NOBANIS – Invasive Alien Species Fact Sheet

Spartina anglica

Authors of this fact sheet: Stefan Nehring[1] & Henning Adsersen[2]
[1] AeT umweltplanung, Bismarckstraße 19, D-56068 Koblenz, Germany; E-mail: nehring@aet-umweltplanung.de
[2] Institute of Biology, University of Copenhagen, Universitetsparken 15, DK-2100 Copenhagen, Denmark E-mail: adser@bi.ku.dk

Bibliographical reference – how to cite this fact sheet:
Nehring, S. and Adsersen, H. (2006): NOBANIS – Invasive Alien Species Fact Sheet – ***Spartina anglica***. – From: Online Database of the North European and Baltic Network on Invasive Alien Species - NOBANIS www.artportalen.se/nobanis, Date of access x/x/200x.

Species description

Scientific names: *Spartina anglica* C.E. Hubbard 1968, Poaceae, Magnoliophyta
Synonyms: *Spartina x townsendii sensu lato; Spartina x townsendii* fertile amphidiploid; *Spartina x townsendii* agg.
Note: *Spartina anglica* (2n=122-124) was the result of chromosome doubling by *Spartina x townsendii* H. and J. Groves (2n=61-62), the sterile hybrid between the 'native' small cord-grass *Spartina maritima* (Curtis) Fernald (2n=60) and the introduced North American smooth cord-grass *Spartina alterniflora* Loiselle (2n=62) (Gray *et al.* 1991, Hammond and Cooper 2002). It is not clear whether the small cord-grass (*Spartina maritima*) is an indigenous species in Europe. It is partly suggested that it had been introduced into Atlantic Europe from Africa by shipping (after Wolff 2005).

Common names: Common cord-grass, English cord-grass, rice grass, salt marsh-grass (GB), Vadegræs, Hybrid-Vadegræs (only for the sterile hybrid) (DK), Englisches Schlickgras, Reisgras, Salz-Schlickgras (DE), Engels Slijkgras (NL), Marsk-gräs (SE), englanninmarskiheinä (FI)


Fig. 1. *Spartina anglica* (at the back) displaces *i.a.* the native glass-wort *Salicornia stricta* (in the foreground): Wadden Sea of Schleswig-Holstein near Eider estuary, Germany, August 2004, photo by Stefan Nehring. **Fig. 2.** *Spartina anglica* sward: Wadden Sea of Schleswig-Holstein near Eider estuary, Germany, August 2004, photo by Stefan Nehring.

 

Fig. 3. *Spartina anglica* seedlings: Elbe estuary, Germany, August 2004, photo by Stefan Nehring.
Fig. 4. *Spartina anglica* clumps on a sandy beach in a recreation area: Udbyhøj, Randers Fjord, Denmark, October 2005, photo by Henning Adsersen.

Species identification
Spartina anglica is a stout, rhizomatous salt marsh grass, with round, hollow stems five mm or more in diameter. The leaves lack auricles and have ligules that consist of a fringe of hairs. The leaf blades, which may be flat or inrolled, are 36 to 46 cm in length, and 5 to 13 mm broad, rough and green-gray in colour and may be persistent or falling. The flowers are inconspicuous and colorless, and occur in numerous, erect, contracted panicles, which consist of closely overlapping spikelets in two rows on one side of the rachis. *S. anglica* grows in roundish clumps up to 130 cm in height, although the height is highly variable. Perhaps as a result of its hybrid origins, there is considerable morphological variation in *S. anglica*. Variable characteristics include shoot density, vegetative vigor, density of inflorescences, flowering times, seed production, and seed germination (ISSG 2005, NWCB 2005, SFEISP 2005).

Spartina anglica differs from the 'native' small cord-grass *Spartina maritima* (Curtis) Fernald in more and longer spikes, in more spikelets and in being longer and wider.

Native range
Spartina is a relatively small genus consisting of approximately 14 species. Members of the genus occur primarily in wetlands, especially estuaries (WAPMS 2004). *Spartina anglica* originated at Hythe, Southampton Water, England, in the nineteenth century. The natural distribution of this fertile hybrid is thought to be between Poole, Dorset, and Pagham, Sussex and possibly northern France (NWCB 2005). In southern and western Britain the habitat range of *S. anglica* is broadly between Mean High Water Neap tides (MHWN) and Mean High Water Spring tides (MHWS). This area comprises mud-flats and salt marsh (Hammond and Cooper 2002).

Alien distribution

History of introduction and geographical spread.
It is thought that the North American smooth cord-grass (*Spartina alterniflora*) was originally introduced in ships' ballast water to Great Britain prior to 1870 (Eno *et al.* 1997). It was first found on mudflats near Southampton in 1879 (Gray *et al.* 1991). Its subsequent crossing with the 'native' small cord-grass (*Spartina maritima*) resulted in the appearance of a sterile hybrid, the cord-grass

