 1991). These changes can lead to the burying of previous mudflat habitat (including the associated flora and fauna), increases in the height of saltmarsh sediments and reductions in the available area for pioneer marsh, such as *Salicornia* marsh (Adam 1990; Huckle et al. 2004).

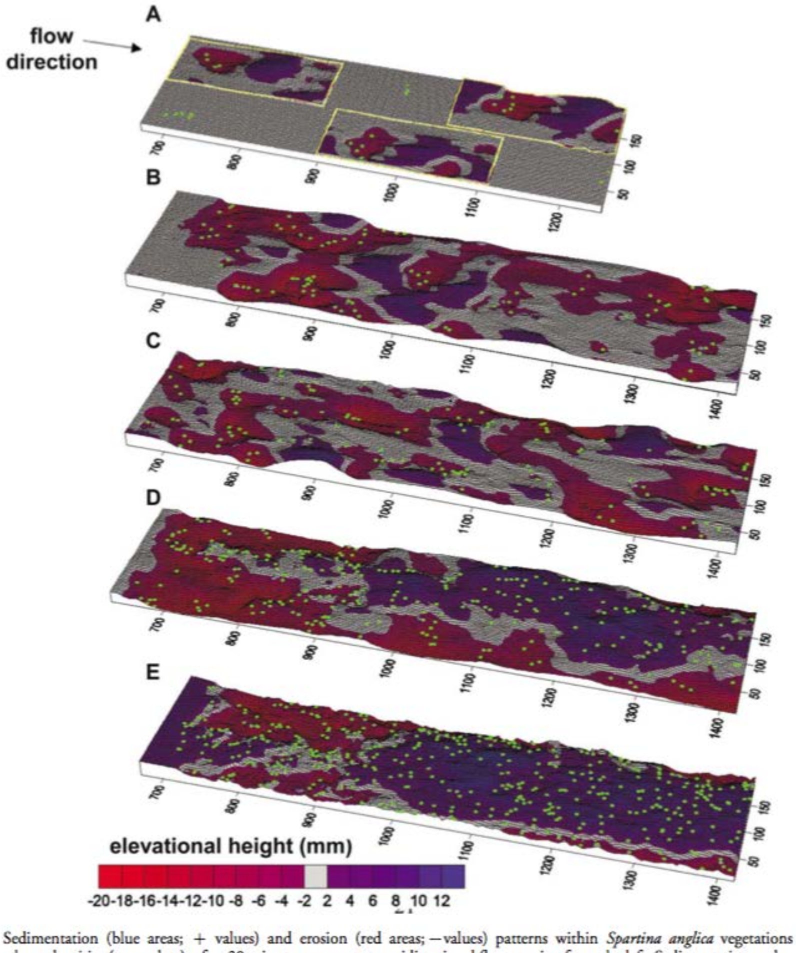
Associations between sediment deposition and the spatial spread and abundance of *S. anglica* were investigated in ex-situ experiments using a flume (T. J. Bouma et al. 2009). Five densities of *S. anglica* shoots were investigated. Sediment deposition was observed both within the *S. anglica* sward and in adjacent areas. The results corroborate previous field observation indicating sediment accretion landward of *S. anglica* swards, but the erosion of sediment was higher beneath the *S. anglica* shoots most exposed to tidal action. Previous authors have suggested that mud deposits are ‘locked’ out of the estuary system in hummocks landward of *S. anglica* stands (Gray et al. 1991). Sediment deposition was observed to be dependent on *S. anglica* shoot density with greater than 1,900 shoots per square metre exhibiting significantly more sediment accretion than lower densities (Figure 2). In addition, significant sediment erosion effects were observed in areas

[1] Ecosystem engineers are organisms that create, modify and maintain habitats (Jones et al. 1994).

adjacent to *S. anglica* samples. The depth of erosion in areas adjacent to the *S. anglica* samples increased with *S. anglica* shoot density (Figure 3). These findings from the adjacent areas were not linked to scouring effects. Scouring was observed at the bases of individual plants within samples with increasing incidence and depth linked to plant density.

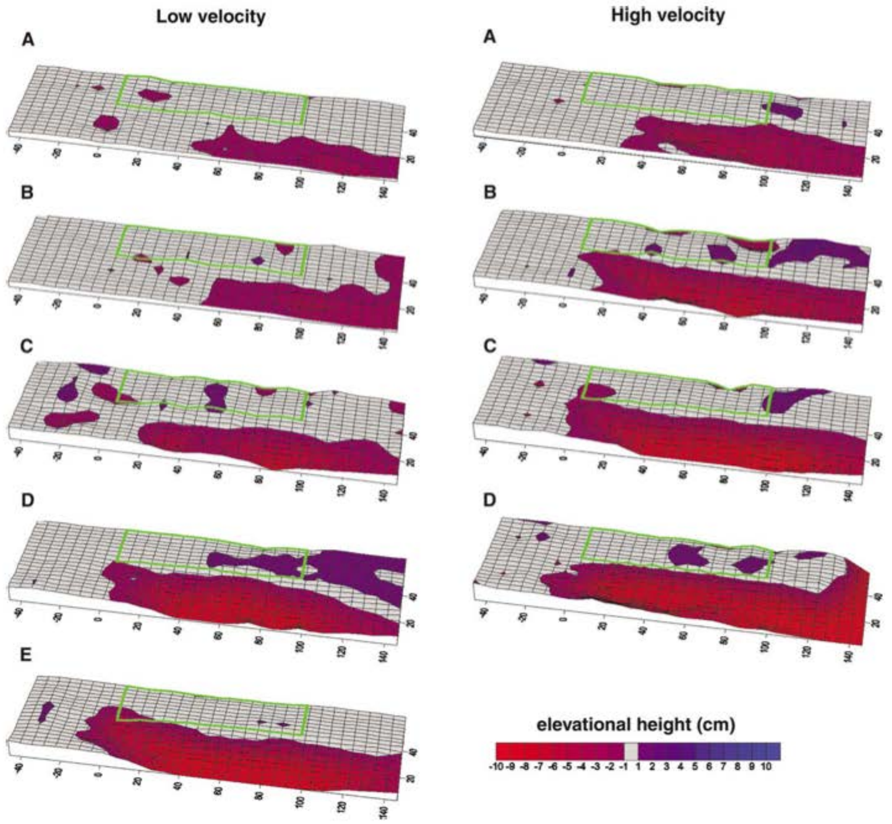
These results indicate that although *S. anglica* might be beneficial to saltmarshes by promoting sediment deposition, it can also be very damaging to saltmarshes and mudflats that are located adjacent to *S. anglica* swards by increasing the rate of sediment erosion (T. J. Bouma et al. 2009).

Not only are there risks of significant changes to the available sediment in estuarine ecosystems from establishment of *S. anglica*, there are also risks of sediment discharge relating to the removal of *S. anglica* through management treatments or natural processes. For example, a study investigating *S. anglica* dieback in Poole Harbour found that cadmium levels in the harbour (caused by previous pollution incidents) were concentrated within the sediments beneath *S. anglica* swards (Hübner et al. 2010). There is a high risk of rapid release of locked-up sediment and cadmium deposits in Poole Harbour if further large scale *S. anglica* die-back occurs.



Sedimentation (blue areas; + values) and erosion (red areas; −values) patterns within *Spartina anglica* vegetations with contrasting shoot densities (green dots), after 30 minutes exposure to unidirectional flow coming from the left. Sedimentation and erosion are represented relative to the initial soil surface height (grey area). Color codes and height classes are arbitrarily chosen to maximize the clarity of the figure. Free stream current velocity was 0.35 m s^{-1}. Vegetation densities range between 240 (A), 550 (B), 800 (C), 1900 (D) and 2800 (E) shoots per square meter. Detailed description of the vegetation characteristics are listed in table 1. The numbers on the axis (mm) indicate the position inside the flume test section. For the lowest vegetation density, surface elevation was only measured for the areas within the yellow lines.

Figure 2 - Results of ex-situ experiments on the influence of *Spartina anglica* on sedimentation and erosion, from Bouma et al. (2009).



Sedimentation (blue areas; + values) and erosion (red areas; —values) patterns adjacent to a patch of *Spartina anglica* vegetation (location indicated by green line) with contrasting shoot densities, after 30 min exposure to unidirectional flow coming from the left. Sedimentation and erosion are represented relative to the initial soil surface height (grey area). Note the magnitude scale difference in color coding, when comparing to Fig. 1. Color codes and height classes are arbitrarily chosen to maximize the clarity of the figure. The graphs on the left were exposed to a free stream current velocity of 0.3 m s^{-1}, those on the right to a free stream velocity of 0.4 m s^{-1} (Fig. 5) Vegetation densities range between 330 (A), 550 (B), 860 (C), 1330 (D) and 2520 (E) shoots per square meter. Detailed description of the vegetation characteristics are listed in Table 1. The numbers on the axis (cm) indicate the position inside the flume test section.

Figure 3 - Results of ex-situ experiments on the influence of *Spartina anglica* on sedimentation and erosion in neighbouring areas, from Bouma et al. (2009).

2.4 Effects on saltmarsh and mudflat vegetation

S. anglica is often considered to be an indicator of negative condition within saltmarsh vegetation swards and is considered to alter the dynamics of the vegetation communities to an ‘un-natural’ state. However, natural succession from *S. anglica* dominated stands is well recorded (from 1926 onwards; Figure 4) including: succession to common saltmarsh-grass *Puccinellia maritima* communities; invasion of *S. anglica* stands by large brackish swamp species such sea club-rush *Bolboschoenus maritimus* and common reed *Phragmites australis*; and succession to sea rush *Juncus maritimus* or red fescue *Festuca rubra* upper marsh (Gray et al. 1991).

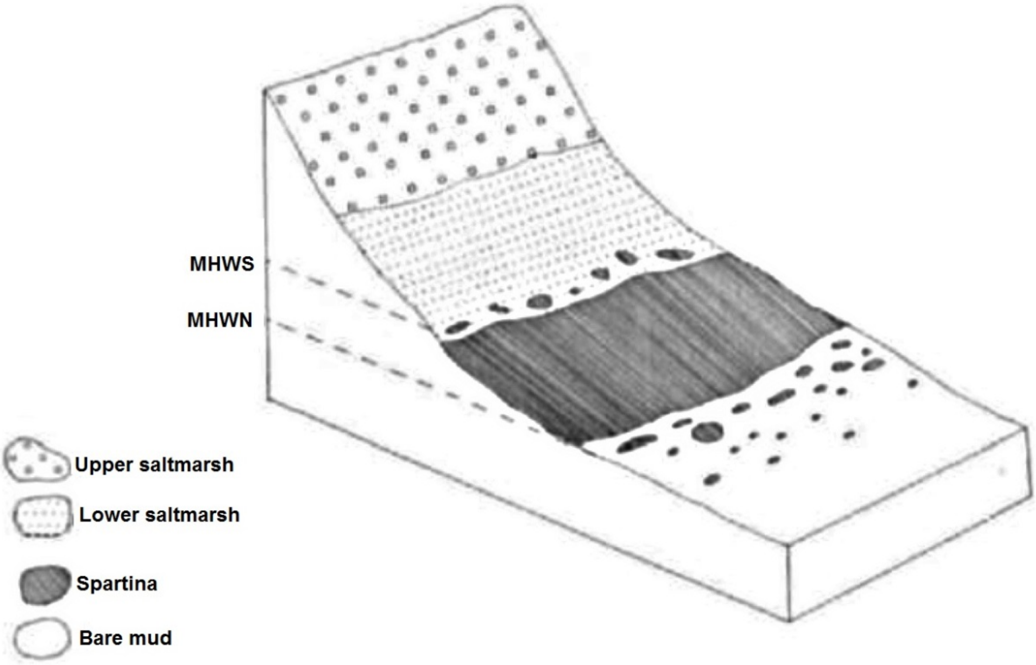


Figure 4 - A diagram of the zone typically occupied by *Spartina anglica* across UK saltmarshes from Gray et al. (1991).

Increases in the height of sediments across the intertidal zone can have negative effects on some species. Previous studies have shown that *S. anglica* has the capacity to modify low marsh into high marsh and in some instances this has contributed to the reduction of pioneer species such as dwarf eelgrass *Zostera noltii* and glasswort *Salicornia* species (Le Goff et al. 1989; Doody 1990; Gray et al. 1997).

There is also evidence that *Salicornia* can be facilitated by the presence of *S. anglica*. An investigation into changes in saltmarsh distribution in the Dee estuary (north west England) indicated that the later stages of *S. anglica* colonisation were formed by a co-dominated mix of both *Salicornia* and *S. anglica*, where only isolated patches of *S. anglica* were previously present (Huckle et al. 2004).

These findings imply a possible positive association between *S. anglica* and *Salicornia* stands. The pattern of isolated *S. anglica* patches was observed between 1965 and 1975, when the saltmarsh was actively accreting, whilst the co-dominated *Spartina/Salicornia* sward was observed in 1997 in a period of minimal erosion and accretion (Figure 5). At the time of the study, the current colonisation process could not be attributed to *S. anglica* alone. Equally, the Dee estuary saltmarshes were expanding before *S. anglica* became firmly established (Huckle et al. 2004; Gatliff 2010).

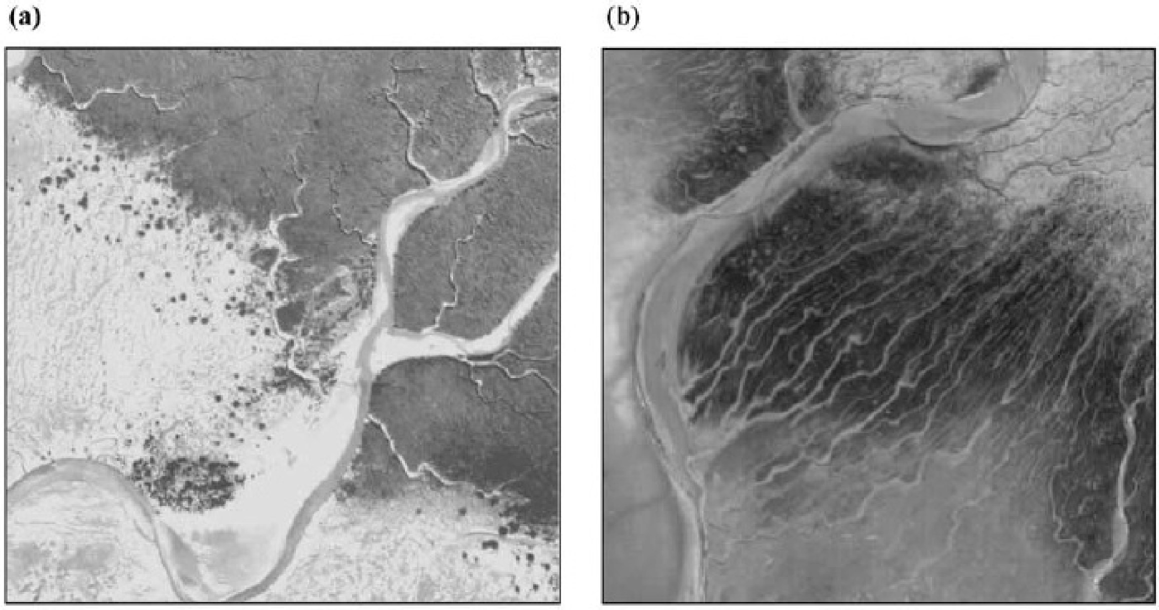


Figure 5 - Aerial photography from the River Dee (England) showing the development of *Spartina anglica* from isolated patches to integration within a pioneer sward. In 1975 (a) individual clones of *S. anglica* (dark spots) are clearly visible. In 1997 (b) the boundary is less distinct with no distinct clumps of *S. anglica* visible in the pioneer zone (scale 1:3300). From Huckle et al. (2004).

Similarly, *S. anglica* is thought to facilitate the establishment of *Puccinellia maritima* and other species by sheltering these areas of marsh from tidal action, which might cause the uprooting of plants. It also increases surface elevations around the plants and can stabilise upper layers of sediment (Gray et al. 1991). Both the facilitation of *P. maritima* and *Salicornia* were also suggested across the north-shore of the Solway (Haynes 2013).

Research into the natural regeneration of saltmarsh vegetation communities on managed realignment sites has shown that species richness declined significantly with increasing cover of *S. anglica* (Garbutt and Wolters 2008). Common sea-lavender *Limonium vulgare*, annual sea-blite *Suaeda maritima* and the seaweed *Bostrychia scorpioides* were shown to take over 70 years to re-establish to natural levels. These findings show a pattern that may relate more to the sediment that underlies *S. anglica* than to the plants themselves. For example, *Suaeda maritima* is more strongly associated with sandy sediments (Rodwell 2000), which are often negatively associated with *S. anglica* dominated areas.

Areas that are exhibiting *S. anglica* dieback may also show different effects on vegetation to those where *S. anglica* is actively colonising. Research on the Lymington and Keyhaven saltmarshes indicate that only sparse areas of *Salicornia* species and *Suaeda maritima* are present within areas of *S. anglica* dieback (Johnson 2000).

2.5 Spartina anglica *and climate change*

No papers reviewed directly investigated the effect of climate change on *S. anglica* swards in the UK. Hübner et al. (2010) raised concerns about the amount of sediment that could be released if *S. anglica* die-back increases due to rising sea-levels or higher storm frequencies. Conversely, research in the Wadden Sea indicated that despite rising sea-levels and increasing storm frequency, *S. anglica* began to colonise and form dense swards, which coincided with an increase in spring temperatures (Loebl et al. 2006). It is also suggested that one of the factors that limits *S. anglica* growth is frost, with leaf development only beginning when mean air temperatures exceed 9 °C in England (Nehring and Hesse 2008) thus, warmer springs could cause *S. anglica* to expand its range. A full assessment of the effects of climate change was not a primary objective for this research and is discussed in more detail in Cogle (2012) and Kirwan et al. (2009).

2.6 Dieback

Many papers reference the occurrence of *S. anglica* dieback and often link dieback to saltmarsh erosion. The cause of dieback is unknown, but it is identified as occurring in poorly drained, waterlogged and highly anaerobic soils with fine particles and a high sulphide content (Gray et al. 1991). It has also been hypothesised that regular inundation allows ergot *Claviceps purpurea* to infect *S. anglica* and soften its rhizomes (Lacambra et al. 2004).

It is important to note that saltmarsh erosion can be caused by other factors, including changes in the sediment regime, increases in storm frequency and grazing pressure. It is also important to note that large areas of saltmarsh may have developed because of *S. anglica*, so erosion due to dieback may be a return to the conditions before *S. anglica* establishment and spread. The presence of *S. anglica* or *Spartina* dieback should not automatically lead to a conclusion that this is responsible for saltmarsh erosion. It is also unclear whether *S. anglica* suffering dieback can be adequately determined as a primary cause of erosion.

2.7 Conclusions

Very few papers reviewed for this report (post Lacambra et al. 2004)) provide further information on the negative effects of *S. anglica* on flora, fauna and Natura 2000 features. Most recent papers that study the response of *S. anglica* to various ecological and environmental stimuli reference much older papers regarding the negative effects of *S. anglica*. Some of these older studies also highlight the possibility that the expansion and decline of *S. anglica* may be a secondary response to an as yet undetermined driver of change (Gray et al. 1997). Overall, the case against *S. anglica* in saltmarshes may not be well founded in all situations.

In summary, negative effects associated with *S. anglica*, taken from the literature, relate to:

- *S. anglica* colonisation
- *S. anglica* expansion
- *S. anglica* density
- *S. anglica* health (e.g. dieback)
- *S. anglica* erosion
- the influence of *S. anglica* on sediment deposition

Very few papers attempted to make predictions relating to the future abundance and distribution of *S. anglica* and how this would impact other flora, fauna and ecological processes. The papers that made predictions were those able to calculate extent and distribution using lidar and aerial photography (e.g. Huckle et al. 2004) and those that considered the colonisation and spread of *S. anglica* (e.g. T. J. Bouma et al. 2009). The density of *S. anglica* stands was seen as an issue that directly impacts a range of species that occupy or feed on mudflats (Long and Mason 1983; Capehart and Hackney 1989; Le Goff et al. 1989; Doody 1990; Gray et al. 1997; Hammond and Cooper 2003). The influence of *S. anglica* on sediment deposition was viewed as a possible cause of decline and change for species and habitats (Gray et al. 1991; Huckle et al. 2004; T. J. Bouma et al. 2009; Hübner et al. 2010). Changes in sedimentation regimes were highlighted as one of the risks associated with *S. anglica* erosion. It is also possible that changes in sedimentation regimes could be a factor in the initial colonisation of *S. anglica* (Gray et al. 1991).

No papers investigated whether *S. anglica* can facilitate other species, despite a number of papers highlighting the possibility (Gray et al. 1991; Huckle et al. 2004; T. J. Bouma et al. 2009).

It should be noted that this review was primarily focussed on *S. anglica* in Natura 2000 sites and that some literature was not available for review. Papers by Bouma et al. (2009), Hacker and Dethier (2006) and Neira et al. (2007) may also be of value to review regarding *S. anglica*.

It is important that any future management or policy decisions for Natura 2000 sites are based on reliable data and knowledge regarding *S. anglica* and its influence on flora, fauna and ecological processes. There are particular instances highlighted within the literature where the presence of *S. anglica* could cause Natura 2000 site features to decline in quality. These instances need to be clearly defined so that policy and management are not based on supposition.

3 *Distribution and extent of Spartina anglica*

The primary aim of this work was to provide an accurate recent estimate of the extent and distribution of *Spartina anglica* within England. It was therefore not appropriate to repeat the estimate of 5,166 ha made by Burd (1989), which was entirely based upon existing survey data, some of which was already a decade old when that estimate was made, and data collected specifically as part of the Saltmarsh Survey of Great Britain. The decision was therefore made to base the new estimate on post-1989 data, prioritising the most recent data, to provide an independent updated estimate.

3.1 Collation of available data

3.1.1 Data available via the National Biodiversity Network Gateway

The National Biodiversity Network (NBN) Gateway is the UK web portal for accessing species records and other biodiversity data (https://data.nbn.org.uk/). The data are contributed by a range of organisations across the UK, including local records centres, national schemes and societies, statutory agencies and charities.

A custom download of *Spartina* records was requested from the NBN Gateway team. This was conducted through Natural England, which as an organisation has access to higher resolution data with a greater number of attributes, due to agreements with the relevant data holders (details of the datasets and the effective resolution for each is provided in Appendix B). This ensured that the most precise and most useful data available were used during the analysis. The custom download included all records of *Spartina* and *Spartina* species, and currently valid and invalid names.

6,893 records of *Spartina* were supplied by the NBN team. All records based upon the Irish National Grid were removed, stripping out any records from Ireland (Republic and North), leaving 6,671 UK records based upon the British National Grid.

Geometries were automatically created for the UK records, mapping them according to the grid references. A square polygon was created for each, correctly located and sized based upon the resolution of the grid reference (see Figure 6). The date of the data varied enormously, with records potentially as far back as 1500 through to 2013, though most of the higher resolution records were more recent.

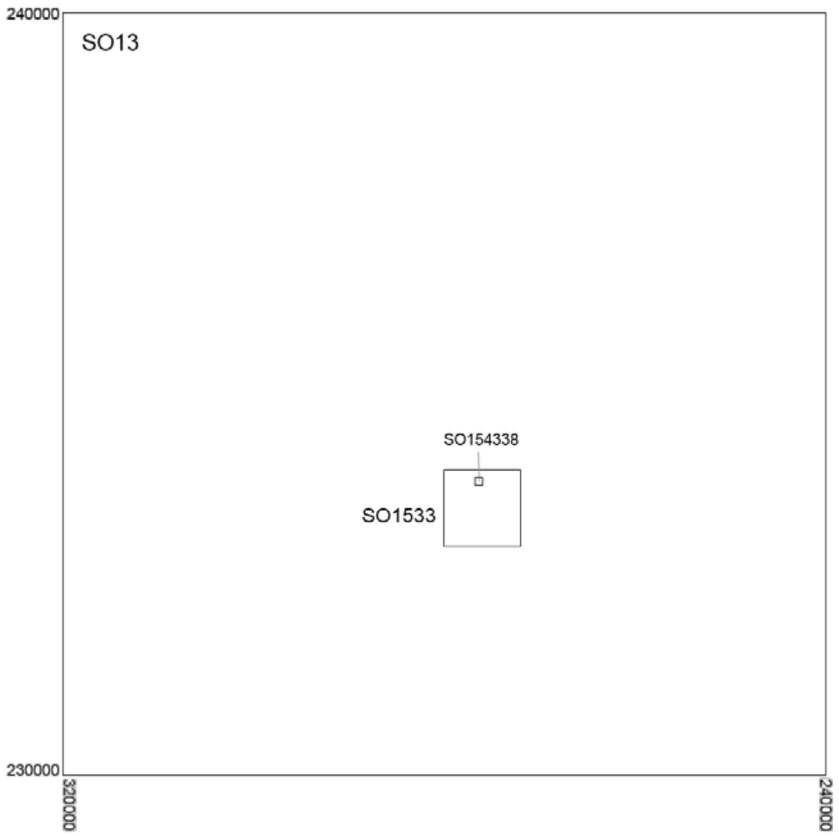


Figure 6 - Example of squares created for various precision grid references for the same location.

3.1.2 Environmental Monitoring Database

Natural England's full Environmental Monitoring Database was made available, allowing ten records of *Spartina* to be extracted. These records were imported into SQL Server and geometries were created. Whilst the spatial referencing system used was the British National Grid only coordinates were provided for each record, with no indication of the resolution of the record. Simple rules were used to convert the coordinates into area geometries based upon the apparent precision of the coordinates (Lush et al. 2014), resulting in seven records at 100 m resolution and three records at 1 m resolution. These data dated from 1996 to 2001.

3.1.3 Miscellaneous data

Further data were obtained via Natural England, the Environment Agency and through internet downloads (Table 2). This included data obtained from staff within Natural England who had information on *S. anglica*. Each person was contacted by telephone or email to determine what data was available for each site and whether it was available in GIS format.

An internet search was also undertaken to determine whether third parties had additional data on saltmarsh, particularly *S. anglica*, that would be relevant to this project. This search focused on data held by coastal observatories, universities, consultants or other agencies. Though five potential data holders were contacted, the data collated as a result were limited. The Institute of Estuarine & Coastal Studies at the University of Hull did a saltmarsh survey in Essex for Natural England, but analysis showed that the data was already present in the Defra MB0102 data (Brown et al. 2012). Scottish Natural Heritage provided a list of *Spartina* records compiled for Scotland.

Table 2 - Summary of data obtained for the analysis of *Spartina anglica* distribution and extent.

NVC= National Vegetation Classification: NNR =National Nature Reserve

Dataset	**Originator**	**Supplied by**	**Year**
Alde-Ore NVC Survey	Abrehart Ecology	Natural England	2013
Cleethorpes Saltmarsh Extent	University of Hull	Natural England	2009-2011
Deben NVC Survey	Abrehart Ecology	Natural England	2013
Defra MB0102 2D Distribution of *Spartina anglica*	Defra	Natural England	1930-2009
Hill Survey Maps	Natural England	NatureBureau	1971
Mersey NVC Survey	Graeme Skelcher	Natural England	2003
North Lincolnshire Coast SSSI NVC Survey	Tom Dargie	Natural England	2001
North Norfolk Coast Saltmarsh Zonation	Natural England	NatureBureau	2007
	Natural England		2011
North Norfolk NVC Survey	Posford Haskoning	NatureBureau	2001
			2002
North Norfolk NVC Survey	NatureBureau		2013
North Northumberland Bays and Inlets Survey	Envision Mapping	Natural England	2010
Plymouth Sound Saltmarsh Survey	Natural England		2013
Saltfleetby & Theddlethorpe NVC Survey	Tom Dargie	Natural England	2001
Saltfleetby NVC Survey	Unknown	Natural England	2008
Saltmarsh – Extent and Records	Environment Agency	Internet download	2007-2012
Saltmarsh – Extent and Zonation	Environment Agency	Environment Agency	2004-2012
Scottish Saltmarsh Survey data	NatureBureau		2010-2012
Severn NVC Survey	Tom Dargie	Natural England	1998
Severn Saltmarsh Revalidation	Benchmark Ecology	Natural England	2010
Somerset *Spartina* records	Unknown	Natural England	1982-2013
South East Saltmarsh Extent	Environment Agency	Natural England	2005
South West Habitat Mapping	Environment Agency	Natural England	Unknown
Spartina records for Scotland	Scottish Natural Heritage		1969-2002
Transitional Water Bodies versions 1 and 2	Environment Agency	Internet download	2004-2013
Walberswick NNR NVC Survey	Norfolk Wildlife Services	Natural England	2013
Wash Saltmarsh Zonation	Natural England	NatureBureau	2008
	Natural England		2011
Wash NVC Survey	Posford Haskoning	NatureBureau	1989
			1997
			2001

3.2 Analysis of Spartina anglica *in Transitional Waterbodies and Natura 2000 sites*

Each of the collated datasets was assessed to determine whether or not they identified either *Spartina* that were not identified to species level (undetermined *Spartina*) or *S. anglica*. Saltmarsh extent data was excluded where it did not identify the type of saltmarsh. Relevant records were then extracted from the source data using the search terms shown in Table 3 and imported into the relational database management system Microsoft SQL Server.

Table 3 - Search terms used to extract *S. anglica* records by data type

Data Type	Search Term
EUNIS	A2.5541
IHS	LS32
NVC	SM6
Species	*Spartina anglica* *Spartina*

Undetermined *Spartina* swards were included in the extracted data as these stands were likely to be *S. anglica*, particularly if the swards did not occur in the known range of the other *Spartina* species.

For non-spatial datasets, geometry was either created or assigned as follows:

- Scripts used to create square of appropriate size based on grid reference – EMD, NBN, Somerset Records, SNH records
- Points created based on easting and northing – EA Saltmarsh records
- Linked to SSSI unit boundaries based on site code – Plymouth Sound

For the SNH records there were two records that were in England based upon the grid reference. These grid references were corrected from NY96 to NX96 based upon the location description in the data.

All of the dataset must be in the same projection to allow SQL Server to undertake spatial analysis. The Defra MB0102 and EA SW habitats data were therefore opened in ArcGIS and converted to British National Grid using the OSGB 1936 to WGS1984 Petroleum and OSGB 1936 to ED 1950 UKOOA transformations respectively.

3.2.1 Determining presence

National Distribution

The national distribution of *S. anglica* and undetermined *Spartina* swards was analysed at both 1 km and 10 km grid resolution. The grids were created using a script in SQL Server based upon Ordnance Survey 4 figure and 6 figure grid references.

For the 1 km resolution distribution, records with a resolution lower than the grid resolution, such as tetrads, were excluded from the analysis. This affected the following datasets:

- Defra MB0102 polygons
- NBN records
- SNH records
- Somerset records

A script was used in SQL Server to select the records that intersected each grid square. The results were aggregated by grid square, dataset and date.

Presence within EA Transitional Waterbodies

Both versions of the EA Transitional Waterbodies dataset were reviewed to determine the differences between datasets. It was decided that the draft EA Transitional Waterbodies version 2 dataset should be used as it is more recent. Four additional waterbodies were present in version 1 of the dataset but not in version 2. These waterbodies were added to create a combined layer for the analysis.

Records were excluded from the analysis where the area was greater than 1 km^2 such as tetrads. This affected the following datasets:

- Defra MB0102 polygons
- NBN records
- SNH records
- Somerset records

Presence of *S. anglica* within transitional water bodies was determined by using a script in SQL Server to select the records that intersected each water body. The results were aggregated by water body, dataset and date.

The transitional water bodies dataset was created based upon Ordnance Survey Meridian data. Analysis of records that did not intersect a transitional water body showed that the extents of the transitional water bodies did not cover saltmarshes above mean high water as shown in Figure 7.

Figure 7 - Map showing areas of *S. anglica* (red) above mean high water (light blue line) that did not intersect the extent of transitional water bodies (dark blue)

This issue was discussed with Natural England and it was agreed that additional analysis of the distribution and extent within SACs and SPAs should be undertaken, as these polygons should cover all areas of interest within estuaries.

Presence within Natura 2000 sites

The latest SAC and SPA boundaries were downloaded from the JNCC website and pre-processed to limit the data to those within England, i.e. Country contained E.

Records were excluded from the analysis where the area was greater than 1km^2 such as tetrads. This affected the following datasets:

- Defra MB0102 polygons
- NBN records
- SNH records
- Somerset records

The presence of *S. anglica* within SACs and SPAs was then determined by using a script in SQL Server to select the records that intersected each SAC or SPA. The results were aggregated by site code, dataset and date.

3.2.2 Creation of extent dataset

A combined extent dataset was created from stand-based data using the data structure as shown in Table 4.

Table 4 - *Spartina* extent dataset table structure.

Column	**Description**
id	Unique ID
Dataset	Name of source dataset
OrigDesc	Habitat code from source dataset
SppDesc	Standardised habitat code
StartDate	Start date from source dataset
EndDate	End Date from source dataset
PercentCover	Percentage cover of *Spartina*
PolygonArea	Area of polygon in m^2
SpartinaArea	Area of *Spartina* within polygon in m^2
InWales	True/False

The data were then reviewed in ArcGIS. There were duplicate datasets in the following locations:

- North Norfolk: NVC 2001, NVC 2002, NVC 2013
- Severn: Defra MB0102, NVC 1998, EA SW Habitats EUNIS 2010
- Essex: Defra MB0102, Royal Haskoning 2001, Natural England 2006

For North Norfolk and Severn these were resolved by removing polygons from earlier datasets where the later data covered the same extent. As a result the North Norfolk NVC for 2001/2001 were removed, together with part of Defra MB0102 and Severn NVC 1998.

For the data in Essex, there was no provenance for the Natural England data and the polygons were poorly digitised. It was therefore decided to treat these data as an extension to the Royal Haskoning data. The Natural England polygons were clipped where they intersected the Royal Haskoning data.

Some of the Defra MB0102 data were in Wales. Any data that did not fall within a SAC or SPA that was partly within England were removed. As a result, the only remaining Defra MB0102 data in Wales were in the Dee Estuary, as the data in the Severn Estuary were a duplicate of the Severn NVC 1998 data.

The InWales column was set as True where Defra MB0102 and Severn NVC 1998 data occurred within Welsh territorial limits. These polygons were excluded from the extent figures for England as a whole, but were included in the calculation of extent figures for the Dee and Severn Estuary SACs/SPAs.

The majority of datasets did not include a column for percentage cover. The following rules (Table 5) were therefore used to assign a percentage cover value for each polygon based upon the OrigDesc column:

Table 5 - Rules used for interpreting NVC data to determine the percentage cover of each community within a mapped stand.

Type	Rule	Example OrigDesc	PercentCover
Single habitat code	Assume entirely one habitat	SM6	100
Mosaic habitat	Assume split equally between habitats	SM6/SM8/SM9	100/No. of habitats listed
Transitional habitat	Assume split equally between habitats	SM13b/SM6 SM6 – SM13	100/No. of habitats listed
Habitat with values in brackets	Assume values in brackets are percentage cover	SM6(90) + SM8(10)	Value in brackets

Some datasets required additional interpretation specific to that dataset. For details see Appendix A.

The SpartinaArea column was calculated using the following formula:

$$Area_{spartina} = Area_{polygon} \times \left(\frac{PercentCover}{100}\right)$$

3.2.3 Assigning extent

The extent of *S. anglica* within EA Transitional Waterbodies, SACs and SPAs was then determined by using a script in SQL Server to select the records that intersected each Transitional Waterbody, SAC or SPA to produce a list of *S. anglica* extent polygons for each site.

In each of the datasets there were some adjacent boundary polygons where tributaries met the main estuary. In a minority of cases, a *S. anglica* extent polygon was duplicated as it intersected with two polygons (Figure 8).

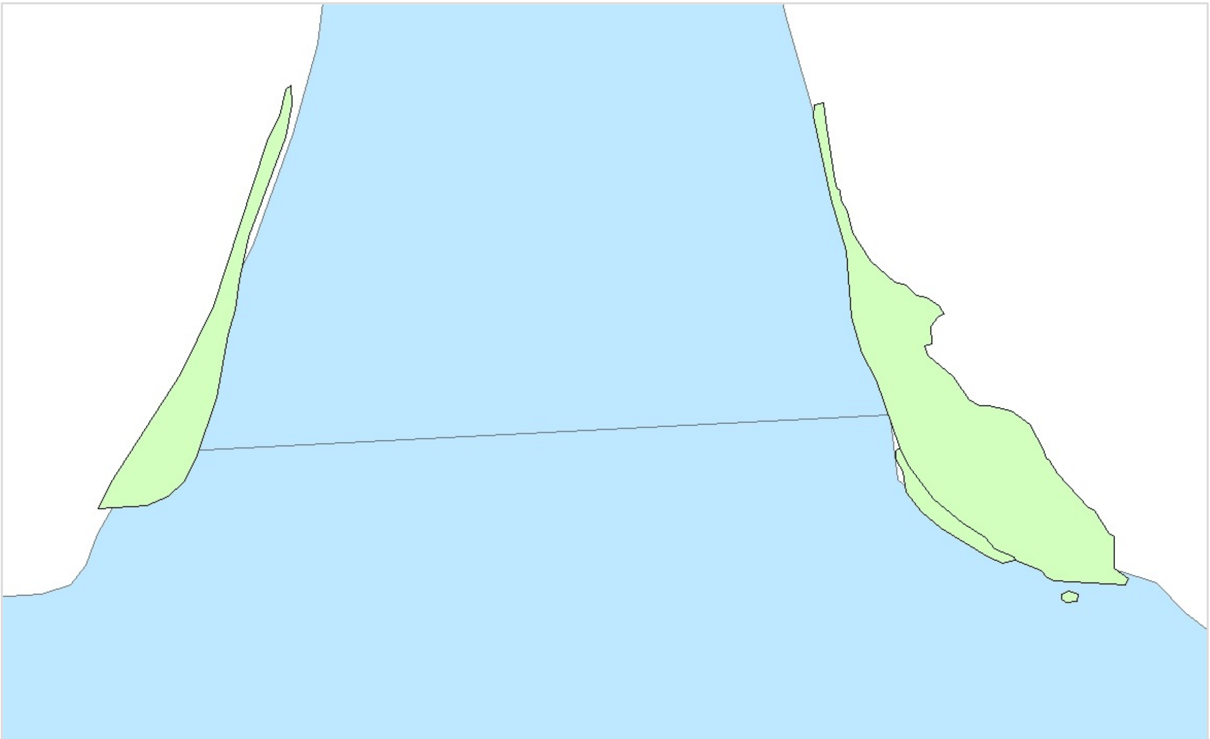


Figure 8 - Diagram showing *Spartina* extent polygons (green) overlapping multiple Environment Agency Transitional Waterbodies (blue).

The affected *Spartina* extent polygons were reviewed in ArcGIS. It was not always easy to allocate a *Spartina* extent polygon to a single SAC, SPA or Transitional Waterbody, so it was decided that a consistent rule should be applied. The *Spartina* extent polygons were therefore assigned to the SAC, SPA or Transitional Waterbody with which they shared the largest intersecting area and any duplicate records were removed.

3.3 Results

3.3.1 Extent and distribution of *Spartina anglica*

Detailed results showing the number of records and extent of *S. anglica* and undetermined *Spartina* species for Transitional Waterbodies, SACs and SPAs are provided in Appendix C

Table 6 shows the calculated extent of *S. anglica* and undetermined *Spartina* spp. based upon the datasets collated during this project (see Section 3.1). The results can be regarded as being relevant to the date range 1989 to 2013. Most of the datasets supplied by Natural England were survey data for Natura 2000 sites, so there were significant gaps in data for the rest of England.

The lack of mapped *S. anglica* stand data between 1989 and 2013 meant that the overall extent of all *Spartina* dominated communities for England (1,128 ha) was significantly lower than the 5,166 ha quoted by Burd (1989). The two results were calculated using very different techniques and entirely different data, and are therefore not directly comparable. It is likely that the estimate made by Burd was more accurate, as it drew upon complete coverage survey data. However, the estimate made by Burd is now dated and is unlikely to accurately reflect the current extent of *S. anglica*.

The mapped *S. anglica* stands collated for this work coincide with only a small part of its distribution (see below), strongly suggesting that the extent calculated for *S. anglica* only during this work (751 ha) is also an underestimate. Most of the data were from Natura 2000 sites, with few mapped stands in undesignated areas, which explain the small difference between *S. anglica* area within SPAs and England as a whole. Extensive further survey, both within and outside of Natura 2000 sites, is required to more accurately determine the extent of *S. anglica*.

Table 6 - Extent of *Spartina anglica* and undetermined *Spartina* species in hectares for Natura 2000 sites, Environment Agency Transitional Waterbodies and the whole of England.

	Polygon Area	***S. anglica* Area**	***Spartina* spp. Area**
SACs	1,634.70	612.50 ha	286.00 ha
SPAs	1,906.65	746.65 ha	333.28 ha
Transitional Waterbodies	1,519.24	665.76 ha	183.76 ha
England	1,954.69	750.55 ha	377.23 ha

Maps A.1 and A.2 in Figure 9 indicate that the distribution of *S. anglica* has remained relatively stable since 1970 with the majority of records since 2000 occurring in 10 km squares that had earlier records.

By contrast Maps B.1 and B.2 in Figure 9 indicate that there have been more records of undetermined *Spartina* species since 2000 with a minority of records occurring before 2000. These records generally occur where *S. anglica* has previously been recorded and were considered likely to be *S. anglica.* The increase in the number of undetermined *Spartina* records may simply reflect the difficultly in identifying the precise species of *Spartina* present.

3.3.2 Limitations

The biggest limitation on the results of this analysis was the lack of data accurately showing the extent of *S. anglica* dominated communities (Table 3) and the uncertainties caused where communities are recorded as a complex (Table 5). The only basis for this estimate was existing and recent survey data, which was extremely limited. The previous estimate by Burd (1989), which covered all *Spartina* species but was likely to be close to the extent of *S. anglica* due to the limited extent of other *Spartina* species, was substantially higher. The data available on the distribution data also suggests that the extent was actually much higher than estimated, as it is unlikely that all records of *S. anglica* where mapped data were lacking did not occur as dense stands. This demonstrates the need for increased survey and mapping of *S. anglica* to determine its actual extent.

In contrast, the data on the distribution of *S. anglica* was considered to be more robust, being based upon the ready available large recording datasets via the NBN Gateway. The sole difficulty was in determining an estimate of distribution based upon recent records only. *S. anglica* is a common species that is likely to go unrecorded by many botanical recorders, so lack of recent data for an area where *S. anglica* had previously been recorded could not be used to infer that the species was no longer present.

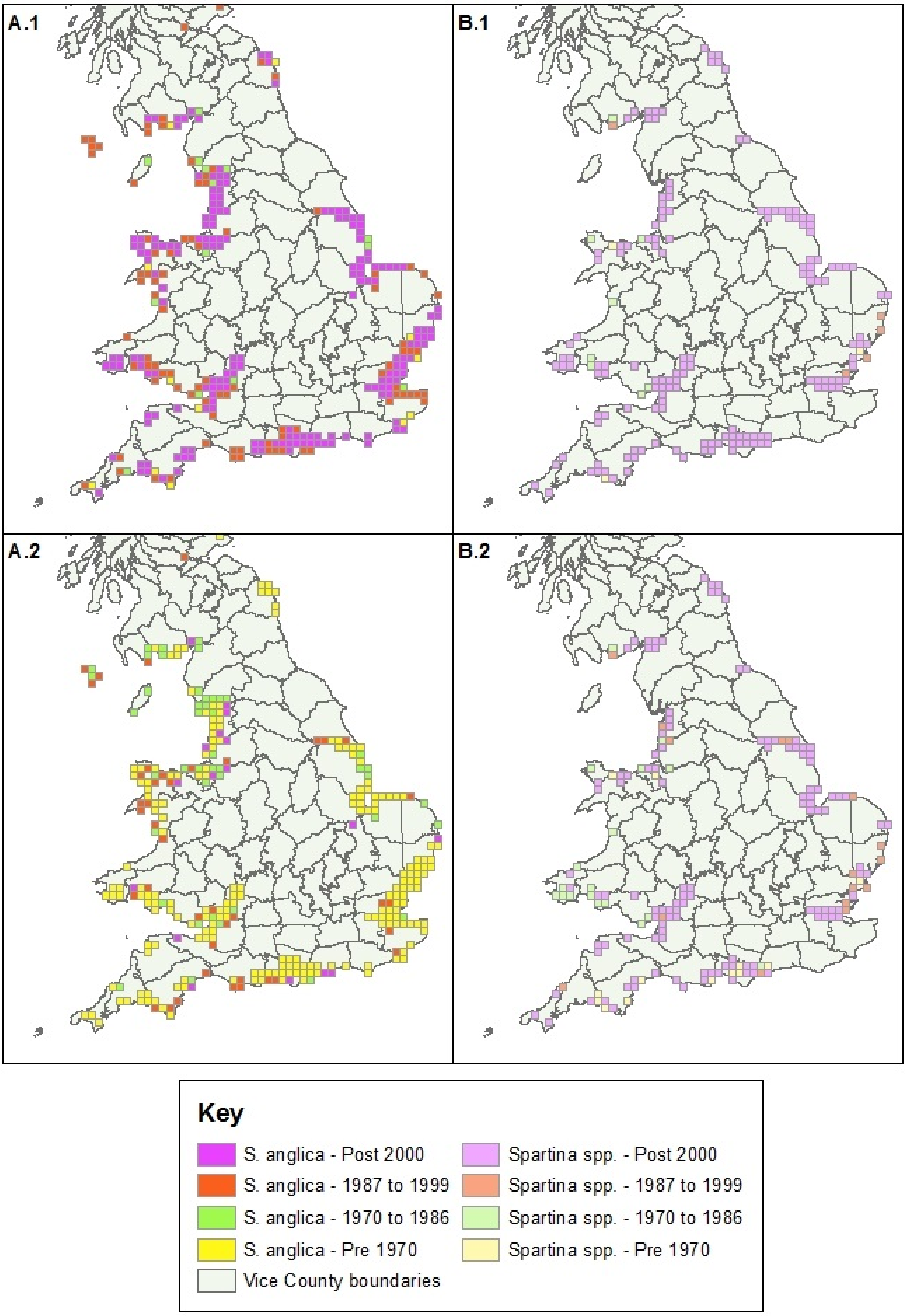


Figure 9 - 10km resolution distribution maps of *S. anglica* (A) and undetermined *Spartina* species (B). A.1 and B.1 prioritise latest records, A.2 and B.2 prioritise oldest records.

S. anglica can also be difficult to identify accurately when not fully in flower. It was therefore necessary to make two estimates of distribution for *S. anglica* and undetermined *Spartina* species. It was likely that most records of undetermined *Spartina* actually reflected *S. anglica*, particularly outside of the known range of the other *Spartina* species. This means that the maps of *S. anglica* distribution may not reflect the actual distribution, and should be used in combination with the undetermined *Spartina* distribution maps with the caveat that some records of undetermined *Spartina* will not relate to *S. anglica*.

Another minor limitation affecting the estimate of *S. anglica* distribution was the lack of confidence in the identification. It is likely that some records were actually misidentifications, possibly more likely in some datasets than others, and this may have affected the distribution maps. This could not be quantified as it would need to be assessed on a record by record basis and such information does not exist.

4 *Current* Spartina anglica *management in the UK on protected sites*

Since the 2004 report on *Spartina anglica* status, dynamics and management (Lacambra et al. 2004) was published there has been a limited number of published *S. anglica* management trials in the UK. Control techniques with herbicides, cutting and smothering have been tested in Northern Ireland (Hammond 2001; Hammond and Cooper 2003) and are discussed in more detail in Section 5.

In an attempt to gather information regarding *S. anglica* management, a number of land managers and officers from Natural England and RSPB were contacted and asked specific questions about their perceptions towards the management of *S. anglica* and current management practices (Box 1).

Most respondents concluded that no management was being undertaken within their areas, which included protected sites in the North-East, North-West, and the South-West. One respondent was aware of planned management of *S. anglica* swards where there had been a change in the sediment regime on a sandy pleasure beach, causing *S. anglica* to colonise the pioneer zone.

Most respondents were able to highlight a range of both positive and negative effects regarding the presence of *S. anglica.* Most negative effects related to competition with other species occupying a similar niche, while most positive effects were attributed to regulation of sediment regimes and reductions in erosion risk.

Box 1 – Questions posed to land managers and officers within Natural England and the RSPB

1. What evidence is there of the negative effects of *S. anglica*? Are there any obvious signs of impacts on:
    - Vegetation communities
    - Coastal and intertidal habitats (e.g. mudflats)
    - Bird populations
    - Benthos
    - Eel grasses
    - Other *Spartina* species
    - Erosion risk
    - Invertebrates
    - *Salicornia* beds
2. Are there any positive effects of *S. anglica* on the features listed above?
3. What changes in communities have been observed in areas where *S. anglica* is present (anecdotal information is also relevant)?
4. Is there an observed pattern to colonisation or decline of *S. anglica*?
5. What management is in place or has been attempted on the species? Was it successful/unsuccessful?
6. What is the perception of *S. anglica* within your management group? Is it considered as a risk to other site features or is it relatively benign or beneficial? Does this perception differ with other known stakeholders?
7. Is it known that *S. anglica* is fertile and therefore capable of reproduction?

Please give a little bit of info about where this experience is from (e.g. '10 years of site management on the Solent' or '6 months intensive surveys of the North Norfolk SAC' etc.). This will help me frame this information in the report.

5 Management Techniques

Several papers have investigated various control methods for *Spartina anglica* since Lacambra et al. (2004). In addition, a systematic review of control methods and management interventions was conducted by Roberts and Pullin (2006) and summarised in a scientific paper (Roberts and Pullin 2008). This review includes international papers due to a lack of research and management in the UK.

5.1 Physical Removal

Physical removal trials were undertaken in Arcachon Bay, France to investigate the effect of *S. anglica* removal on benthic communities (Cottet et al. 2007). Three samples were monitored:

1. *S. anglica* was uprooted and removed from the intertidal mudflats
2. an inversion treatment was conducted, exposing *S. anglica* root systems and squashing the leaves onto the sediment
3. left undisturbed to act as a control

Physical removal was the most effective treatment, but the treatment was time consuming and required transport and storage of *S. anglica* vegetation waste, which could also raise issues about disposal. The inversion treatment showed some signs of *S. anglica* recovery, which was also observed in a similar trial by Levasseur et al. (1993), and anoxic organic matter decomposition caused a sulphide odour to develop across the mudflats. The inversion treatment also decreased the attractiveness of the landscape. All treatments had a minimal effect on benthic communities, as benthic communities are generally species poor in *S. anglica* stands.

S. anglica vegetative growth and seedling recruitment were investigated using different removal techniques in Puget Sound, Washington, USA (Reeder and Hacker 2004). The potential for habitat restoration was also investigated. Both removal techniques focused on small scale mowing with brush cutters and walk-behind mowers with follow-up herbicide application on new growth (in the same year). Experimental areas also included areas where arisings were removed and where arisings were left on site. Two treatments were undertaken across four habitat types (low salinity marsh, high salinity marsh, mudflat, and shingle beach):

1. a consistent removal across three years (July 1998, 1999 and 2000)
2. removal in the first two years (July 1998, 1999) with the area left untreated in the third year

The results showed that *S. anglica* is highly resistant to removal and requires multiple years of consistent management treatment to cause a significant decline. A 100-500% increase in *S. anglica* cover, tiller numbers and flowering spikes (compared to the previous year of management) was observed from the treatment that remained unmanaged for one year, while areas under the three year treatment showed 50-75% decline in cover and tiller numbers (but still showed some signs of recovery) with no flowering spikes observed.

Physical removal from the site also requires the transportation and disposal of cut material, which could result in spread of the species to new areas, whilst leaving uprooted material could simply lead to a redistribution of *S. anglica* on site.

5.2 *Smothering techniques*

Cutting and smothering was identified as the treatment able to achieve the greatest mean density decline of *S. anglica* (97.9%) within Robert & Pullin's (2008) systematic review of the effectiveness of *S. anglica* management interventions. These findings were primarily retrieved from work on two study sites in Northern Ireland (Hammond 2001; Hammond and Cooper 2003). These management trials focused on six different management treatments using 5 × 5 m random block formation, including two herbicide treatments and four cutting treatments. The most successful treatment was a sward cut (to 10 cm) and smothering of the remaining *S. anglica* cover with industrial black plastic sheeting for six months. The sheeting was held down by chicken wire netting and pegged to the substrate, and was checked for tidal damage each month. This treatment caused a decline in dry root weight, which was not reported from other treatments within the review.

5.3 *Grazing*

Despite the fact that grazing of saltmarshes has been undertaken through most of the 20th century, no published papers were found that investigate the effects of grazing management on *S. anglica* stands in the UK. Most trials were undertaken with *S. alterniflora*. Robert & Pullin's (2008) systematic review found that grazing animals were not effective in reducing the densities of S. alterniflora with a mean percentage decrease of *S. anglica* calculated to be 24.4%.

5.4 *Burning*

No studies of the effect of burning upon *S. anglica* were identified.

5.5 *Herbicides*

This section reports on studies which have investigated the use of herbicides over many years, across a range of countries and with different legislative and environmental protection requirements. The following information does not imply any recommendation or approval for the use of herbicides to control *S. anglica*.

Several studies have investigated various herbicide applications on *S. anglica* stands. Chemical treatments with herbicide, although cheaper than other methods, were considered not as effective as mechanical removal methods (Kriwoken and Hedge 2000; Cottet et al. 2007).

Roberts & Pullin (2006) reviewed trials of different herbicides and found that their efficacy varied between different *Spartina* species. This suggests that studies on *Spartina* species other than *S. anglica* and probably *S. × townsendii* (e.g. Patten 2002; Williams et al. 2009) are not relevant to this review.

The highest reduction reported from Roberts & Pullin's review was using dalapon (2,2-dichloroproprionic acid) on *S. × townsendii* (97.5% reduction in density). Complete eradication was reported if two or more treatments of dalapon were applied in a single year. No studies on dalapon application were referenced for *S. anglica*. However, dalapon treatments on *S. anglica* achieved a 95% reduction of live stem density in trials in Northern Ireland (Hammond and Cooper 2003). It is important to note that dalapon is not licensed for use with the UK intertidal zone.

The most effective herbicides against *S. anglica* within Robert and Pullin's review were fenuron and aminote-T achieving an 88.2% and 75.8% reduction in density respectively. It should be noted that both results were based on a small data pool (Roberts and Pullin 2008).

Application of glyphosate to *S. anglica* and other *Spartina* species was considered be a less effective treatment which achieved a 43% decline in *S. anglica* density. Nevertheless, significant reductions in the density and above ground biomass of *S. anglica* could be attained from glyphosate application with a wetting agent additive. Treatment in July had the greatest impact while September treatments did not have significant influence on *S. anglica* stands.

The maturity of *S. anglica* plants is considered to be an important factor within herbicide treatments and can significantly influence the percentage of reduction. Less significant reductions were reported from mature stands of *S.* × *townsendii*, while younger plants were highly susceptible. Flowering plants showed the lowest susceptibility to herbicide treatment. It should be noted that these results are from a different, but closely related, species of *Spartina*.

It is important to consider that there are a number of risks to habitats, ecosystems and biota from the application of herbicides in coastal situations. Herbicide can also induce *S. anglica* dieback and the remobilisation of and significantly alter estuarine sedimentation systems (Swales et al. 2005; Hübner et al. 2010). There are also legal requirements for the use of herbicides near water and further information must be sought to determine what products are approved for used in such situations.

5.6 Biological control

The planthopper, *Prokelisia marginata* is the most widespread and abundant *Spartina* species insect herbivore in the USA (Wu et al. 1999). It is a recent introduction to England, possibly arriving as eggs on plant material. It was first recorded from Hythe in England in 2008 and is now established in southern England and South Wales (Stewart 2011). *P. marginata* is a stenophagous species and is believed to pose a minimal threat to other floral species (Wu et al. 1999).

Two planthopper species were tested as a biological control agent against *S. anglica* in an *ex-situ* experiment in Washington, USA (*Prokelisia marginata* and *P. dolus*). The trials were separated into two high density planthopper treatments (one for each species) and one low density planthopper treatment.

The results showed that over 90% of *S. anglica* plants were killed in the two high density treatments (Wu et al. 1999), which was achieved with over 2,000 *Prokelisia* individuals per 0.5 m^2 (Roberts and Pullin 2008).

5.7 Steam and infra-heat treatment

No studies of the effect of steam and infra-heat treatment upon *S. anglica* were identified.

5.8 Cutting

Cutting alone is not a sufficient control treatment for *S. anglica*. Evidence suggests that cutting causes increases in *S. anglica* density, with Roberts and Pullin (2008) suggesting a 42.8% density increase the year after a cut has taken place.

As discussed in the Section 5.5, evidence suggests that cutting and subsequent treatment with herbicide can also increase the density of *S. anglica*.

Cutting and smothering is reported to be the most effective management technique and can reduce *S. anglica* density by 98% (Roberts and Pullin 2008; Hammond and Cooper 2003).

5.9 Mechanical Removal/Rotoburying

The use of mechanical vehicles with caterpillar tracks or rollers to crush *Spartina* was reported to show significant declines in *S. alterniflora* with a mean density decline of 61% (Roberts and Pullin 2008). No data was provided for *S. anglica*. Substrate was considered to be an important factor, with the most significant reductions obtained from sands and soft silts and less from firm silt. Winter treatments were also reported to be twice as effective as treatments undertaken at other times of the year.

A tracked vehicle has been used at Lindisfarne NNR in North East England to deliberately damage, bury and kill *S. anglica*. These management trials are reported in Lacambra et al. (2004), but follow up work has also explored the effects of such a management treatment on macrobenthic fauna (Frid et al. 1999).

The results showed that the number of *S. anglica* individuals was much lower than in the area treated with mechanical removal than in surrounding areas after 12, 31, 92 and 383 days and two years after treatment. A sparse growth of *Salicornia* sp. was recorded from the treated area in the spring following treatment, but had changed to the same levels as non-treated areas three years later (Frid et al. 1999).

5.10 Conclusions

From the control methods reviewed above it is clear that a mixture of cutting, smothering and herbicide application can be used as part of an effective control strategy, at least at a relatively small scale. Cutting alone is observed to increase the area and density of *S. anglica* and is not recommended. Herbicide application requires repeated applications for a number of years to control the species. Although dalapon was shown to be the most effective herbicide tested on *S. anglica*, it is also illegal to apply this herbicide within the UK intertidal zone. Cutting and smothering with industrial plastic sheeting was shown to be the most effective method of controlling *S. anglica*.

All of these potential control or management measures have to take account of a number of factors. For herbicide use, there are a range of legal requirements that must be met for use in or near water. For the physical measures, there will be issues with access to the site, disturbance to other wildlife, disposal of cuttings or other waste, and use of plastic sheeting in smothering. All should consider the potential implications of the loss and/or change to the habitats and species within and on surrounding areas.

The critical element is to understand the status of *Spartina anglica* at a site level, including recent changes and known history. Without this information, control measures cannot be effectively considered or targeted or monitored. A survey protocol is set out in Section 6.2.

6 **Spartina anglica** ***monitoring protocol for Natura 2000 sites***

6.1 Survey protocol

6.1.1 Introduction

This section describes a protocol for undertaking a sample-based monitoring survey of *S. anglica* populations on Natura 2000 sites in England. To increase the speed at which *S. anglica* can be surveyed, the protocol does not require the stands of *S. anglica* within a site to be mapped, though this may also be a useful exercise. Instead it is based upon transects within the site to sample the population of *S. anglica* and assess other variables associated with saltmarsh change.

The habitats primarily assessed by the protocol are:

- Saltmarshes (including pioneer marsh)
- Mudflats/sandflats

Modifications to the form would be required to make the survey suitable for sand dune systems and saline lagoons, but it should be suitable for use in sandy saltmarsh systems such as back-barrier marsh.

The data collected focuses primarily on *S. anglica* plants and associated saltmarsh and littoral flora, with some basic information relating to sedimentation processes.

The results of the survey can be utilised to assess trends in *S. anglica* stands at a site unit level and provide evidence for management. Collating consistent information across sites can also help to inform policy decisions.

6.1.2 Aims and Objectives

The aim of the *S. anglica* monitoring protocol is to provide specific data that can be used to assess the status of *S. anglica* on Natura 2000 sites which would then influence decisions on whether any management is required.

The objectives of the monitoring protocol are:

- To ensure that *S. anglica* management and policy are based on reliable information
- To investigate the likelihood of *S. anglica* expansion or decline
- To investigate the association of *S. anglica* with sediment deposition
- To investigate existing management practices and modifications to habitats that may influence *S. anglica* expansion or decline.

6.1.3 Designing principles

The design of the monitoring protocol is based on the conclusions of the literature review in Section 2 and the work undertaken on *S.anglica* distribution and extent in Section 3. Section 2.7 concluded that it is important that any future management or policy decisions for Natura 2000 sites are based on reliable data and knowledge regarding *S. anglica* and its influence on flora, fauna and ecological processes. The findings of the literature review in Section 2 also highlighted uncertainty in the causes of *S.anglica* expansion and decline. To ensure that such uncertainty can be discounted on a site by site basis and specific management actions taken (if required), it is important that a range of data relating to *S. Anglica's* surrounding habitat, taxonomy, health, species associations and environmental conditions is collected and used to inform management. Such data includes ensuring accurate species identification of *S.anglica.*

The accurate separation of *Spartina* spp. is an important aspect of assessment, due to contrasting policy and management objectives for *S. anglica* and *Spartina maritima*. Correct identification should still be considered important outside of the known ranges of *Spartina maritima*, *S. alterniflora* and *S.* × *townsendii*, due to the small potential for these species to spread to new areas and the introduction of other species of *Spartina*, such as *S. patens* (Botanical Society of the British Isles 2006).

6.2 Development of survey protocol

The finalised *Spartina anglica* monitoring protocol for Natura 2000 sites is described in Section 6.3. This section details its development.

6.2.1 Initial development

A two-step process was felt to be required to identify that change is occurring on Natura 2000 sites, which may have been identified using other methods such as Common Standards Monitoring (Joint Nature Conservation Committee 2004), and then to try to identify what factors are driving the change. As suggested in Section 2, the factors driving the change may or may not include *S. anglica*, even where *S. anglica* is a visible feature of the change. The survey protocol therefore needed to collect relevant information on *S. anglica* as well as indicators of other causes of change, with the opportunity for change to be identified through repeat survey using the protocol.

The first stage of development focused on reviewing other monitoring protocols that consider *S. anglica* in order to assess their suitability in assessing the drivers of change associated with *S. anglica*. Three protocols were considered (UK Technical Advisory Group, Water Framework Directive 2014; Scottish Natural Heritage 2010a; Bhatti 2010; Scottish Environment Protection Agency 2007). The Scottish Natural Heritage (SNH) guidance provided the most information regarding *S. anglica*; the other two guidance documents focused on presence and abundance. The SNH survey methodology required the presence and abundance of *S. anglica* in the pioneer saltmarsh zone and the main saltmarsh (lower-upper zones) to be recorded. Any evidence of saltmarsh erosion and changes in the natural formation of creeks and pans were also required (but not linked to *S. anglica*). If the SNH guidance had focused on *S. anglica* more specifically, then more information relating to *S. anglica* cover, health and prevailing conditions would be required to make informed judgements on the management of *S. anglica*.

In addition, it was considered important that the monitoring protocol was compliant with Common Standards Monitoring (Joint Nature Conservation Committee 2004) and the monitoring of marine SACs (Davies et al. 2001).

The findings of the literature review conducted to appraise the effects of *S. anglica* on Natura 2000 sites (see Section 2) considered the known impacts of *S. anglica* on coastal systems and the evidence provided in published papers and reports to draw conclusions on negative effects and future changes. It was clear that most negative effects are attributed to:

- *S. anglica* colonisation
- *S. anglica* expansion
- *S. anglica* density

- *S. anglica* health (e.g. dieback)
- *S. anglica* erosion
- the influence of *S. anglica* on sediment deposition

The above list of negative effects was analysed to consider the data required to draw conclusions about *S. anglica* effects on Natura 2000 sites. It was considered that the following data types require assessment at different spatial scales (described in Section 6.2.6) within a monitoring protocol to take account of the listed negative effects:

- Percentage cover of *S. anglica*
- *S. anglica* distribution
- *S. anglica* population growth stage/type
- Distance between *S. anglica* plants
- Evidence of *S. anglica* reproduction (both vegetative and by seed)
- Evidence of decay and disease on *S. anglica* plants
- *Spartina* identified to species level
- Evidence of erosion of *S. anglica* stands
- Sediment type and depth
- Modifications to habitats
- Current management of habitats
- Presence of other species

Following the review of existing methodologies a brainstorming session was held between NatureBureau and exeGesIS SDM to discuss the methodology and the key data to be collected. The need for rapid data collection and collation was recognised. The sampling strategy and data formats were proposed in this session, aiming to ensure that appropriate analyses could be undertaken on the results.

Following the teleconference an initial draft of the survey form was developed by exeGesIS SDM. The majority of questions were designed to have a series of pre-defined answers, rather than requiring the surveyor to enter notes. This approach is quicker for the surveyor to complete in the field and ensures standardised survey data that can readily be analysed. The whole form was designed to be as clear as possible, precisely explaining the requirements wherever possible and referring to other guidance only when necessary.

The initial design was reviewed by exeGesIS SDM and Nature Bureau to identify any potential issues prior to the first survey and the form redeveloped to incorporate any changes required.

6.2.2 Redevelopment during survey

The first trial of the survey methodology was undertaken on part of the Severn Estuary SAC at Northwick Oaze near Aust on the 12th and 13th June. Four transects were completed across the trial. Required revisions to the survey methodology included:

- changes to how samples are selected within saltmarsh zones
- the need to create a repeatable method of measuring the distance between *S. anglica* individuals

Changes to the survey forms were identified including:

- the addition of ‘Are any of the following natural features present on this unit?’ to the unit form (Section 6.2.9)
- the addition of ‘Is the decline of *S. anglica* causing erosion?’ to the transect recording form (Section 6.2.10)
- the addition of space to record precise 10 m quadrat grid references (Section 6.2.10)
- modifications to ‘Are the following *Spartina* species definitely present?’ to allow a more nuanced response and to account for uncertainties in *Spartina* identification (Section 6.2.10)
- movement of ‘What is the average distance in centimetres between the clumps of *S. anglica* that are present in the quadrat?’ and ‘What is the average height in centimetres of the *S. anglica* present in the quadrat?’ from the 10 m quadrat to the 2 m quadrats (Section 6.2.10)
- The addition of ‘Is the *S. anglica* showing signs of vegetative spread?’ to the 2 m quadrats (Section 6.2.10)

Moving the question ‘Which of the following best describes the sediment type beneath the *S. anglica* sward?’ to the 2 m quadrat was also considered. Given that this would have meant repeating the question on the form and due to the desire to keep the form short it was decided to keep it in the 10 m quadrat

Time was also taken during the trial surveys to undertake *Spartina* species identification using various vegetation keys (Cope and Gray 2009; Hubbard 1992; Rose 1989; Stace 1999; Streeter et al. 2009) to assess the level of difficulty in separating species.

The revised methods and data forms were then tested in a second set of trials on the Essex Estuaries SAC and Blackwater Estuary SAC on 25th-26th June. Amendments to the survey methodology and survey forms based on the results of the second trial were minimal and required more information to be provided about the presence of other *Spartina* spp. within samples, ensuring that additional data is gathered for wider saltmarsh zonations (over 100 m) and ensuring a more nuanced assessment of poaching.

Further minor changes to the methodology and survey form were made following the survey on the Berwickshire and North Northumberland SAC on 18th-19th September. This included changes to the wording of two questions to make them clearer and recommendations on what to record if only one individual plant of *S. anglica* is present.

6.3 Spartina anglica monitoring protocol for Natura 2000 sites

6.3.1 Terminology

The following terms are used within this survey protocol and summaries of their definitions within the context of the survey protocol are provided below:

- Site – the Natura 2000 site (Special Area of Conservation or Special Protection Area) being surveyed
- Unit – a division of the saltmarsh area of the Natura 2000 site, see Section 6.2.6
- Survey – the full rapid assessment survey of *S. anglica* described within this protocol
- Survey forms – pre-designed forms developed for data entry while undertaking the field survey (Appendix D)

- Field survey – the portion of the survey that is undertaken on the site
- *Spartina anglica* – the species under investigation
- *Spartina* spp. – the genus including *S. anglica* as well as the other *Spartina* species that may be encountered while conducting this survey
- *Spartina anglica* population – a broad scale definition of one area of *S. anglica* plants at any density that is capable of transferring genetic material by seed and vegetative processes.
- *Spartina anglica* clumps – a fine scale definition of an area of *S. anglica* plants that are often derived from one plant and are possibly interconnected beneath the sediment. Often forming round shapes and hummocks of various sizes.

6.3.2 Key skill requirements

The following skills are considered as essential for surveyors to be able to complete the survey:

- an understanding of the features utilised in botanical keys to separate *Spartina* spp. and grasses to species level
- familiarity with surveying saltmarshes and mudflats and the associated health and safety risks associated with working in these habitats
- the ability to identify the flora of saltmarshes and mudflats
- the ability to make a reasonable field assessment of the signs of coastal erosion and sediment deposition – such signs can be difficult to identify and attribute to erosion or accretion
- the ability to identify different saltmarsh zones (e.g. pioneer, lower, middle, upper)

The following skills are considered an advantage for enhanced survey results:

- a thorough understanding of the ecology of saltmarshes and littoral habitats
- familiarity with the study site across a number of years

6.3.3 Equipment requirements

The equipment requirements for undertaking the survey are basic. As well as the equipment required to ensure the survey is undertaken safely the following are required:

- measuring tape (30m)
- pens/pencils and paper
- camera
- GPS (set to WGS84 Long/Lat coordinates)
- gardener's trowel
- large sample bags
- survey forms
- ruler

6.3.4 Survey structure

Each Natura 2000 site to be surveyed should be split into units. These should cover only those areas of saltmarsh to be surveyed, but it may be appropriate to further split the saltmarsh areas into smaller units. These may be created to coincide with existing SSSI units where appropriate[2], to coincide with ownership or management compartments outside of SSSIs, or may simply be used to provide granularity on the survey results. Natura 2000 sites with a single small area of saltmarsh may be treated as a single unit. Each unit should be given a number or a code that corresponds to an area marked on a map.

This survey is based on a multiple transect walks across the littoral zone (landward – seaward) traversing saltmarsh and mudflat habitat within each site unit. Samples are recorded from each saltmarsh zone within each transect that includes *S. anglica* (using pre-formatted survey forms). Two sizes of quadrat are sampled within each zone within each transect when *S. anglica* is present. Data from each site is therefore recorded at five different spatial scales (Figure 10). The locations of transects and quadrats along each transect are recorded using GPS, to assist with their relocation in future surveys.

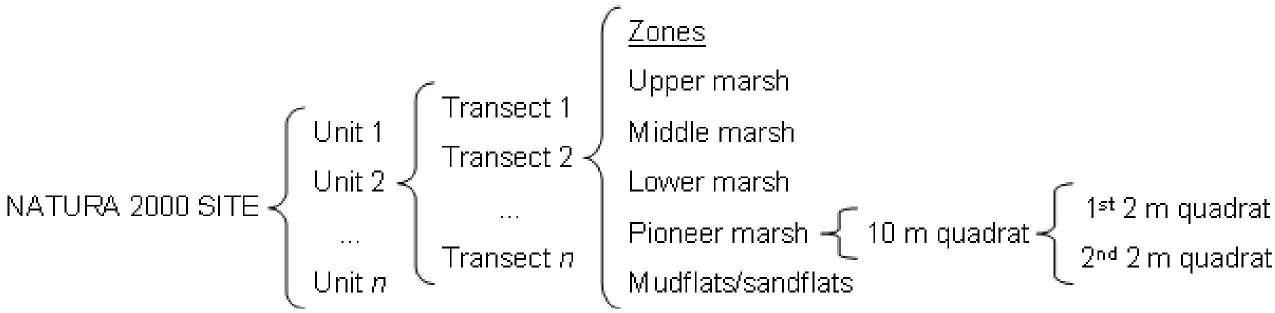


Figure 10 - The structure of the *Spartina anglica* monitoring protocol. Several units can occur within each site and each unit can contain several transects. Within each transect each saltmarsh zone is considered separately. Where *S. anglica* is present a 10 m quadrat and two 2 m quadrats nested within the 10 m quadrat are surveyed.

6.3.5 Pre-survey desk research

Obtaining data and seeking local knowledge is essential for effective planning of the survey protocol. Research is required prior to the survey to identify locations of *S. anglica*, which could use previous reports and information from site managers. This information can help to target specific area where *S. anglica* is thought to occur or changes to the saltmarsh potentially related to *S. anglica* have been observed. It may also help to determine when would be an appropriate time to survey, aiming to cover the *S. anglica* flowering period and avoid times when management or other activities are taking place that could disrupt the survey or affect the results.

Is it also useful to research the history of *S. anglica* on the site, as information including when it arrived, what it displaced and its perceived impacts upon other species and communities. Any information on past management should be obtained, especially where it relates to management of *S. anglica*. Need to consider sediment movement, sources and sinks, coastal management policies, and beneficial use of dredge material. Contextual information should also be gathered, such as nearby shipping channels, aggregate dredging, vessel movement, fishing activities and saltmarsh grazing.

[2] To monitor sites, Natural England divides SSSIs into smaller areas called ‘units’.

6.3.6 Survey location, timing, duration and frequency

The survey should be conducted across the saltmarsh habitat and onto the mudflats that fringe the seaward edge of the marsh. The survey transect commences from the point of terrestrial transition (e.g. the point where terrestrial grassland communities or wetland vegetation are present and the upper marsh begins). This transition point is normally defined by the presence of an artificial earthbank or hard engineered sea defences at the landward edge of modified saltmarshes.

It is recommended that transects are conducted from landward to seaward (Figure 11), so the survey forms are presented in this order, but it is also possible to complete the field survey from seaward to landward. Each transect should take approximately two hours to complete, excluding travel times to the unit, etc. The length of time the survey will take will be dependent on familiarity with the survey methods and the distance from the landward to the seaward extents of the saltmarsh.

The survey can be conducted from the start of June to the end of September. Mid-July to mid-August, or when *S. anglica* flowers are present, is the optimum period of assessment.

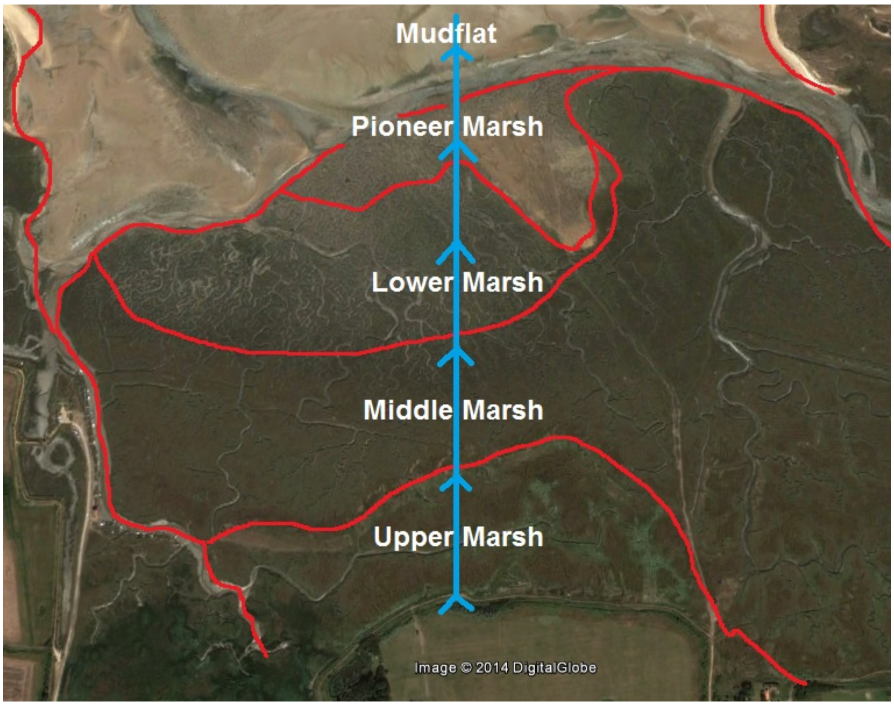


Figure 11 - An example of the type of transect to be walked (landward to seaward). Blue = the transect; red = the borders of saltmarsh zones.

Linking *S. anglica* survey transects to Environment Agency or coastal group topographic monitoring transects used for Regional Coastal Monitoring Programmes (e.g. East Anglian Coastal Group 2014; see www.channelcoast.org) or where there is existing *S. anglica* survey data is recommended. Transects used for Regional Coastal Monitoring Programmes may be spaced as close as 500 m apart and will have records of elevation change for these transects. The number of transects requiring survey at each unit is dependent on the size and variation of the unit, as well as the availability of information regarding the abundance and distribution of *S. anglica* populations. As a guide, it should be assumed that one transect should be conducted for every two kilometres of saltmarsh/mudflat length (see Figure 12) where no other information is available to indicate the spacing.

Transects at two kilometre intervals should be applied to units where *S. anglica* distribution is unknown or unclear or where *S. anglica* is found across a large length of the site under investigation. It is not necessary to survey areas where *S. anglica* is known to be absent.

Transects can be more specifically located if *S. anglica* populations on the unit are known. For example, if there are two populations of *S. anglica* that are spatially isolated from each other it might be logical to apply one transect to each population (see Figure 13).

It is also important to note that field surveys using transects at two kilometre intervals in the first year of survey can be refined to specific *S. anglica* populations in subsequent years.

The frequency of repeat surveys is flexible and should be linked to management objectives. As a guide, the monitoring should be matched to Habitats Directive reporting and therefore needs to be conducted at least once every six years. If management of *S. anglica* is occurring on the unit, then more frequent field surveys should be conducted to assess the response and any recovery, thus informing the need for any follow up treatment.

Figure 12 - An example of how to divide up a Natura 2000 saltmarsh unit into transects for assessment at two kilometre intervals. The yellow line is the lateral measurement across the saltmarsh (a length of eight kilometres) and the blue lines are the transects that require survey.

Figure 13 - An example of how to establish transects to survey isolated *Spartina anglica* populations. Red = Populations of *Spartina anglica*; blue = transects.

6.3.7 Unit form

The unit form (part of which is explained here) is designed to be completed once for each Natura 2000 site unit (Section 6.2.6). It has been designed to ensure that the factors relevant at a whole unit level are recorded, whilst minimising repetition of the details on the transect forms. One or more transect forms should be associated with each unit form.

Natura 2000 site name:		**Unit:**	
Assessed by:		**Date of assessment:**	D D / M M / Y Y Y Y
Unit manager:		**OS grid reference:**	A A 0 0 0 0 0 0 0 0
Are data available from a previous survey?	Yes ☐ No ☐	**Is a map available?**	Yes ☐ No ☐

The initial questions on the unit form are where all the basic information about the survey should be recorded, including the site name, unit code, OS grid reference, surveyor name and date of the survey.

Dates should be recorded in the form DD/MM/YYYY, e.g. 16/02/2011. If the survey is conducted over more than one day then a single day should be chosen from the middle of the survey period. The survey should be undertaken to coincide with the flowering period for *S. anglica*, in order to ensure that identification is possible.

The Ordnance Survey (OS) grid reference should be a six-figure (100 m) grid reference for the centre of the unit in the format AA000000, e.g. SO154338. A GPS location should also be recorded. For guidance on identifying OS grid references please see Ordnance Survey's website at http://www.ordnancesurvey.co.uk/resources/maps-and-geographic-resources/the-national-grid.html.

If data are available from a previous *S. anglica* monitoring survey the relevant box should be ticked. This will act as a record that there are data to compare the survey results with and inform future investigators that there are prior survey data that are available that should be sought. Equally, a record of the unit manager will assist future investigators and those undertaking surveys at a later date.

The survey should be conducted with a unit map and recent aerial photography. Aerial photography can be used to relate features and habitat stands on the ground to the position within the unit. There are a number of reasons why you may find it valuable to record information on a map of the unit:

- To record the approximate location of the transects and quadrats.
- To indicate the saltmarsh zonation
- To record additional habitat or stand boundaries.
- To record management compartments or historic features, which may assist with future management decisions.
- To assist with repeat surveys, by identifying hazards, recording access or features of note that can be monitored in the future.
- To provide a record of features of particular interest that otherwise would not be recorded.

If a map is available this can be indicated by ticking the appropriate box.

The remaining questions on the unit form may be easiest to complete at the end of the survey.

Are any of the following pressures present on this unit? *Tick yes or no for each pressure that occurs on or near to the unit.*					
Shipping channels	Yes ☐	No ☐	Drainage	Yes ☐	No ☐
Dredging/aggregate mining	Yes ☐	No ☐	Evidence of grazing	Yes ☐	No ☐
Seawall/revetment	Yes ☐	No ☐	Other *(describe)*	Yes ☐	No ☐
Other built structures	Yes ☐	No ☐			
(e.g. pipelines)					

Pressures on saltmarsh can affect accretion and erosion rates, as well as species composition and the incidence of natural processes. Recording where they occur indicates other factors that may be affecting the survey unit, other than factors caused by *S. anglica*. The presence of the following pressures should be recorded:

- Signs of shipping/navigation activities in adjacent channels.
- Signs of removal of sediment in adjacent channel (e.g. dredging vessels) and any data on consented activities collated from relevant bodies to be recorded on form.
- Seawall/revetment – any built structure designed to deflect or reduce the impact of tidal waters. These can occur on the seaward or landward side of saltmarsh or may divide the saltmarsh.
- Other built structures (e.g. pipelines, groynes) – any other built structure that crosses the saltmarsh.
- Drainage – straight channels dug into the saltmarsh or other structures designed to remove water from the land more rapidly. Sinuous channels are likely to be creeks, some straight creeks are natural, a natural feature of saltmarsh that should not be recorded here.
- Evidence of grazing – any evidence of grazing by livestock or wild animals, including dung, prints and hair on internal fence lines.
- Other (describe) – any other factors observed that could be causing pressure on the site.

Factors recorded in the ‘other’ category may be added to future versions of the survey form.

		High	Medium	Low
Rate the impact of the following pressures on the unit? *Tick high, medium or low for each pressure that occurs on or near to the unit.*	Recreational use	☐	☐	☐
	Pollution	☐	☐	☐
	Poaching	☐	☐	☐

The impact of recreational use, pollution and poaching on the survey unit may be significant and more readily assessed than the impacts listed in the previous question. The perceived impact that these are having on the saltmarsh should be recorded as high, medium or low, taking into account the areas seen on the transects and whilst walking between them.

Poaching is a muddy, rutted area free from vegetation occurring where livestock congregate in one place and churn up the soil. It does not include flat and smooth areas of bare ground that have been caused by light trampling or dry pans. Poaching should only be recorded where it occurs away from access points and water troughs, as away from these areas it is a sign that stocking densities are too high.

Include marine activities that can cause disturbance to mudflats and pioneer marsh e.g. marine activities, bait digging, fishing (cockle/clam dredging) at high water over intertidal.

Are any of the following natural features present on this unit? *Tick yes or no for each feature that occurs on the unit.*								
Creeks	Yes ☐	No ☐	Dry Pans	Yes ☐	No ☐	Wet Pans	Yes ☐	No ☐

The occurrence of natural features within a saltmarsh indicates that natural processes are occurring, which in turn suggest that the unit is less impacted by non-natural activities and pressures. This may help to understand the interaction of natural processes and *S. anglica*.

The presence of the following natural features on the survey unit should be recorded:

- Creeks – natural, normally sinuous channels caused by the outflow of water.
- Dry pans – mostly unvegetated depressions in the ground that are seasonally or tidally filled with water.
- Wet pans – pools of water not visibly connected to the creek network.

Please provide any information relating to erosion of the saltmarsh. Examples include: • widening creeks; • saltmarsh islands & sediment clumps in the intertidal zone; • vegetation dieback; • stepping and overhanging/collapsing pan and creek edges. Refer to the relevant transect or area within the unit where appropriate.

S. anglica is believed to effect erosion rates (Section 2.3), but is not the only potential factor involved. Teasing out the potential causes of erosion is one of the key requirements of this survey methodology. Space is provided to record any information that may indicate that erosion is occurring or its causes. Where appropriate, this information should refer to specific transects or areas within the survey site.

Are any of the following *Spartina anglica* specific control techniques occurring on the unit? *Tick yes or no for each technique.*					
Cutting	Yes ☐	No ☐	Steam and infra-heat treatment	Yes ☐	No ☐
Physical removal	Yes ☐	No ☐	Biological control	Yes ☐	No ☐
Roto-burying	Yes ☐	No ☐	Other *(describe)*	Yes ☐	No ☐
Smothering	Yes ☐	No ☐			
Herbicide use	Yes ☐	No ☐			
Burning	Yes ☐	No ☐			

S. anglica is or has been controlled on some saltmarsh sites, which will clearly have an impact on the abundance of this and other species, as well as having potential physical impacts on the unit, such as affecting erosion rates. The following types of *S. anglica* control should be recorded where known (see also Section 5):

- Cutting – removal of part of the above ground vegetation.
- Physical removal – uprooting and removal from the site.
- Roto-burying – mechanical burying of vegetation beneath the sediment surface.
- Smothering – the placement of an impermeable barrier over the sward in order to inhibit photosynthesis and elevate temperature.
- Herbicide use – chemical treatments designed to kill all or part of the vegetation.
- Burning – planned burning of vegetation.
- Steam and infra-heat treatment – the use of either steam at 100°C or infrared heat generated from a grill or other device to destroy above and below ground vegetation.
- Biological control – biological agents, such as herbivores and plant diseases, released to remove all or part of the vegetation.
- Other (describe) – any other type of control being employed.

Types of *S. anglica* control recorded in the 'other' category may be added to future versions of the survey form.

Please provide further information regarding the interaction of *Spartina anglica* with other species, habitats and vegetation communities. Consider the following example questions: • Is *Spartina anglica* competing or limiting conditions for other species (not just plants)? • Has *Spartina anglica* recently colonised this area? What was there before? • Are other species being promoted/facilitated by the presence of *Spartina anglica*? • How is *Spartina anglica* influencing the surrounding vegetation? • Is the sedimentation rate and type changing in areas where *Spartina anglica* is present?

A space is provided on the form to record general information about the interaction of *S. anglica* with other species, habitats and vegetation communities on the survey site. This may not always be obvious in a field visit, so information from unit managers can also be recorded here. This can help to support an assessment of the impacts of *S. anglica* overall.

6.3.8 Transect recording form

Within each unit one or more transects should be surveyed. These are linear survey routes that stretch from the landward edge of the saltmarsh to the most seaward vegetated part. The width of each transect is five metres, 2.5 metres either side of the surveyor, and should be as straight as possible.

The transect recording forms are focused upon recording the presence, cover and health of *S. anglica*, as well as its relationship with other species in the area. It may also suggest where other survey may be required, for example to establish the frequency and cover of important species or communities.

Site name:				**Unit:**	
Transect code:		**Assessed by:**		**Date of assessment:**	DD / MM / YYYY
Please provide OS grid references for the start and end of the transect.				Start: AA00000000	End: AA00000000

The initial part of the transect recording form and subsequent pages duplicate the information recorded at the top of the unit form, as this ensures that if the forms become separated it is clear they form part of the same record.

In addition to these basic questions, the start and end positions of the transect should be recorded, in British National Grid format. Space for a 10 m resolution grid reference is provided, as GPS should be used to pinpoint the precise location; lower resolution grid references can be used if necessary, but will not be accurate enough to allow the transect to be relocated in future surveys.

Saltmarsh zone	**Upper marsh**	**Middle marsh**	**Lower marsh**	**Pioneer marsh**	**Mudflats/ Sandflats**
Is this saltmarsh zone present?	Yes ☐ No ☐	Yes ☐ No ☐	Yes ☐ No ☐	Yes ☐ No ☐	Yes ☐ No ☐
The questions for each zone below need only be answered if the relevant zone is present.					
Which of the following best describes the predominant form of *Spartina anglica*? *Tick one for each zone. See the survey handbook for guidance.*					
Isolated individual plants	☐	☐	☐	☐	☐
Sporadic clumps	☐	☐	☐	☐	☐
Expanding clumps	☐	☐	☐	☐	☐
Integrated into vegetation sward	☐	☐	☐	☐	☐
Co-dominating the vegetation sward	☐	☐	☐	☐	☐
Dominant	☐	☐	☐	☐	☐
Absent	☐	☐	☐	☐	☐
The questions for each zone below need only be answered if Spartina anglica *is present.*					
What is the overall percentage of decline or dieback of *Spartina anglica* in this zone?	☐ %	☐ %	☐ %	☐ %	☐ %
If percentage of decline or dieback of Spartina anglica *is greater than 0%, please answer the following question:*					
Is the decline of *Spartina anglica* causing erosion?	Yes ☐ No ☐	Yes ☐ No ☐	Yes ☐ No ☐	Yes ☐ No ☐	Yes ☐ No ☐
Recording in the 10 m and two nested 2 m quadrats below need only be undertaken where Spartina anglica *is present in the relevant zone.*					

Each transect is split into sections relating to saltmarsh zonation. These relate to proximity to the seaward edge of the saltmarsh, with mudflats and sandflats being the closest to the sea and upper marsh being the furthest away. Saltmarsh zones are defined to identify the various stages of saltmarsh development, in terms of vegetation succession. A number of classifications exist, but one of the most suitable classifications for assessment is provided by SNH (2010b), which matches vegetation communities within saltmarsh zones to NVC level (Rodwell 2000). Each zone may or may not be present, so the presence of each should be recorded. If a zone is absent from transect then there is no need to answer any further questions relating to it.

Small areas more typical of other zones should be treated as the predominant zone they occur within. For example, an area of a lower saltmarsh community occurring within the upper saltmarsh zone due to the presence of a creek or depression should be treated as part of the upper saltmarsh.

For each zone, the predominant form of *S. anglica* should be selected from the options provided. The best way to achieve this is to walk the length of the transect within the zone whilst looking for *S. anglica* within the width of the transect. Only the single best description should be ticked; small areas where a different form of S. anglica predominates can be described on page 3 of the transect form. The options are:

- Isolated individual plants – *S. anglica* occurring as single isolated plants often found on mudflats and saltmarshes (Figure 14)[3].
- Sporadic clumps – *S. anglica* occurring in small distinct isolated or widely spaced clumps that exclude other vegetation (Figure 15).
- Expanding clumps – *S. anglica* occurring in larger distinct clumps that exclude other vegetation (Figure 16). There is normally evidence of some clumps merging together.
- Integrated into vegetation sward – *S. anglica* occurring throughout the saltmarsh sward without forming distinct clumps that exclude other vegetation or being noticeably dominant (Figure 17).
- Co-dominating the vegetation sward – *S. anglica* occurs in roughly equal quantities to the other main species present. *Puccinellia maritima*, *Salicornia*, and *Suaeda maritima* are the most likely species to co-dominate with *S. anglica*.
- Dominant – *S. anglica* covers most of the zone to the near exclusion of other species (Figure 18).
- Absent – *S. anglica* is not present within the zone.

If *S. anglica* is absent then there is no need to answer further questions for that zone. It is not the objective of this survey to record information on the rarer species of *Spartina* spp. in the absence of *S. anglica*, though additional survey to record relevant information may be appropriate. If it is not clear which species of *Spartina* spp. are present the zone should be surveyed based upon the assumption that the unknown *Spartina* spp. is *S. anglica*.

Figure 14 - Typical examples of isolated individual plants of *Spartina anglica*

[3] Since *S. anglica* is a rhizomatous perennial it tends to form loose clumps, making it difficult to define a single plant. *S. anglica* should be regarded as individual plants where their visible above ground growth forms clearly separated discrete areas with other vegetation or greater than 10 cm of bare mud between.

Figure 15 - Typical examples of sporadic clumps of *Spartina anglica.*

Figure 16 - Typical examples of expanding clumps.

Figure 17 - Typical examples of *Spartina anglica* integrated into the vegetation sward.

Figure 18 - Typical examples of *Spartina anglica* dominance.

The overall percentage of decline or dieback of *S. anglica* within the zone should be recorded. Signs of decline and dieback include dead, brown or yellowing parts of plants or entire plants, or decaying stems and roots within the sediment. Note that *S. anglica* may have a similar appearance after erosion and storm damage, so any visible evidence of these should be taken into account.

Where some decline or dieback is occurring an assessment of whether this is causing erosion should be made, useful to refer to previous survey data where available, with the result recorded. This is inevitably a subjective assessment, so to improve consistency the following questions should be considered:

- Is erosion only occurring around areas of *S. anglica* dieback?
- Are there other areas where saltmarsh is eroding?
- Are there signs of sediment scour around clumps as *S. anglica* decays?
- Is there evidence of healthy *S. anglica* that is also suffering from erosion, which may be indicated by the presence of tussocks with cliffed edges (Balke et al. 2012)?

<u>10 m quadrat</u>

The 10 m and 2 m quadrats need only be surveyed if *S. anglica* is present within the zone. The entire length of the transect within each zone should be walked before selecting a 10 m quadrat to ensure that the quadrat is representative of the zone as a whole. Within particularly wide zones one 10 m quadrat and its nested 2 m quadrats should be completed for each 100 m length of transect or part thereof. Note that in order to save space the survey form is not currently designed to accommodate multiple quadrats in a single zone, so additional quadrats will need to be recorded separately.

The 10 m quadrat is a square with 10 m edges orientated so that the transect line forms a midline through the quadrat (Figure 19). It should be located such that it is representative of the spatial pattern and abundance of *S. anglica* in the zone as a whole, which may be a lot or very little. A photograph of the 10 m quadrat should be taken for future reference.

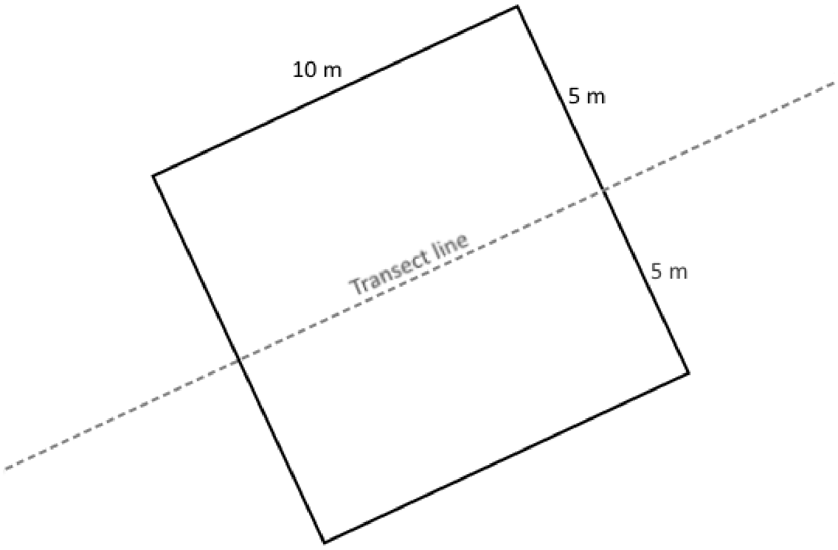


Figure 19 - Location and orientation of the 10 m quadrat along the transect.

Enter the OS grid reference for each 10 m quadrat:

Upper AA000000000 Lower AA000000000 Mudflats/ Sandflats AA000000000

Middle AA000000000 Pioneer AA000000000

Saltmarsh zone	Upper marsh	Middle marsh	Lower marsh	Pioneer marsh	Mudflats/ Sandflats
Which of the following best describes the sediment type beneath the *Spartina anglica* sward? *Tick one for each zone.*					
Waterlogged mud	☐	☐	☐	☐	☐
Firm mud	☐	☐	☐	☐	☐
Waterlogged sand	☐	☐	☐	☐	☐
Firm sand	☐	☐	☐	☐	☐
Rock	☐	☐	☐	☐	☐
Shingle	☐	☐	☐	☐	☐
How deep is the soft sediment beneath the *Spartina anglica* sward in centimetres? *Use a stick or a ruler to measure the depth.*					
	☐ cm	☐ cm	☐ cm	☐ cm	☐ cm
Are the following *Spartina* species definitely present. *Tick 'Y' if definitely present, 'N' if definitely not present and 'U' if unknown.*					
	Y N U	Y N U	Y N U	Y N U	Y N U
Spartina anglica	☐☐☐	☐☐☐	☐☐☐	☐☐☐	☐☐☐
Spartina anglica / × townsendii	☐☐☐	☐☐☐	☐☐☐	☐☐☐	☐☐☐
Spartina × townsendii	☐☐☐	☐☐☐	☐☐☐	☐☐☐	☐☐☐
Spartina alterniflora	☐☐☐	☐☐☐	☐☐☐	☐☐☐	☐☐☐
Spartina patens	☐☐☐	☐☐☐	☐☐☐	☐☐☐	☐☐☐
Spartina maritima	☐☐☐	☐☐☐	☐☐☐	☐☐☐	☐☐☐
Unknown non *Spartina anglica*	☐☐☐	☐☐☐	☐☐☐	☐☐☐	☐☐☐

The central location of the 10 m quadrat in each zone should be recorded by entering a grid reference in the relevant boxes. This should be blank where a quadrat was not surveyed either because the zone was absent or because it contained no *S. anglica*.

S. anglica is associated with changes in the type and depth of sediment, but it is unclear whether it causes the changes or simply quickly occupies a new niche formed by another process. The sediment type beneath the *S. anglica* sward within each 10 m quadrat should be recorded. This might differ from the sediment beneath other plants. One of the following that best describes the sediment should be ticked:

- Waterlogged mud
- Firm mud
- Waterlogged sand
- Firm sand
- Rock
- Shingle

The depth in centimetres of the sediment should also be recorded. A stick or a ruler should be used to measure the depth. The thickness of the measuring implement has an effect on the depth it will penetrate, so it is recommended that the area of the implement in cross section is approximately 1 cm^2 to improve consistency. Some sediment may be very deep, in which case it is acceptable to record that it is greater than *x*, e.g. > 30 cm.

The presence of the possible *Spartina* spp. should be confirmed as either present, not present or unknown. It is advisable to use keys, and only if necessary and subject to obtaining permission to collect at least one sample of each species present, which can be dug from the ground using a gardening trowel. Primarily this enables the confidence in the identification of *S. anglica* to be recorded, with an alternative of *S. anglica* / × *townsendii* possible where it is known to be one but unclear whether it is the fertile or sterile hybrid. It also allows the presence of other *Spartina* spp. to be recorded, including definite *S.* × *townsendii*, *S. alternifolia*, *S. maritima* and the relatively new arrival *S. patens* (Botanical Society of the British Isles 2006), as well as a category for any *Spartina* spp. that is definitely not *S. anglica* but whose precise identity is unknown.

Note that the uprooting of any wild plant without the consent of the owner or occupier and without SSSI consent is an offence. Permission should be gained if the removal of plant material is likely. It is inadvisable to remove whole plants where *S. maritima* occurs, due to the risk of inadvertently weakening populations of this rare species.

Reliable identification of *S. anglica* involves measuring the length of the mature anthers, which at 7-10mm (sometimes up to 13mm), (Stace 2010) are generally larger in *S. anglica* than in *S.* × *townsendii* or *S. maritima*. The height, and length of spikelets, leaves and panicles are less reliable (Garbutt, A. (Table 5.1 (In preparation) and Marchant, C. 1967) The ligule in *S. anglica* is usually longer than in other species, but this is often irregular and prone to damage, so cannot be considered reliable without other diagnostic characteristics (Trist 1988). It may be possible to separate a number of the species using their root/rhizoid systems, but these conclusions require further research and are not recommended for this method.

Saltmarsh zone	**Upper marsh**	**Middle marsh**	**Lower marsh**	**Pioneer marsh**	**Mudflats/ Sandflats**
Record the cover of the plant species present using the DOMIN scale: 10 = 91-100%, 9 = 76-90%, 8 = 51-75%, 7 = 34-50%, 6 = 23-33%, 5 = 11-25%, 4 = 4-10%, 3 = <4% (many plants), 2 = <4% (several plants), 1 = <4% (few plants). *Record any additional plants in the spaces and continue on a separate sheet if necessary.*					
Bare mud					
Open water					
Algal mat					
Common cord-grass *Spartina anglica*					
Sea couch *Elytrigia atherica*					

A full survey should be undertaken of the 10 m quadrat within each zone. The cover of all plants and unvegetated areas should be recorded using the DOMIN scale, which is shown on the form. A list of species is included on the quadrat form, along with spaces for other species to be added. Surveyors should continue on a separate sheet should the space be insufficient for the species recorded. It is important that substrates such as bare mud and areas of algae or algal mats are also included.

Full recording of the species present within a representative area of each zone will assist with understanding the relationship between *S. anglica* and the other species in the sward. Where it is not possible to ensure a representative sample within a single quadrat, two or more should be surveyed.

Please use the space below to record any additional information about the *Spartina anglica* within the 10 m quadrats. Refer to the relevant quadrat or zone along the transect where appropriate.

Space is provided for recording any other information about the *S. anglica* within the 10 m quadrat that is not recorded elsewhere on the form. This could include more detail about the confidence in its identification, its growth form, apparent health, status as a component of the plant community and its relationship with and apparent impact on the other species present. Any visible damage to the saltmarsh may also be important to consider. These details should relate to each 10 m quadrat, as appropriate.

<u>2 m quadrat</u>

Two 2 m quadrats should be nested within each 10 m quadrat. Each should be centred over a relatively large patch of *S. anglica*, which may be a single plant or a dense clump depending upon the nature of the 10 m quadrat. Where only a single *S. anglica* plant occurs within the zone it will only be possible to conduct one 2 m quadrat, in which case the form for the second should be left blank.

Saltmarsh zone	**Upper marsh**	**Middle marsh**	**Lower marsh**	**Pioneer marsh**	**Mudflats/ Sandflats**
What is the average distance in centimetres between the patches of *Spartina anglica* that are present in the quadrat? *Distance should be measured by taking the central patches and averaging the distance to the nearest four others.*	cm	cm	cm	cm	cm
What is the average height in centimetres of the *Spartina anglica* present in the quadrat?	cm	cm	cm	cm	cm
Is the *Spartina anglica* showing signs of vegetative spread?	Yes No	Yes No	Yes No	Yes No	Yes No
What proportion of the *Spartina anglica* stems are flowering or setting seed in this season? *Record the percentage of culms and tillers that are likely to produce viable seeds.*	%	%	%	%	%
What proportion of the *Spartina anglica* are showing any obvious signs of disease or poor health? *This includes dead or yellowing leaves, fungal growth, rust and smut, etc.*	%	%	%	%	%

The average distance in centimetres between the *S. anglica* patch in the centre of the 2 m quadrat to nearest four other patches should be recorded. The four other patches can be either within or outside of the quadrat. Where relevant, the distance between the edges of clumps should be measured, though where there a no distinct clumps it is necessary to measure between the centres of patches. This helps to indicate the density of the *S. anglica* and the likely effect it is having upon the plant community as a whole.

Where fewer than four *S. anglica* patches are present in the area around the quadrat the average distance between the available patches should be recorded. Where only a single *S. anglica* plant is present it will not be possible to record an average distance to the next nearest, in which case an X should be recorded in the box.

The average height of the *S. anglica* within the 2 m quadrat should be recorded in centimetres, which indicates the vigour and maturity of the plants. This can be estimated from the heights of the culms and tillers present within the quadrat.

Clear signs of vegetative spread of *S. anglica* within the 2 m quadrat should be recorded, which could include the presence of new rhizomes or tillering on the periphery of patches. This can be used to determine whether the *S. anglica* is increasing, stable or in decline. Tussock shape may also be used to determine whether *S. anglica* is spreading (Figure 20).

The proportion of *S. anglica* culms and tillers that have inflorescences that are likely to produce viable seeds should be recorded as a percentage. Inflorescences may be still developing or may have already begun to form seeds. This indicates the likely *S. anglica* seed set and subsequent spread to other areas. Where the *Spartina* spp. are not showing any signs of inflorescences it may not be possible to answer this question, in which case the relevant box should be left blank.

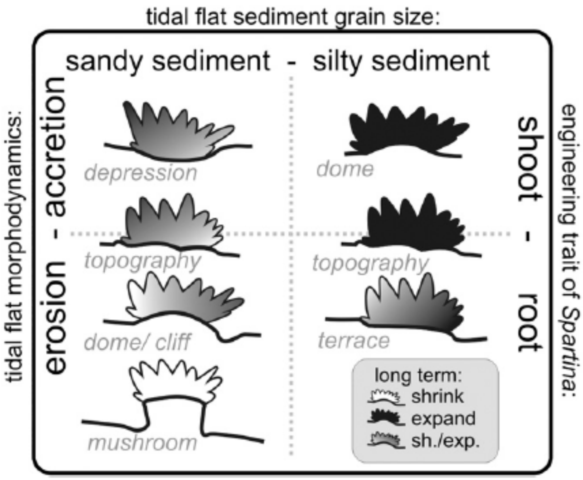


Figure 20 - Schematic representation of the likely future spread of *Spartina anglica* tussocks in different substrates and tidal flat morphologies. In sandy sediments *S. anglica* tussocks showing depressed (accreting), domed (eroding) or those following the overall topography may be expanding or shrinking, whilst mushroom-shaped tussock are likely to be shrinking due to the effects of erosion. In silty sediments *S. anglica* tussocks that are domed (accreting) or follow the overall topography are likely to be expanding, whilst those that are terraced-shaped (eroding) may be expanding or shrinking. From Balke et al. (2012).

The proportion of *S. anglica* showing obvious signs of disease or poor health should also be recorded as a percentage. Note that saline environments often cause plants to look unhealthy and stunted. Signs of disease include:

- dead or yellowing leaves
- mildews, rusts and smuts, including ergot *Claviceps purpurea* (see Section 2.6)
- visible fungal hyphae
- leaf spots
- foliar and stem lesions
- crown rot or leaf rot

6.3.9 Post survey

Following the survey all data should be compiled and captured electronically, to improve its usefulness in further studies. All transects and quadrats should be mapped in GIS, using the GPS coordinates recorded, to get an accurate picture of their location. It is also useful to map the *S. anglica* stands if it is possible to use the survey results to identify them on aerial imagery.

There is no clear assessment protocol for the survey results, as this would require further testing and development of the survey protocol. Until this is done, the data collected should therefore be used as best available evidence to support objective decisions about the impact of and risk posed by *S. anglica*, taking into account other geomorphological and biotic factors relevant to the site. The flow chart in Section 8 should be used to decide whether management of *S. anglica* or further research to determine its likely impact or risk is required.

6.4 Selection of case study sites

Four case study sites were selected objectively, in order to target examples of as many different scenarios involving *S. anglica* as possible, such as:

- Increasing *S. anglica*
- *S. anglica* appearing as a clear pioneer
- Increasing *S. anglica* and erosion
- *S. anglica* increasing along with other species
- Increasing and decreasing *S. anglica* in different areas
- Increases in dense *S. anglica* (e.g. on bare mud)
- Decreases in *S. anglica* in mixed communities
- *S. anglica* being replaced by other communities.
- *S. anglica* dieback
- *S. anglica* dieback and erosion
- *S. anglica* occurring with other *Spartina* spp.

Sites were also prioritised where they had past survey data that might show change. Sites with recent surveys were excluded, as it was thought that little would be gained from surveying sites that were unlikely to have changed.

Evidence from recent surveys suggested that the Severn Estuary SAC (and also SSSI) would contain examples of *S. anglica* occurring as a component of but not dominating established communities. The Severn Estuary has had two historic surveys: the Severn NVC Survey 1998 (Dargie 1999), which had a complete habitat map, and the Severn saltmarsh revalidation in 2010

(Harvey and Nuttall 2010), which aimed to resurvey the same transects but did not result in an updated habitat map. It was also covered by Environment Agency South West Habitat Mapping data (Environment Agency 2011), which allowed for additional comparison.

The data suggested that a location near Aust would be the best area to target survey, as this would demonstrate both the decline and increase of SM6 *Spartina anglica* salt-marsh community, and decreasing frequency of *S. anglica* within more mixed sward plant communities. Permission to survey was sought through Natural England and obtained from two out of the three landowners concerned, allowing approximately half of the unit to be surveyed.

Saltmarsh sites on the Essex coast within the Essex Estuaries SAC were included as survey sites, as they were discussed in a number of the published papers reviewed. They also contained records of *S. maritima*, *S.* × *townsendii* and *S. alternifolia* in addition to *S. anglica* according to the data from the NBN Gateway, which was the sole source of information for these sites other than correspondence.

Two suitable survey sites in Essex were identified through discussion with local Natural England staff, within the Crouch Estuary and the Blackwater Estuary, within two component SSSIs of the SAC. These were believed to demonstrate pioneer stands of *S. anglica*, including some expanding areas, plus the presence of *S. maritima*, *S. alternifolia* and *S.* × *townsendii*. Permission to survey these sites was also gained through Natural England.

The saltmarshes around the Lindisfarne causeway, within the Berwickshire and North Northumberland Coast SAC, (and also within the Lindisfarne NNR) were also visited to assess the monitoring protocol across a site where *Spartina* management has taken place. This site was also investigated due to reports of *Spartina anglica* expanding across both sandy and muddy substrates.

6.5 Field survey results from case study sites

The findings of the trial surveys are presented in Appendix E. It should be noted that the results for the Severn Estuary SAC and Essex Estuaries SAC were only collected as a means of testing the survey methods and forms. The results are also not directly comparable as different survey forms were used for the Severn Estuary and the surveys in the two Essex Estuaries locations. Further more detailed work would be needed across a wider area of these SACs. Additional survey work was conducted within the Berwickshire and North Northumberland Coast SAC at Lindisfarne to make data comparisons across *Spartina* management treatments. These findings are discussed at the end if this section.

6.5.1 Severn Estuary SAC and Essex Estuaries SAC

Four transects were surveyed in the Severn Estuary SAC, all within one SSSI unit. These transects included areas of *S. anglica* within the middle and lower marsh zones. *S. anglica* was integrated into the saltmarsh vegetation sward across both zones. The pioneer zone included areas of expanding *S. anglica* clumps. Erosion was evident in the pioneer zone, but *S. anglica* was not considered to be the cause.

Two transects were surveyed across the narrow area of saltmarsh on the River Crouch. *S. anglica* was integrated into the sward across both transects. Very few *S. anglica* plants were found across the pioneer zone, which was instead occupied by *S. maritima*. Significant erosion was occurring on this saltmarsh, but it was not attributed to the presence of *S. anglica*.

Only isolated *S. anglica* clumps and individual plants were recorded from the two transects surveyed on Blackwater Estuary, despite previous surveys indicating large areas of the species. It was possible that larger areas could be found in other parts of this large saltmarsh complex. Erosion was evident across this saltmarsh, but *S. anglica* was clearly not the primary driver of erosion.

6.5.2 Berwickshire and North Northumberland Coast SAC

Four transects were surveyed within the Berwickshire and North Northumberland Coast SAC (Figure 21). Transect 1 was located to the south of the Lindisfarne causeway, within an area where rotoburying of *S. anglica* was conducted in the past five years as part of the NNR management. Transects 2 and 3 were also located to the south of the Lindisfarne causeway, in areas where no management had taken place on *S. anglica* swards. Transect 4 was located on the east side of the Lindisfarne causeway where the substrate was sandier and no management was reported.

Transect 1 clearly showed that the monitoring protocol can detect the effects of management on *S. anglica*. In the middle and lower saltmarsh zones where no management had occurred *S. anglica* was integrated into the sward and as isolated plants. This is similar to the form and distribution of *S. anglica* observed on the two pilot study sites. Significant expansion of the saltmarsh on the south side of the causeway, onto the mudflats, was evident and had become a wide area of pioneer marsh dominated by *S. anglica*. Evidence of erosion, including creek widening, was recorded from this pioneer zone. Significantly less *S. anglica* was recorded in areas where rotoburying had taken place on the mud flats (Appendix E.4). Only isolated plants were recorded with few signs of expansion from the managed areas. Of note was the lack of a muddy substrate within the managed areas, which was occupied by waterlogged and firm sand. *Zostera* was also present in the managed areas.

Figure 21 - Transect locations in the Berwickshire and North Northumberland Coast SAC (Lindisfarne). Red lines denote the locations of the four transects. Yellow lines indicate what appear to be areas of erosion. The blue line indicates the location of the causeway.

Comparison between the transects within managed and unmanaged areas of *S. anglica* was confounded by significant erosion in the unmanaged areas on both sides of the causeway, possibly due to storm surges in the winter of 2013. Transect 2's saltmarshes were eroded to a narrow belt of lower marsh fronted by *S. anglica* pioneer marsh. Transect 3 was also very narrow, but showed signs of *S. anglica* expansion.

Transect 4 was situated on the opposite side of the causeway, where a sandier substrate was present. Significant erosion was also recorded from this area, but it was noteworthy that *S. anglica* was recorded as integrated into the sward on this substrate. Observations in Transect 4 showed that *S. anglica* colonises pans populated with *Puccinellia maritima*. Some areas of Transect 4 showed signs of complete saltmarsh erosion, where only sediment clumps covered in algae were present at the time of the survey. It was clear that *S. anglica* was the only species able to sustain itself throughout such erosion processes, as *S. anglica* plants and clumps were found in former pans.

Despite the significant accretion of mud and expansion of *S. anglica* on the southern side of the Lindisfarne causeway, it was evident that there had been significant erosion of the saltmarshes on sandy substrates on the north side of the causeway and in the south-east of the estuary (Transect 2). There is evidence that *S. anglica* is the cause of saltmarsh accretion, but there was no evidence that *S. anglica* was the cause of the erosion observed. The sedimentation processes taking place between Holy Island and the mainland are complex and appear to be changing. These changes are possibly associated with the construction of the causeway across the estuary.

The estuary included large populations of *Zostera spp*, which was recorded seaward of the *S. anglica* swards. It is possible that larger areas of *Zostera spp* may have been able to occupy the areas of mudflat now occupied by *S. anglica* pioneer marsh in the past (see Transect 1), but it was also noted that dead *Zostera spp* was recorded from the eroded areas of saltmarsh in Transect 4. *Zostera spp* appeared to be re-colonising areas of sandflat where *S. anglica* management had taken place.

In conclusion, *S. anglica* could be a potential threat to *Zostera* beds around the Lindisfarne causeway, but further work to understand the changes in sedimentation regimes occurring across the estuary is required. This should ascertain whether sufficient exposed mudflats or sandflats will be maintained for *Zostera spp* and to help predict future saltmarsh erosion and accretion. The evidence collected as part of the survey indicates that *S. anglica* is likely to expand where mud deposits continue to develop, erosion permitting, but it is less likely to dominate sandier substrates. Signs of ill-health including mould and fungus were recorded on a small number of *S. anglica* plants, which may also influence future changes to the Lindisfarne saltmarshes.

6.6 Appraisal of survey protocol

The survey method is simple to use and can be completed quickly, though this is dependent on the width of the saltmarsh. The results collected from the survey, when used in conjunction with the management flow chart (see Figure 22), should provide a useful aid to decision makers regarding the appraisal of the effects of *S. anglica* and will support the setting of management objectives where required. However, the protocol should be tested on a larger number of sites and refined when new situations encountered dictate that change is required.

7 Recommendations for further work

7.1 Further testing and development of survey protocol

The monitoring protocol developed during this work was tested on only three sites during this work (Section 6.4), none of which had extensive stands dominated by *S. anglica*. It is strongly recommended that it is tested on a much larger sample of survey sites containing *S. anglica* in a wide range of different situations. Following this more extensive test it may be appropriate to redevelop the survey form to add in questions to collect additional key information and remove those considered to be superfluous.

More extensive implementation of the survey protocol should generate more survey data than was available during this work. This could be used to determine a robust approach to analysing the survey results, which could then be documented as a process. This could build upon the decision making process described in Section 8.

7.2 Recording multiple quadrats in a single zone

As noted in Section 6.2.10, it is currently not possible to record multiple quadrats from a single zone on the survey form, although this can be a requirement of the survey protocol. This was due to conflicts between the need to make the survey form comprehensive and the ambition to keep it short and reduce the use of paper. The current recommendation is to record additional quadrats separately, though this is not ideal.

One solution would be to create a separate quadrat form, but this would cover only a single zone, which would make finding a sensible layout for the form very challenging. It would also reduce the remainder of the transect recording form to half an A4 page. The addition of a separate form would also increase the complexity of the survey.

A preferable solution would be the development of electronic forms that could be completed on a smartphone, tablet or other handheld device. This would allow the relational structure of the survey to be fully reflected in the form, with multiple transects per unit, etc. It could also allow any number of transect or quadrat forms to be completed.

Ideally the electronic forms would be implemented as an app, which would ensure robust data collection and could then allow other functionality. For example the app could include mapping or aerial photography that linked to on-board GPS and allowed surveyors to accurately locate their position. The locations of transect start and end points, and quadrats could also be captured using on-board GPS. It could also only present the questions required so that, for example, if *S. anglica* is not present within zone no further questions are presented for that zone.

7.3 *Survey to determine the extent of* Spartina anglica *communities*

It is clear from the results in Section 3.3 that good data were available showing the distribution of *S. anglica*, but recent data on the extent of *S. anglica* is very limited, confined mainly to a few protected sites. Good information on the extent of *S. anglica* is critical to gaining an understanding and making a robust assessment of its impact. There are two ways this could be achieved: through remote sensing and field survey.

7.3.1 Development of an approach to remote identification of *Spartina anglica*

Brief trials of using aerial photography to identify *S. anglica* were undertaken during this project. By assessing aerial photography against the known extent of *S. anglica* it was possible to distinguish some *S. anglica* stands, based upon the following rules:

- *S. anglica* tends to have a purplish green colour
- *S. anglica* stands tend to have a smooth texture
- *S. anglica* stands become less purple, sometimes becoming browner, and more textured as the move towards SM13 *Puccinellia maritima* salt-marsh community, due to the presence of other species
- Other communities may be distinguished as follows:
    - SM16 *Festuca rubra* salt-marsh community appears more heavily textured, with pale green bands
    - S21 *Scirpus maritimus* swamp appears as dark purplish brown textured blobs

The substantial variation in *S. anglica* height will have an impact on the texture of stands on aerial photography, which means that this potentially important diagnostic feature may be unreliable. This was apparent in one of the areas investigated, where a stand of SM6 *Spartina anglica* salt-marsh community showed a noticeably rougher texture than other stands of the same community.

Other investigators have considered the use of satellite imagery (Li et al. 2010; Zhang et al. 2009; Gross et al. 1986). This has the benefit of greater numbers of spectral bands and may prove to be more accurate, though there is evidence that the reflective response of *S. anglica* varies seasonally due to the growth form of the plant and the combination of summer and winter imagery is necessary (Dehouck et al. 2012).

Interpretation of both aerial photography and satellite imagery is only likely to successfully identify stands dominated by *S. anglica*. It is therefore likely that an assessment based entirely upon remote sensing will miss communities that are not dominated by *S. anglica* but that nevertheless make a large contribution to its extent. Where *S. anglica* is mixed in with other vegetation, information will need to be gathered through use of ground-based field surveys to validate and provide detail for wider mapping from remote sensing.

It is recommended that the approaches available and practicalities of remote sensing *S. anglica* should be further investigated, covering aerial photography and a range of satellite imagery products available. This will take forward the initial work reported in Lacambra et al (2004) which aimed to map changes in the seaward extent of *Spartina*-dominated stands over time at two study sites. Should it prove to be effective, even only partially, it may provide a way of effectively targeting field survey and helping to validate and locate boundaries.

7.3.2 Further targeted survey

The alternative to remote sensing *S. anglica* extent would be to determine it through ground-based field survey, using GPS to locate boundaries. This has advantages and disadvantages compared to remote sensing. Whilst it is easier to accurately identify the locations and extent of *S. anglica* through field survey, it could be expensive to undertake for all suitable coastal areas, or even for those areas within Natura 2000 sites, but ensuring *Spartina anglica* communities are mapped in any programme of NVC saltmarsh surveys within Natura 2000 sites.

The monitoring protocol developed by this work can be used in combination with stand mapping to determine the extent of *S. anglica* on a site by site basis. This could be combined to create a clear national picture of *S. anglica* extent.

The last national survey of saltmarsh communities was Burd (1989), which includes figures for the extent of *Spartina* species as a group. It is therefore clear that field survey can provide adequate data for determining the national extent of *S. anglica*, but would require clear standards and adequate resources. A two pronged approach would be ideal: (i) mapping from air photo analysis (validated by ground checking) of *S. anglica* dominated vegetation, and (ii) data gathering from a range of field survey techniques to accurately map other saltmarsh vegetation types that contain an element of *S. anglica.*

It is therefore recommended that field survey to determine the extent of *S. anglica* should be targeted at those areas where it is known or suspected to be present, but its extent is not known. This could be combined with a survey covering all *Spartina* stands or other saltmarsh communities, which could then inform reporting for Article 17 of the Habitats Directive.

7.4 Further review of the impact of Spartina anglica

The results of the review conducted as part of this work failed to provide unequivocal evidence that *S. anglica* had an overall negative or positive impact on saltmarsh ecology (Section 2). This is probably because it was not possible to undertake a comprehensive review. It is also likely that the impact varies with individual site conditions and the other species or communities present.

We therefore strongly recommend further research to review papers not obtained for this work, as well as unpublished work such as university theses. We suggest that this should be a separate study, so that resources can be directed solely at establishing the impacts of *S. anglica* and the further research required to fill gaps in the information. It would be useful to publish the results of this more comprehensive review in a peer reviewed publication, to bring them to a wider audience.

It would also be useful to undertake a further study of Lindisfarne to act as a case study. This should include further field survey and an assessment of the sediment regime to fully understand the impact of *S. anglica* on saltmarsh erosion and *Zostera* spp. It should then be possible to make a robust assessment of the need for and effectiveness of *S. anglica* control, to allow a cost benefit analysis of continued *S. anglica* management and the identification of areas where it should be targeted.

7.5 Understanding when and where Spartina anglica *was planted*

Though *S. anglica* is known to have been planted during the 1920s to 1960s, there is very little information detailing precisely where and when. This is essential for determining where *S. anglica* colonised naturally and where it was planted, which will enable its historic spread to be accurately charted and add a finer level of detail to the distribution maps provided in Section 3.3.1.

It may be possible to draw upon historic records to estimate how far *S. anglica* would have spread without human intervention, i.e. its native range. It may also be possible to identify and chart the spread of *S. anglica* from introduction sites, which in combination with the likelihood that it would have spread to an area naturally could be used to determine the likely range of the species as a non-native. This would provide valuable support for management decisions involving *S. anglica* on Natura 2000 sites.

Further work to investigate historic plantings of *S. anglica* is therefore recommended. It is likely that most of the information will be paper-based and will be held in local authority and other archives, so these will need to be sought and recorded digitally. The data will then need to be analysed spatially, alongside a wider range of *S. anglica* records, to identify patterns in its distribution and spread. In order to account for its spread to northwest England this study would also need to include Wales.

It is clear that *S. anglica* is responsible for the creation of saltmarsh, so this study should also seek to investigate the link between *S. anglica* and saltmarsh distribution. This may be possible through linking the spread of *S. anglica* with saltmarsh survey data or the spatio-temporal distribution of records of other saltmarsh species.

7.6 Research into sediment deposition rates and changes relating to Spartina anglica

Though much research has been undertaken in the area of *S. anglica* and sedimentation, the overall impact of *S. anglica* is still unclear (Section 2.3). Further research is required to determine whether the overall effect of *S. anglica* on sedimentation regimes and thus saltmarsh ecosystems and biodiversity is positive, negative or neutral. This may require that the following additional questions are addressed in future research:

- What is the relationship between *S. anglica* and bioturbation (Section 2.2)?
- Do changes in sedimentation caused by other factors increase the likelihood of initial colonisation by *S. anglica* (Section 2.7)?
- What is the effect of *S. anglica* removal using different management techniques on sedimentation discharge and sediment deposition regimes overall (Sections 2.7 and 5.5)?

7.7 Understanding Spartina anglica *climate change scenarios*

As stated in Section 2.5, there has been very little research into the effect of climate change on *S. anglica*. The evidence indicates that climate change may lead to an increase in *S. anglica*, though this has not been fully investigated. Any change in the ability of *S. anglica* to spread and colonise new areas may have a negative effect, or may help to protect coastlines against some of the impact of climate change.

Due to the uncertainties and the potentially very large impact it is recommended that the effect of climate change on *S. anglica* and resulting effects on saltmarsh as a whole should be investigated. This repeats the recommendation made in the NOBANIS factsheet (Nehring and Adsersen 2006).

8 *Decision making processes for* **Spartina anglica** *management on Natura 2000 sites*

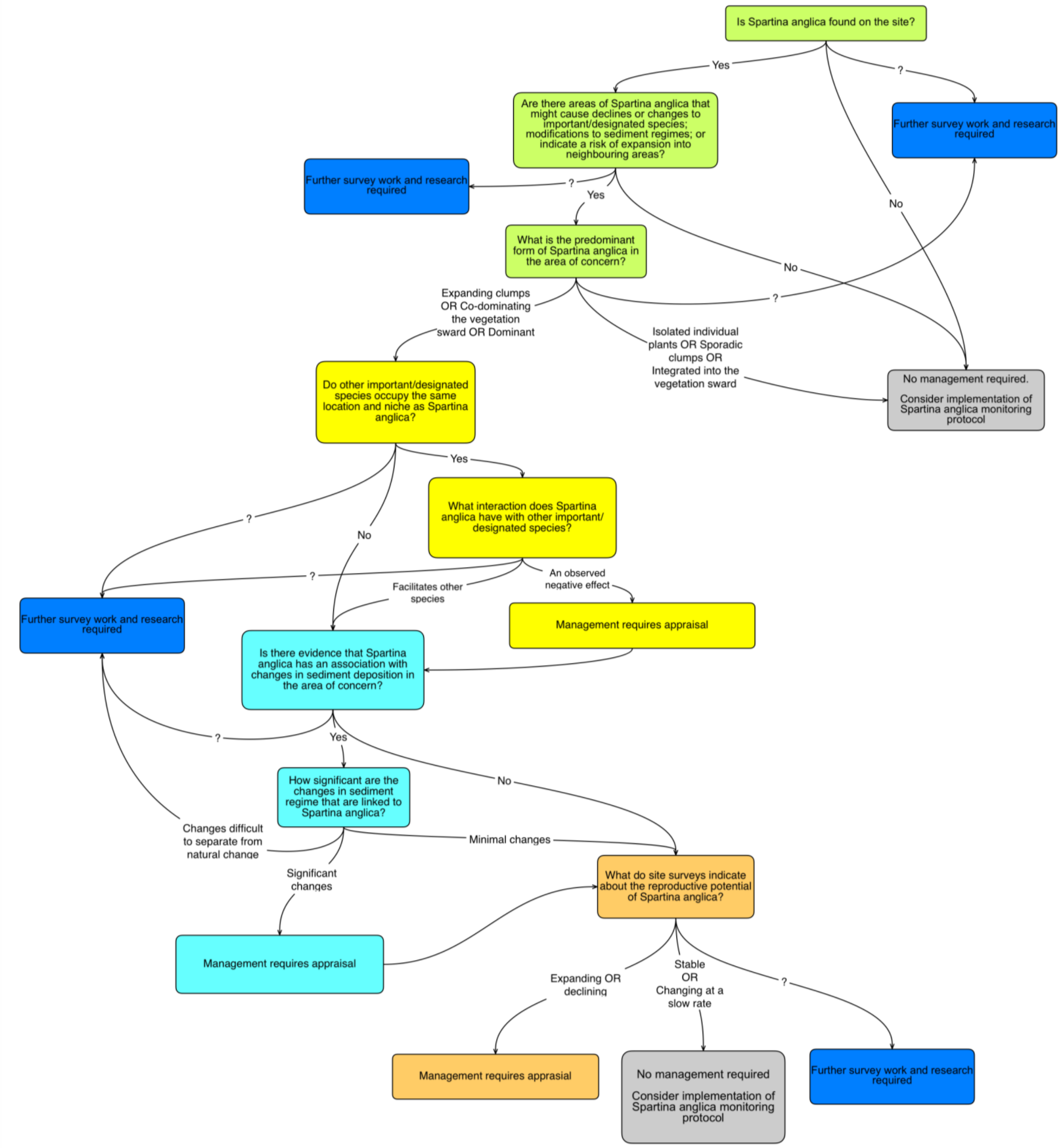
There is considerable literature regarding *Spartina anglica*, but very few papers that detail clear signs of negative effects on other species and the functioning of coastal ecosystems caused by *S. anglica*. This paucity of information, added to confusion as to the species' status (Section 1.1), causes confusion regarding appropriate policy and management (see Section 2).

The review of literature within this report has provided information on the effects of *S. anglica* on coastal ecosystems and their associated species. There are certain instances where management should be considered for populations of *S. anglica*, but these are more specific than currently suggested in UK reports and literature. Figure 22 provides a *S. anglica* management planning flow chart, to enable managers and policy makers to make sound judgements based on reliable evidence and informed study. The flow chart is colour coded to specific negative effects that were identified in the literature review. By following the management flow chart, it is clear that there are a number of instances where further research is required before management can take place. Equally there may only a limited number of instances where it is viable or necessary to manage *S. anglica* swards as a direct aspect of site management. Where a decision is taken to implement management, it is essential to have a complete audit trail of the decision.

It is very important to consider the feedback effects of any *S. anglica* management considered. It is possible that mudflats and saltmarshes may see a significant release of stored mud deposits and/or pollutants, or other species might be damaged during management works.

The use of Figure 22 and the collection of reliable data using the survey protocol should improve the decision making process relating to understanding whether there is a need for *S. anglica* management on Natura 2000 sites and will promote establishment of effective monitoring approaches to identify changes and trends at a site level.

Figure 22 - *Spartina anglica* management flow chart. Green = general questions; dark blue = further survey work and research required; grey = no management required; yellow = important/designated species questions; light blue = sediment deposition questions; orange =colonisation and expansion questions.



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Appendix A Deriving PercentCover – Dataset specific processing

In addition to the general rules given in Section 3.2.2, the following rules were applied to specific datasets based upon interpretation of the data and additional details taken from the associated reports.

Envision Biotopes 2010

Data was collected using marine biotope codes which include a single code for saltmarsh, LS.LMp.Sm, PercentCover was therefore based on BIOTA description:

- PercentCover = 100 for Dense *Spartina*
- PercentCover split equally between habitats for mosaics e.g. *Spartina*/Salicornia

The quadrat data associated with the biotope map shows few quadrats with *Spartina* which indicates that this dataset is liable to overestimate the *Spartina* extent.

Mersey NVC

The report indicated that a habitat code in brackets indicates where patches of that habitat occurred within another habitat. No indication was given in the report on the size of these patches, so it was assumed that:

- PercentCover = 0 where there are only patches within another habitat e.g. SM8 (SM6)
- PercentCover = 100 where SM6 contains patches of another habitat e.g. SM6 (SM13a)
- PercentCover = 0 where habitat shown in brackets e.g. (SM6) as it was assumed that this represented bare mud with patches of *Spartina anglica*

North Norfolk SAC NVC 2013

The values in brackets for this dataset are out of a maximum of 10 so it was assumed that:

- PercentCover = value in brackets multiplied by 10

Severn NVC

This dataset included a code of DS for Dead *Spartina*. This was included in the extent calculations following the generic rules.

Wash NVC 2002 – South

For this data the polygons were not attributed. Polygons which were likely to contain *Spartina* were interpreted from the key provided. Some polygons had text labels in a separate layer which indicated the habitat code and percentage cover. These values were added as attributes to the polygons.

This data contained some values which were not numeric. The following rules were applied:

- PercentCover <1% - These polygons were excluded from the analysis.
- PercentCover 1-5% - For ranges the maximum value was used so PercentCover = 5

Appendix B *Datasets contributing data available through the NBN Gateway*

The following table summarises the data providers and datasets that contributed *Spartina* records through the NBN Gateway. The effective resolution refers to the highest resolution for relevant species records; the best available resolution for the entire dataset may be higher. Equally, each dataset may also contain lower resolution records, details of which were visible on the Geographical tab of the dataset summary on the NBN Gateway.

Organisation name	Dataset name	Effective resolution	Number of Records
Botanical Society of the British Isles	SNH Site Condition Monitoring - Vascular plants (2000-2006)	100 m	1
Botanical Society of the British Isles	Vascular Plants Database	100 m	1603
Botanical Society of the British Isles	Vascular Plants Database additions since 2000	100 m	1359
Bristol Regional Environmental Records Centre	BRERC April 2013	100 m	158
Cofnod (North Wales Environmental Information Service)	NRW Regional Data: North Wales	100 m	133
Cumbria Biodiversity Data Centre	Additional species observations for Cumbria Biodiversity Data Centre Partners ONLY containing species observations for Cumbria for the period 1000 to 2013	100 m	8
Devon Biodiversity Records Centre	Invasive Non-Native Species (INNS) Devon	2 km	38
Dorset Environmental Records Centre	Dorset SSSI Species Records 1952 - 2004 (Natural England)	100 m	8
Dorset Environmental Records Centre	Dorset Sites of Nature Conservation Interest (SNCI) species records 2000-2008	100 m	2
Dorset Environmental Records Centre	Dorset Important Species 2013 for statutory agencies only	100 m	71
Dorset Environmental Records Centre	Dorset Sites of Nature Conservation Interest (SNCI) species records pre 2000	100 m	1
Dr Francis Rose Field Notebook Project	Field Notebook Records of Dr Francis Rose 1950's to 1990's	100 m	35
Environment Agency (Biodiversity staff)	Environment Agency Non-native Species records v1	100 m	970
Greater Lincolnshire Nature Partnership	Lincolnshire Vascular Plants (north)	100 m	90
Hampshire Biodiversity Information Centre	HBIC and partners species records	100 m	42
Hampshire Biodiversity Information Centre	HBIC Protected and notable species	100 m	66

Organisation name	Dataset name	Effective resolution	Number of Records
Joint Nature Conservation Committee	Vegetation surveys of coastal shingle in Great Britain	1 km	1
Lancashire Environment Record Network	LERN Records	2 km	220
Merseyside BioBank	North Merseyside Flowering Plants (unverified)	100 m	53
Merseyside BioBank	Merseyside BioBank Active Naturalists (unverified)	1 km	1
Merseyside BioBank	North Merseyside Flowering Plants (verified)	100 m	19
National Trust	Sutton Hoo species data held by The National Trust.	100 m	6
Natural Resources Wales	Coastal Saltmarsh Monitoring	100 m	1206
Natural Resources Wales	Welsh Invertebrate Database (WID)	100 m	1
Norfolk Biodiversity Information Service	Norfolk Non Native Species Records	2 km	100
North & East Yorkshire Ecological Data Centre	North and East Yorkshire Ecological Data Centre - Non-sensitive Records from all taxonomic groups.	10 km	7
Scottish Wildlife Trust	Commissioned surveys and staff surveys and reports for Scottish Wildlife Trust reserves - Verified data	100 m	1
Somerset Environmental Records Centre	Species Recorded in Somerset	100 m	38
South East Wales Biodiversity Records Centre	NRW Regional Data : South East Wales Non-sensitive Species Records	10 km	37
Suffolk Biological Records Centre	Suffolk Biological Records Centre (SBRC) dataset	100 m	203
Sussex Biodiversity Record Centre	Patrick Roper's Notebooks	100 m	1
Sussex Biodiversity Record Centre	SxBRC Full dataset for Environment Agency and Natural England use only	100 m	165
West Wales Biodiversity Information Centre	NRW Regional Data: all taxa (excluding sensitive species), West Wales	100 m	27

Appendix C Summary results tables

C.1 Distribution and extent of Spartina anglica *in transitional waterbodies*

The following table shows the number of *Spartina anglica* or undetermined *Spartina* species for each Environment Agency Transitional Waterbody. The records are summarised in the date ranges used in Figure 9, in order to show how recent the records are.

Waterbody ID	**Waterbody name**	**No. *Spartina anglica* records**					**No. undetermined *Spartina* records**				
		Pre-1970	**1970-1986**	**1987-1999**	**Post-1999**	**Total**	**Pre-1970**	**1970-1986**	**1987-1999**	**Post-1999**	**Total**
GB510070073000	Langstone Oysterbeds				1	1				1	1
GB510202110000	Tweed									1	1
GB510302509900	Tees									2	2
GB510503403500	Burn				7	7				3	3
GB510503410700	Bure & Waveney & Yare & Lothing									1	1
GB510503503700	Blyth (S)			3	3	6					
GB510804505400	Axe									1	1
GB510804505500	Otter									1	1
GB510804505600	Exe				1	1				3	3
GB510804605800	Teign									1	1
GB510804605900	Dart									1	1
GB510804606000	Avon									1	1
GB510804606100	Erme									1	1
GB511006115200	Nyfer									1	1
GB511006206900	Teifi							1		2	3
GB511006407000	Dyfi & Leri				1	1		1			1
GB511006407100	Mawddach	2			1	3					
GB511006414900	Dysynni										

Waterbody ID	Waterbody name	No. *Spartina anglica* records					No. undetermined *Spartina* records				
		Pre-1970	1970-1986	1987-1999	Post-1999	Total	Pre-1970	1970-1986	1987-1999	Post-1999	Total
GB511006507300	Glaslyn										
GB520503403600	Stiffkey & Glaven				7	7				3	3
GB520503503800	Alde & Ore	2	2	12	4	20					
GB520503503900	Deben	3		4	14	21					
GB520503613601	Orwell				2	2				1	1
GB520503613602	Stour (Essex)		11	9	1	21				4	4
GB520503704100	Crouch								1		1
GB520503713700	Hamford Water		3	8		11					
GB520503713800	Colne	1	11	22	1	35					
GB520503714000	Blackwater	1	18	30	3	52					
GB520704201400	Beaulieu River		1	1		2				1	1
GB520704202100	Lymington									1	1
GB520704202800	Southampton Water	4	2	8	10	24			2	5	7
GB520710101600	Medina			6	2	8				1	1
GB520710101700	Newtown River			6	1	7				1	1
GB520710101800	Western Yar			4	1	5				1	1
GB520710101900	Wootton Creek		1	2	1	4					
GB520710102000	Eastern Yar	2		1		3					
GB520804315900	Christchurch Harbour		1	1		2				1	1
GB520804415800	Poole Harbour	2	2		45	49				2	2
GB520804714300	Plymouth Tamar				1	1				3	3
GB520804809100	Helford				1	1				1	1
GB521006407200	Atro										
GB521006501200	Foryd Bay									5	5

Waterbody ID	Waterbody name	No. *Spartina anglica* records					No. undetermined *Spartina* records				
		Pre-1970	1970-1986	1987-1999	Post-1999	Total	Pre-1970	1970-1986	1987-1999	Post-1999	Total
GB521010201000	Braint				1	1					
GB521010207400	Ffraw										
GB521010207500	Cefni				2	2					
GB530207614700	Solway		2	2	3	7				2	2
GB530402609201	Humber Lower	1		3	40	44				3	3
GB530402609202	Humber Middle	1			19	20				1	1
GB530402609203	Humber Upper									1	1
GB530503000100	Witham				3	3				3	3
GB530503016300	Steeping				2	2				3	3
GB530503100400	Welland				1	1				3	3
GB530503200200	Nene				1	1				3	3
GB530503300300	Great Ouse				16	16				3	3
GB530503311300	Wash Inner			3	8	11				3	3
GB530603911401	Thames Lower	1			10	11				3	3
GB530603911402	Thames Middle				4	4				3	3
GB530604002300	Medway			1		1					
GB530604011500	Swale		3			3					
GB530804906600	Camel									3	3
GB530804906700	Hayle			1		1					
GB530905415401	Severn Lower	12	24	61	39	136			1	23	24
GB530905415402	Severn Middle	7	16	10	11	44				7	7
GB530905415403	Severn Upper		2		3	5				1	1
GB530905415404	Usk			1	6	7				1	1
GB530905415405	Bristol Avon	9	1	26	8	44				2	2

Waterbody ID	Waterbody name	No. *Spartina anglica* records					No. undetermined *Spartina* records				
		Pre-1970	1970-1986	1987-1999	Post-1999	Total	Pre-1970	1970-1986	1987-1999	Post-1999	Total
GB530905415406	Wye			1	1	2				3	3
GB531005913500	Loughor				1	1				1	1
GB531006013400	Tywi & Cywyn & Gwendraeth		1	1	4	6		3			3
GB531006114100	Milford Haven Inner		1		15	16		1		4	5
GB531106708200	Dee (N. Wales)	1	10	1	15	27	1	1		1	3
GB531206908100	Mersey		2	2	2	6		1			1
GB531206908300	Alt		2			2				1	1
GB531207112400	Ribble		2	3	5	10		1		16	17
GB531207212100	Lune				2	2				8	8
GB531207212200	Wyre									6	6
GB531207311900	Leven				1	1					
GB531207312000	Kent				2	2					
GB531207408400	Esk (W)		2	2		4					
GB540704016100	Rother	1		5	5	11					
GB540704104800	Cuckmere				2	2					
GB540704105000	Arun				1	1					
GB540804906500	Gannel									1	1
GB540805015500	Taw / Torridge			1	16	17				2	2
GB540805210900	Parrett	5	1	1	12	19				1	1
GB541006608000	Clwyd										
GB541006614800	Conwy			1		1				6	6
GB560402916600	Barrow Clay Pits				3	3					
GB560402916700	North Killingholme Haven Pitts				2	2					
GB560402917500	Northcoates Point Lagoon									1	1

Waterbody ID	Waterbody name	No. *Spartina anglica* records					No. undetermined *Spartina* records				
		Pre-1970	**1970-1986**	**1987-1999**	**Post-1999**	**Total**	**Pre-1970**	**1970-1986**	**1987-1999**	**Post-1999**	**Total**
GB560704217200	Black Water Lagoons		1	1		2					
GB560710116900	Old Mill Ponds			1		1					
GB560710117000	Bembridge Harbour Lagoon										
GB570704700000	Pagham Harbour			1	11	12				5	5
GB580705130000	Langstone Harbour			7	3	10				2	2
GB580705140000	Portsmouth Harbour		2	1	5	8				2	2
GB580705210000	Chichester Harbour	2	4	19	8	33			2	1	3
Total		**57**	**128**	**273**	**401**	**859**	**1**	**9**	**6**	**179**	**195**

The following table shows the known extent of *Spartina anglica* or undetermined *Spartina* species within each Environment Agency Transitional Waterbody. The years shown relate to the earliest and latest years for which complementary survey data is available. Where surveys overlapped, only the new ground survey data were used.

Waterbody ID	Waterbody name	Earliest survey year	Latest survey year	*Spartina anglica* extent (ha)	Undetermined *Spartina* extent (ha)
GB510080077000	Fleet Lagoon	2010	2010		0.00
GB510503403500	Burn	2013	2013	3.21	
GB510503503700	Blyth (S)	2013	2013	2.84	
GB510804505400	Axe	2010	2010		0.06
GB510804505600	Exe	2010	2010		4.34
GB510804605800	Teign	2010	2010		0.28
GB510804606000	Avon	2010	2010		1.95
GB510804606100	Erme	2010	2010		2.25
GB520503403600	Stiffkey & Glaven	2013	2013	142.57	
GB520503503800	Alde & Ore	2013	2013	27.37	

Waterbody ID	Waterbody name	Earliest survey year	Latest survey year	*Spartina anglica* extent (ha)	Undetermined *Spartina* extent (ha)
GB520503503900	Deben	2013	2013	82.28	
GB520503704100	Crouch	2001	2001	1.68	
GB520503713800	Colne	2001	2001	7.56	
GB520503714000	Blackwater	2001	2006	38.97	
GB520804315900	Christchurch Harbour	2010	2010		0.22
GB520804415800	Poole Harbour	2010	2010		41.65
GB520804714300	Plymouth Tamar	2010	2010		4.02
GB520804809100	Helford	2010	2010		1.11
GB530402609201	Humber Lower	1999	2001	117.53	
GB530402609202	Humber Middle	2001	2001	1.12	
GB530503100400	Welland	2000	2001	0.55	
GB530503300300	Great Ouse	2000	2001	57.78	
GB530503311300	Wash Inner	2000	2001	55.57	
GB530603911401	Thames Lower	2001	2006	3.80	
GB530804906600	Camel	2010	2010		10.09
GB530804906700	Hayle	2010	2010		0.84
GB530905415401	Severn Lower	1998	2010	60.50	60.60
GB530905415402	Severn Middle	1998	2010	13.35	15.67
GB530905415404	Usk	1998	1998	7.16	
GB530905415405	Bristol Avon	2010	2010		10.55
GB530905415406	Wye	1998	1998	0.60	
GB531106708200	Dee (N. Wales)	2006	2006	0.85	
GB531206908100	Mersey	2002	2002	40.43	
GB540805015500	Taw / Torridge	2010	2010		15.62
GB540805210900	Parrett	2010	2010		14.52
GB541006608000	Clwyd	2006	2006	0.02	
Total				**772.35**	**183.76**

C.2 Distribution and extent of Spartina anglica *in Special Areas of Conservation*

The following table shows the number of *Spartina anglica* or undetermined *Spartina* species records for each Special Area of Conservation (SAC). The records are summarised in the date ranges used in Figure 9, in order to show the range of years for the records.

SAC code	**SAC name**	**No. *Spartina anglica* records**					**No. undetermined *Spartina* records**				
		Pre-1970	**1970-1986**	**1987-1999**	**Post-1999**	**Total**	**Pre-1970**	**1970-1986**	**1987-1999**	**Post-1999**	**Total**
UK0012557	The New Forest									1	1
UK0012570	Braunton Burrows									1	1
UK0012642	River Wye/ Afon Gwy									1	1
UK0012734	Avon Gorge Woodlands	2		7	4	13					
UK0012809	Minsmere to Walberswick Heaths and Marshes			5	3	8			1		1
UK0013025	Solway Firth		3	3	5	11				2	2
UK0013027	Morecambe Bay				6	6				17	17
UK0013031	Drigg Coast		2	2		4					
UK0013059	Dungeness			1	1	2					
UK0013076	Sefton Coast		16	8	17	41				5	5
UK0013111	Plymouth Sound and Estuaries				1	1				3	3
UK0013112	Fal and Helford									1	1
UK0013690	Essex Estuaries	2	30	51	7	90			1	3	4
UK0014780	Orfordness – Shingle Street	2	2	9	3	16			1		1
UK0017072	Berwickshire and North Northumberland Coast				4	4				10	10
UK0017073	Solent and Isle of Wight Lagoons			2		2				1	1
UK0017075	The Wash and North Norfolk Coast	2		4	63	69				5	5
UK0017076	Chesil and the Fleet									1	1

SAC code	SAC name	No. *Spartina anglica* records					No. undetermined *Spartina* records				
		Pre-1970	**1970-1986**	**1987-1999**	**Post-1999**	**Total**	**Pre-1970**	**1970-1986**	**1987-1999**	**Post-1999**	**Total**
UK0017097	North Northumberland Dunes				3	3				9	9
UK0019838	North Norfolk Coast	2		1	8	11			2	3	5
UK0019857	Dorset Heaths	1		1	4	6				2	2
UK0030038	Dorset Heaths (Purbeck and Wareham) and Studland Dunes	2	1		7	10				2	2
UK0030059	Solent Maritime	4	7	57	28	96			4	6	10
UK0030061	South Wight Maritime		1	1		2					
UK0030076	Alde, Ore and Butley Estuaries	2	2	14	6	24					
UK0030130	Dawlish Warren									2	2
UK0030170	Humber Estuary	1		3	80	84				5	5
UK0030203	Mendip Limestone Grasslands		1	1	4	6					
UK0030252	River Dee and Bala Lake/ Afon Dyfrdwy a Llyn Tegid										
UK0030270	Saltfleetby–Theddlethorpe Dunes and Gibraltar Point			2	10	12				2	2
UK0030292	Tweed Estuary									1	1
UK0030328	Briddlesford Copses			1		1					
UK0030131	Dee Estuary/Aber Dyfrdwy	1	10	2	24	37	1	2		2	5
UK0013030	Severn Estuary/Môr Hafren	20	43	81	81	225			1	43	44
UK0030377	Hamford Water		4	8		12					
Total		**41**	**122**	**264**	**369**	**796**	**1**	**2**	**10**	**128**	**141**

The following table shows the known extent of *Spartina anglica* or undetermined *Spartina* species within each Special Area of Conservation (SAC). The years shown relate to the earliest and latest years for which complementary survey data is available. Where surveys overlapped, only the new survey data were used.

SAC code	SAC name	Earliest survey year	Latest survey year	*Spartina anglica* extent (ha)	Undetermined *Spartina* extent (ha)
UK0012809	Minsmere to Walberswick Heaths and Marshes	2013	2013	2.23	
UK0013030	Severn Estuary/Môr Hafren	1998	2010	83.07	108.71
UK0013111	Plymouth Sound and Estuaries	2010	2010		4.13
UK0013112	Fal and Helford	2010	2010		0.90
UK0013690	Essex Estuaries	2001	2006	86.39	
UK0017072	Berwickshire and North Northumberland Coast	2010	2010		160.75
UK0017075	The Wash and North Norfolk Coast	2000	2013	271.73	
UK0017076	Chesil and the Fleet	2010	2010		0.07
UK0017097	North Northumberland Dunes	2010	2010		9.31
UK0019838	North Norfolk Coast	2013	2013	2.94	
UK0019857	Dorset Heaths	2010	2010		0.26
UK0030038	Dorset Heaths (Purbeck and Wareham) and Studland Dunes	2010	2010		1.34
UK0030076	Alde, Ore and Butley Estuaries	2013	2013	29.46	
UK0030130	Dawlish Warren	2010	2010		0.53
UK0030131	Dee Estuary/Aber Dyfrdwy	2006	2006	0.91	
UK0030170	Humber Estuary	1999	2001	132.94	
UK0030252	River Dee and Bala Lake/ Afon Dyfrdwy a Llyn Tegid	2006	2006	0.01	
UK0030270	Saltfleetby–Theddlethorpe Dunes and Gibraltar Point	1989	1997	2.81	
Total				**719.09**	**286.00**

C.3 Distribution and extent of Spartina anglica *in Special Protection Areas*

The following table shows the number of *Spartina anglica* or undetermined *Spartina* species for each Special Protection Area (SPA). The records are summarised in the date ranges used in Figure 9, in order to show the recency of the records.

SPA code	SPA name	No. *Spartina anglica* records					No. undetermined *Spartina* records				
		Pre-1970	**1970-1986**	**1987-1999**	**Post-1999**	**Total**	**Pre-1970**	**1970-1986**	**1987-1999**	**Post-1999**	**Total**
UK9020287	Mersey Narrows and North Wirral Foreshore										
UK9005012	Upper Solway Flats and Marshes		3	3	5	11				2	2
UK9005031	Duddon Estuary				1	1					
UK9005081	Morecambe Bay				5	5				23	23
UK9005103	Ribble and Alt Estuaries		12	21	22	55		1		25	26
UK9005131	Mersey Estuary		2	2	2	6		2	2	1	5
UK9006011	Lindisfarne				4	4				10	10
UK9006061	Teesmouth and Cleveland Coast									2	2
UK9006111	Humber Estuary	1		4	83	88				5	5
UK9006131	Northumbria Coast									1	1
UK9008021	The Wash			3	53	56				3	3
UK9008022	Gibraltar Point			2	8	10				1	1
UK9009031	North Norfolk Coast	2		1	9	12			2	3	5
UK9009101	Minsmere–Walberswick			5	4	9			1		1
UK9009112	Alde–Ore Estuary	2	2	14	6	24			1		1
UK9009121	Stour and Orwell Estuaries		12	9	6	27			1	9	10
UK9009131	Hamford Water		4	9		13					
UK9009171	Benfleet and Southend Marshes				3	3				1	1
UK9009181	Breydon Water									1	1
UK9009242	Dengie (Mid-Essex Coast Phase 1)		4	7		11				2	2
UK9009243	Colne Estuary (Mid-Essex Coast Phase 2)	1	11	20	2	34			1	2	3

SPA code	SPA name	No. *Spartina anglica* records					No. undetermined *Spartina* records				
		Pre-1970	1970-1986	1987-1999	Post-1999	Total	Pre-1970	1970-1986	1987-1999	Post-1999	Total
UK9009244	Crouch and Roach Estuaries (Mid-Essex Coast Phase								1		1
UK9009245	Blackwater Estuary (Mid-Essex Coast Phase 4)	1	18	33	4	56					
UK9009246	Foulness (Mid-Essex Coast Phase 5)	1			2	3			1	1	2
UK9009261	Deben Estuary	3		4	10	17					
UK9010081	Exe Estuary				2	2				3	3
UK9010091	Chesil Beach and The Fleet									1	1
UK9010101	Dorset Heathlands	3	1	1	13	18				2	2
UK9010111	Poole Harbour	2	2		62	66				2	2
UK9010141	Tamar Estuaries Complex				1	1				3	3
UK9011011	Chichester and Langstone Harbours	2	5	32	12	51			2	2	4
UK9011031	New Forest									1	1
UK9011051	Portsmouth Harbour		2	1	4	7				2	2
UK9011061	Solent and Southampton Water	4	3	38	17	62			2	5	7
UK9012011	The Swale		3			3					
UK9012021	Thames Estuary and Marshes				14	14				3	3
UK9012041	Pagham Harbour		1	1	11	13				5	5
UK9012091	Dungeness to Pett Level	1		1	1	3					
UK9015022	Severn Estuary	20	45	81	80	226			1	43	44
UK9020286	Sandlings										
UK9020309	Outer Thames Estuary	2	2	15	3	22					
UK9013011	The Dee Estuary	1	10	2	24	37	1	2		2	5
Total		**46**	**142**	**309**	**473**	**970**	**1**	**5**	**15**	**166**	**187**

The following table shows the known extent of *Spartina anglica* or undetermined *Spartina* species within each Special Protection Area (SPA). The years shown relate to the earliest and latest years for which complementary survey data is available. Where surveys overlapped, only the new survey data were used.

SPA code	SPA name	Earliest survey year	Latest survey year	*Spartina anglica* extent (ha)	Undetermined *Spartina* extent (ha)
UK9005131	Mersey Estuary	2002	2002	46.46	
UK9006011	Lindisfarne	2010	2010		169.64
UK9006111	Humber Estuary	1999	2008	135.14	
UK9008021	The Wash	2000	2001	128.84	
UK9008022	Gibraltar Point	1989	1997	2.81	
UK9009031	North Norfolk Coast	2013	2013	145.83	
UK9009101	Minsmere–Walberswick	2013	2013	2.98	
UK9009112	Alde–Ore Estuary	2013	2013	29.46	
UK9009242	Dengie (Mid-Essex Coast Phase 1)	2001	2001	2.31	
UK9009243	Colne Estuary (Mid-Essex Coast Phase 2)	2001	2001	18.33	
UK9009244	Crouch and Roach Estuaries (Mid-Essex Coast Phase 3)	2001	2001	1.41	
UK9009245	Blackwater Estuary (Mid-Essex Coast Phase 4)	2001	2006	44.78	
UK9009246	Foulness (Mid-Essex Coast Phase 5)	2001	2006	19.52	
UK9009261	Deben Estuary	2013	2013	84.80	
UK9010081	Exe Estuary	2010	2010		4.95
UK9010091	Chesil Beach and The Fleet	2010	2010		0.08
UK9010101	Dorset Heathlands	2010	2010		0.12
UK9010111	Poole Harbour	2010	2010		47.38
UK9010141	Tamar Estuaries Complex	2010	2010		4.08
UK9013011	The Dee Estuary	2006	2006	0.91	
UK9015022	Severn Estuary	1998	2010	83.06	107.04
Total				**853.23**	**333.28**

Appendix D Spartina anglica *survey form*

SPARTINA ANGLICA SURVEY FORM

Do not write outside of the grey areas

Unit - Page 1

UNIT FORM

Natura 2000 site name:		**Unit:**	
Assessed by:		**Date of assessment:**	D D / M M / Y Y Y Y
Unit manager:		**OS grid reference:**	A A 0 0 0 0 0 0 0 0
Are data available from a previous survey?	Yes ☐ No ☐	**Is a map available?**	Yes ☐ No ☐

Are any of the following pressures present on this unit? *Tick yes or no for each pressure that occurs on or near to the unit.*

Shipping channels	Yes ☐	No ☐	Drainage	Yes ☐	No ☐
Dredging/aggregate mining	Yes ☐	No ☐	Evidence of grazing	Yes ☐	No ☐
Seawall/revetment	Yes ☐	No ☐	Other *(describe)*	Yes ☐	No ☐
Other built structures *(e.g. pipelines)*	Yes ☐	No ☐			

Rate the impact of the following pressures on the unit?
Tick high, medium or low for each pressure that occurs on or near to the unit.

	High	Medium	Low
Recreational use	☐	☐	☐
Pollution	☐	☐	☐
Poaching	☐	☐	☐

Are any of the following natural features present on this unit? *Tick yes or no for each feature that occurs on the unit.*

Creeks Yes ☐ No ☐ Dry Pans Yes ☐ No ☐ Wet Pans Yes ☐ No ☐

Please provide any information relating to erosion of the saltmarsh. Examples include:

- widening creeks;
- saltmarsh islands & sediment clumps in the intertidal zone;
- vegetation dieback;
- stepping and overhanging/collapsing pan and creek edges.

Refer to the relevant transect or area within the unit where appropriate.

Are any of the following *Spartina anglica* specific control techniques occurring on the unit? *Tick yes or no for each technique.*

Cutting	Yes ☐	No ☐	Steam and infra-heat treatment	Yes ☐	No ☐
Physical removal	Yes ☐	No ☐	Biological control	Yes ☐	No ☐
Roto-burying	Yes ☐	No ☐	Other *(describe)*	Yes ☐	No ☐
Smothering	Yes ☐	No ☐			
Herbicide use	Yes ☐	No ☐			
Burning	Yes ☐	No ☐			

Please provide further information regarding the interaction of *Spartina anglica* with other species, habitats and vegetation communities. Consider the following example questions:

- Is *Spartina anglica* competing or limiting conditions for other species (not just plants)?
- Has *Spartina anglica* recently colonised this area? What was there before?
- Are other species being promoted/facilitated by the presence of *Spartina anglica*?
- How is *Spartina anglica* influencing the surrounding vegetation?
- Is the sedimentation rate and type changing in areas where *Spartina anglica* is present?

SPARTINA ANGLICA SURVEY FORM

Do not write outside of the grey areas

TRANSECT RECORDING FORM

Site name: **Unit:**

Transect code: **Assessed by:** **Date of assessment:** D D / M M / Y Y Y Y

Please provide OS grid references for the start and end of the transect. Start: A A 0 0 0 0 0 0 0 0 End: A A 0 0 0 0 0 0 0 0

Saltmarsh zone	**Upper marsh**	**Middle marsh**	**Lower marsh**	**Pioneer marsh**	**Mudflats/ Sandflats**
Is this saltmarsh zone present?	Yes ☐ No ☐	Yes ☐ No ☐	Yes ☐ No ☐	Yes ☐ No ☐	Yes ☐ No ☐

The questions for each zone below need only be answered if the relevant zone is present.

Which of the following best describes the predominant form of *Spartina anglica*? *Tick one for each zone. See the survey handbook for guidance.*

Isolated individual plants	☐	☐	☐	☐	☐
Sporadic clumps	☐	☐	☐	☐	☐
Expanding clumps	☐	☐	☐	☐	☐
Integrated into vegetation sward	☐	☐	☐	☐	☐
Co-dominating the vegetation sward	☐	☐	☐	☐	☐
Dominant	☐	☐	☐	☐	☐
Absent	☐	☐	☐	☐	☐

The questions for each zone below need only be answered if Spartina anglica *is present.*

What is the overall percentage of decline or dieback of *Spartina anglica* in this zone?	%	%	%	%	%

If percentage of decline or dieback of Spartina anglica *is greater than 0%, please answer the following question:*

Is the decline of *Spartina anglica* causing erosion?	Yes ☐ No ☐	Yes ☐ No ☐	Yes ☐ No ☐	Yes ☐ No ☐	Yes ☐ No ☐

Recording in the 10 m and two nested 2 m quadrats below need only be undertaken where Spartina anglica *is present in the relevant zone.*

10 m quadrat

Enter the OS grid reference for each 10 m quadrat:

Upper A A 0 0 0 0 0 0 0 0 Lower A A 0 0 0 0 0 0 0 0 Mudflats/ Sandflats A A 0 0 0 0 0 0 0 0

Middle A A 0 0 0 0 0 0 0 0 Pioneer A A 0 0 0 0 0 0 0 0

Saltmarsh zone	**Upper marsh**	**Middle marsh**	**Lower marsh**	**Pioneer marsh**	**Mudflats/ Sandflats**

Which of the following best describes the sediment type beneath the *Spartina anglica* sward? *Tick one for each zone.*

Waterlogged mud	☐	☐	☐	☐	☐
Firm mud	☐	☐	☐	☐	☐
Waterlogged sand	☐	☐	☐	☐	☐
Firm sand	☐	☐	☐	☐	☐
Rock	☐	☐	☐	☐	☐
Shingle	☐	☐	☐	☐	☐

How deep is the soft sediment beneath the *Spartina anglica* sward in centimetres? *Use a stick or a ruler to measure the depth.*

	cm	cm	cm	cm	cm

Are the following *Spartina* species definitely present. *Tick 'Y' if definitely present, 'N' if definitely not present and 'U' if uncertain.*

	Y N U	Y N U	Y N U	Y N U	Y N U
Spartina anglica	☐ ☐ ☐	☐ ☐ ☐	☐ ☐ ☐	☐ ☐ ☐	☐ ☐ ☐
Spartina anglica / × townsendii	☐ ☐ ☐	☐ ☐ ☐	☐ ☐ ☐	☐ ☐ ☐	☐ ☐ ☐
Spartina × townsendii	☐ ☐ ☐	☐ ☐ ☐	☐ ☐ ☐	☐ ☐ ☐	☐ ☐ ☐
Spartina alterniflora	☐ ☐ ☐	☐ ☐ ☐	☐ ☐ ☐	☐ ☐ ☐	☐ ☐ ☐
Spartina patens	☐ ☐ ☐	☐ ☐ ☐	☐ ☐ ☐	☐ ☐ ☐	☐ ☐ ☐
Spartina maritima	☐ ☐ ☐	☐ ☐ ☐	☐ ☐ ☐	☐ ☐ ☐	☐ ☐ ☐
Unknown non *Spartina anglica*	☐ ☐ ☐	☐ ☐ ☐	☐ ☐ ☐	☐ ☐ ☐	☐ ☐ ☐

TRANSECT RECORDING FORM

Site name:		**Unit:**	
Transect code:	**Assessed by:**	**Date of assessment:**	D D / M M / Y Y Y Y

10 m quadrat (continued)

Record the cover of the plant species present using the DOMIN scale: 10 = 91-100%, 9 = 76-90%, 8 = 51-75%, 7 = 34-50%, 6 = 23-33%, 5 = 11-25%, 4 = 4-10%, 3 = <4% (many plants), 2 = <4% (several plants), 1 = <4% (few plants). *Record any additional plants in the spaces and continue on a separate sheet if necessary.*

Saltmarsh zone	**Upper marsh**	**Middle marsh**	**Lower marsh**	**Pioneer marsh**	**Mudflats/ Sandflats**
Bare mud					
Open water					
Algal mat					
Common cord-grass *Spartina anglica*					
Sea couch *Elytrigia atherica*					
Red fescue *Festuca rubra*					
Common reed *Phragmites australis*					
Reflexed saltmarsh-grass *Puccinellia distans*					
Common saltmarsh-grass *Puccinellia maritima*					
Saltmarsh rush *Juncus gerardii*					
Sea rush *Juncus maritimus*					
Thrift *Armeria maritima*					
Sea aster *Aster tripolium*					
Sea-purslane *Atriplex portulacoides*					
Spear-leaved orache *Atriplex prostrata*					
Sea milkwort *Glaux maritima*					
Lax-flowered sea-lavender *Limonium humile*					
Common sea-lavender *Limonium vulgare*					
Sea plantain *Plantago maritima*					
Long-spiked glasswort *Salicornia dolichostachya*					
Common glasswort *Salicornia europaea*					
Purple glasswort *Salicornia ramosissima*					
Perennial glasswort *Sarcocornia perennis*					
Greater sea-spurrey *Spergularia media*					
Annual sea-blite *Suaeda maritima*					
Sea Arrowgrass *Triglochin maritimum*					
Gutweed *Ulva intestinalis*					
Sea lettuce *Ulva lactuca*					
Bladder wrack *Fucus vesiculosus*					

TRANSECT RECORDING FORM

Site name:		**Unit:**	
Transect code:	**Assessed by:**	**Date of assessment:**	D D / M M / Y Y Y Y

Please use the space below to record any additional information about the *Spartina anglica* within the 10 m quadrats. Refer to the relevant quadrat or zone along the transect where appropriate.

First 2 m quadrat

Saltmarsh zone	**Upper marsh**	**Middle marsh**	**Lower marsh**	**Pioneer marsh**	**Mudflats/ Sandflats**
What is the average distance in centimetres between the patches of *Spartina anglica* that are present in the quadrat? *Distance should be measured by taking the central patches and averaging the distance to the nearest four others.*	cm	cm	cm	cm	cm
What is the average height in centimetres of the *Spartina anglica* present in the quadrat?	cm	cm	cm	cm	cm
Is the *Spartina anglica* showing signs of vegetative spread?	Yes No	Yes No	Yes No	Yes No	Yes No
What proportion of the *Spartina anglica* stems are flowering or setting seed in this season? *Record the percentage of culms and tillers that are likely to produce viable seeds.*	%	%	%	%	%
What proportion of the *Spartina anglica* are showing any obvious signs of disease or poor health? *This includes dead or yellowing leaves, fungal growth, rust and smut, etc.*	%	%	%	%	%

Second 2 m quadrat

Saltmarsh zone	**Upper marsh**	**Middle marsh**	**Lower marsh**	**Pioneer marsh**	**Mudflats/ Sandflats**
What is the average distance in centimetres between the patches of *Spartina anglica* that are present in the quadrat? *Distance should be measured by taking the central patches and averaging the distance to the nearest four others.*	cm	cm	cm	cm	cm
What is the average height in centimetres of the *Spartina anglica* present in the quadrat?	cm	cm	cm	cm	cm
Is the *Spartina anglica* showing signs of vegetative spread?	Yes No	Yes No	Yes No	Yes No	Yes No
What proportion of the *Spartina anglica* stems are flowering or setting seed in this season? *Record the percentage of culms and tillers that are likely to produce viable seeds.*	%	%	%	%	%
What proportion of the *Spartina anglica* are showing any obvious signs of disease or poor health? *This includes dead or yellowing leaves, fungal growth, rust and smut, etc.*	%	%	%	%	%

Appendix E Results of the survey trials

The following sections summarise the results from the trials of the *Spartina anglica* monitoring protocol. The following acronyms have been used:

- Forms of *S. anglica*:
    - Dom = dominant;
    - Int = integrated into the sward;
    - Iso Pl = isolated plants;
    - Spo Cl = sporadic clumps;
    - Iso Cl = isolated clumps;
    - Exp Cl = expanding clumps
- Sediment types:
    - WL = waterlogged mud;
    - WS = waterlogged sand;
    - FM = firm mud;
    - FS = firm sand

E.1 Aust, Severn Estuary SAC

	Transect 1					**Transect 2**				
Saltmarsh zone	Mudflats	Pioneer	Lower	Middle	Upper	Mudflats	Pioneer	Lower	Middle	Upper
S. anglica present?	No	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes
Form of *S. anglica*		Dom	Int	Int	Iso Pl	Exp Cl		Spo Cl		Int
Sediment type		WL	FM	FM	FM	WL		FM		FM
Depth of sediment (cm)		30	7	15	3	100		7		
First 2 metre quadrat										
Av. Distance (cm)		1	5	40	2.4	3		15		40
Av. Height (cm)		30	15	20	15	20		15		25
Vegetative growth?		yes	yes	yes	n/a	n/a		n/a		n/a
Signs of disease?		no	no	no	yes	no		no		no
Second 2 metre quadrat										
Av. Distance (cm)		1	20	20		30		50		50
Av. Height (cm)		30	10	10		20		15		25
Vegetative growth?		yes	n/a	n/a	spreading	n/a		n/a		n/a
Signs of disease?		yes	no	no	no	no		no		no

	Transcect 3					Transect 4				
Saltmarsh zone	Mudflats	Pioneer	Lower	Middle	Upper	Mudflats	Pioneer	Lower	Middle	Upper
S. anglica present?	no	yes	yes	yes	no	no	yes	yes	yes	no
Form of *S. anglica*		Exp Cl	Int	Int			Exp Cl	Int	Int	
Sediment type		WL	FM	FM			WL	FM	FM	
Depth of sediment (cm)		20	1	8			30	15	30	
First 2 metre quadrat										
Av. Distance (cm)		10	8	40			2	50	6	
Av. Height (cm)		5	12	30			30	10	15	
Vegetative growth?		yes	yes	yes			yes	yes	yes	
Signs of disease?		no	no	no			no	no	no	
Second 2 metre quadrat										
Av. Distance (cm)		5	4	30			2	40	6	
Av. Height (cm)		1	15	15			15	5	16	
Vegetative growth?		yes	yes	yes			yes	yes	yes	
Signs of disease?		no	no	no			no	no	no	

E.2 River Crouch, Essex Estuaries SAC

	Transcect 1					Transect 2				
Saltmarsh zone	Mudflats	Pioneer	Lower	Middle	Upper	Mudflats	Pioneer	Lower	Middle	Upper
S. anglica present?	no	no	yes	no	no	no	no	yes	no	no
Form of *S. anglica*			Iso Pl					Iso Cl		
Sediment type			FM					FM		
Depth of sediment (cm)			15					10		
First 2 metre quadrat										
Av. Distance (cm)			2					12		
Av. Height (cm)			15					25		
Vegetative growth?			yes					yes		
Signs of disease?			no					no		
Proportion flowering			20%					50%		
Second 2 metre quadrat										
Av. Distance (cm)			30					90		
Av. Height (cm)			8					30		
Vegetative growth?			yes					yes		
Signs of disease?			no					no		
Proportion flowering			0%					40%		

E.3 Blackwater Bay SAC

	Transect 1					Transect 2				
Saltmarsh zone	Mudflats	Pioneer	Lower	Middle	Upper	Mudflats	Pioneer	Lower	Middle	Upper
S. anglica present?	no	no	no	yes	no	no	no	no	yes	no
Form of *S. anglica*				Iso Cl					Iso Cl	
Sediment type				FM					FM	
Depth of sediment (cm)				12					10	
First 2 metre quadrat										
Av. Distance (cm)				5					12	
Av. Height (cm)				15					25	
Vegetative growth?				yes					yes	
Signs of disease?				no					no	
Proportion flowering				20%					60%	
Second 2 metre quadrat										
Av. Distance (cm)				30					100	
Av. Height (cm)				8					30	
Vegetative growth?				yes					yes	
Signs of disease?				no					no	
Proportion flowering				0%					20%	

E.4 Berwickshire & North Northumberland Coast SAC

<u>Transect under *Spartina* management, south of the causeway:</u>

	Transect 1						
Saltmarsh zone	Managed Mudflats 2	Managed Mudflats 1	Pioneer 2	Pioneer 1	Lower	Middle	Upper
S. anglica present?	Yes	Yes	Yes	Yes	Yes	Yes	No
Form of *S. anglica*	Iso Pl	Spo Cl	Dom	Dom	Int	Iso Pl	
Dieback	98%	95%	0%	0%	0%	0%	
Dieback causing erosion	Yes	No	No	No	No	No	
Sediment type	FS	FS	FM	FM	FM	FM	
Depth of sediment (cm)	5	5	15	80	25	15	
First 2 metre quadrat							
Av. Distance (cm)	N/A (only 1)	4	1	1	5	35	
Av. Height (cm)	25	20	40	30	30	30	
Vegetative growth?	No	Yes	Yes	Yes	Yes	Yes	
Signs of disease?	No	No	No	No	Yes	Yes	
Proportion flowering	100%	5%	20%	5%	10%	15%	
Second 2 metre quadrat							
Av. Distance (cm)	N/A (only 1)	1	1	1	25	30	
Av. Height (cm)	25	10	40	30	25	30	
Vegetative growth?	No	Yes	Yes	Yes	Yes	Yes	
Signs of disease?	No	No	No	No	Yes	Yes	
Proportion flowering	100%	5%	20%	5%	10%	15%	

Transects in unmanaged eroding areas, south of the causeway:

	Transect 2					Transect 3				
Saltmarsh zone	Mudflats	Pioneer	Lower	Middle	Upper	Mudflats	Pioneer	Lower	Middle	Upper
S. anglica present?	No	Yes	No	Yes	No	Yes	Yes	No	No	No
Form of *S. anglica*		Dom		Iso Pl		Exp Cl	Spo Cl			
Dieback		0%		40%		0%	0%			
Sediment type		FM		FM		FM	FM			
Depth of sediment (cm)		5		5		<5	10			
First 2 metre quadrat										
Av. Distance (cm)		100+		2		1	20			
Av. Height (cm)		30		30		40	40			
Vegetative growth?		Yes		Yes		Yes	Yes			
Signs of disease?		Yes		No		Yes	No			
Proportion flowering		50%		25%		10%	1%			
Second 2 metre quadrat										
Av. Distance (cm)		100+		2		1	20			
Av. Height (cm)		40		30		40	40			
Vegetative growth?		Yes		Yes		Yes	Yes			
Signs of disease?		Yes		No		Yes	No			
Proportion flowering		50%		25%		10%	1%			

Transects in unmanaged eroding areas, north of the causeway:

	Transect 4				
Saltmarsh zone	Mudflats	Pioneer	Lower	Middle	Upper
S. anglica present?	No	Yes	No	Yes	No
Form of *S. anglica*		Dom		Iso Pl	
Dieback		0%		40%	
Sediment type		FM		FM	
Depth of sediment (cm)		5		5	
First 2 metre quadrat					
Av. Distance (cm)		100+		2	
Av. Height (cm)		30		30	
Vegetative growth?		Yes		Yes	
Signs of disease?		Yes		No	
Proportion flowering		50%		25%	
Second 2 metre quadrat					
Av. Distance (cm)		100+		2	
Av. Height (cm)		40		30	
Vegetative growth?		Yes		Yes	
Signs of disease?		Yes		No	
Proportion flowering		50%		25%	