Spartina x townsendii. The hybridization brought together maternal and paternal chromosomes that were too dissimilar to pair up during meiosis, so sterile gametes were produced. However, when the chromosomes replicated to produce two copies of each parental chromosome, the chromosomes were then able to form bivalent pairs in meiosis, which resulted in a fertile polyploid (having more than two complete sets of chromosomes per nucleus) (NWCB 2005). This fertile hybrid is *Spartina anglica* the first specimen of which was recorded in Britain from Lymington, Hampshire in 1892 (Gray *et al.* 1991).
In Britain the natural spread of *S. anglica* was rapid (Eno *et al.* 1997). It was suggested that *S. anglica* can accrete large volumes of tidal sediment leading to substantial increases in marsh elevation. This property made *S. anglica* a valuable species for coastal protection and reclamation schemes in the early twentieth century throughout Britain and in Europe, China and western USA (Gray *et al.* 1991).
In Germany *S. anglica* was planted at several sites in the East and North Frisian Wadden Sea in 1927-1937 (Kolumbe 1931, König 1948, Forschungsstelle Norderney 1973). In all probability, more than 70,000 shoots were imported from Britain. The introduction of *S. anglica* to Germany was succesful and the species has apparently become part of the German coastal flora. The rate of spread at individual sites has varied greatly but in many areas has involved the rapid spread from transplants or other propagating units to form a continuous sward. Within several decades this alien species was frequently observed along the entire German Wadden Sea coast (Nehring and Hesse 2006). *S. anglica* is the only species of cord-grass found throughout German waters. On account of its occurrence in coherent swards at the seaward front of salt marshes in Germany, a new plant community was named after this alien species: Spartinetea.
In Denmark the first plantation of *Spartina* took place in 1930 and 1931 in the Wadden Sea area. 6000 plants imported from England were planted at 4 stations on the island of Fanø and 10 stations along the marshy coast from the border to Germany to the Skallingen peninsula. At 11 of the stations the stands were thriving well in 1933 (Jørgensen 1934). It had spread to the island of Mandø in 1943 and was planted on Rømø in 1936, on Jordsand in 1944 and on Langli in 1946. (Pedersen 1974). In the 1940s it spread rapidly to the entire Danish Wadden Sea area, where it is now common from -40 to 0 cm sea level (Meesenburg 1972). Plants from here were on experimental scale or more massively tranferred to Ringkøbing Fjord 1952 (unsuccessfully), Randers Fjord and Mariager Fjord 1948-1953 (70,000 plants, now very common in the area and spreading along the coast), Limfjorden 1950-54 (few 100 plants, only successful in the eastern part). It may have been introduced to Alrø in Horsens Fjord, from here it has spread to Vorsø (Adsersen 1974) and the northern coast of the fjord. In 1982 it was recorded in North West Sjælland (may be remains from experimental planting, J.T. Møller, pers.comm.). In the 1960ies a few plants were experimentally planted in Stavns Fjord on Samsø. They were allegedly uprooted, but during the latest twenty years *Spartina* has infested appr. 4000 m^2 of the Salicornia marsh there (roughly half of the extent) and is found scattered all around the bay (Randløv 2006). In 1997 it was recorded on the island of Læsø (Vestergaard 2000) and in 2005 on Funen (Tranberg 2006). No experimental plantings have been reported from these islands. It has recently been recorded at Bankel near Haderslev (Randløv 2006; figure 5, number 8), this is the first record along the Baltic coast.
A few plants were transplanted from the North Kattegat stands to Norway (Tønsberg, Oslofjord). The plants died off after three years (Christiansen and Møller 1983)

Pathways of introduction

Spartina anglica has a hybrid origin and originated in British coastal waters in the nineteenth century. Its alleged ability to increase sediment accretion in coastal protection schemes led to numerous requests for plant fragments and seeds. Between 1924 and 1936 more than 175,000 fragments and many seed samples from British waters were sent to more than 130 sites around the world (Gray *et al.* 1991). It follows from this that most of the populations around the world are

intentional introductions.
In Germany, *S. anglica* was first planted in 1927, in the northern Wadden Sea near Husum (Kolumbe 1931). In later years, more plants have been imported from England to be planted in other sites in the Wadden Sea. From these planting areas *S. anglica* population slowly expanded its range north-, south- and westwards along the entire coastline.
In Denmark the first plantations (1930-31) were plants from Poole Harbour in England. The later plantations along the Kattegat coast apparently all originated from stands in the Wadden Sea.

Alien status in region
Spartina anglica is found established in the Wadden Sea area of Denmark and Germany as well as of The Netherlands (Reise *et al.* 2005; see figure 5 and table 1). In the Kattegat area it is spreading from the established stands. There are no records from the German or Danish Baltic coasts.
The Northern limit for *S. anglica* apparently goes through the Norwegian Sea, Skagerak and Kattegat. There is so far only one record south or east of the Danish Belts, probably because the Baltic is too limnic or with too much icecover for *S. anglica* to survive and to reproduce successfully. Recently an increase in abundance in the northern Wadden Sea could be observed. Locally, this may be due to reduced domestic grazing pressure on salt marshes, but more generally this introduced alien species may take advantage of higher spring and winter temperatures over the last two decades (Nehring 2003, Loebl *et al.* 2006).
The true *Spartina x townsendii* has not been found in German waters yet, but several of the older records from Denmark have been referred to this taxon (Pedersen 1974), and from The Netherlands four records are available (Wolff 2005).
There are no records of *S. anglica* from Sweden, but it should be expected to spread to the Swedish Kattegat coast.

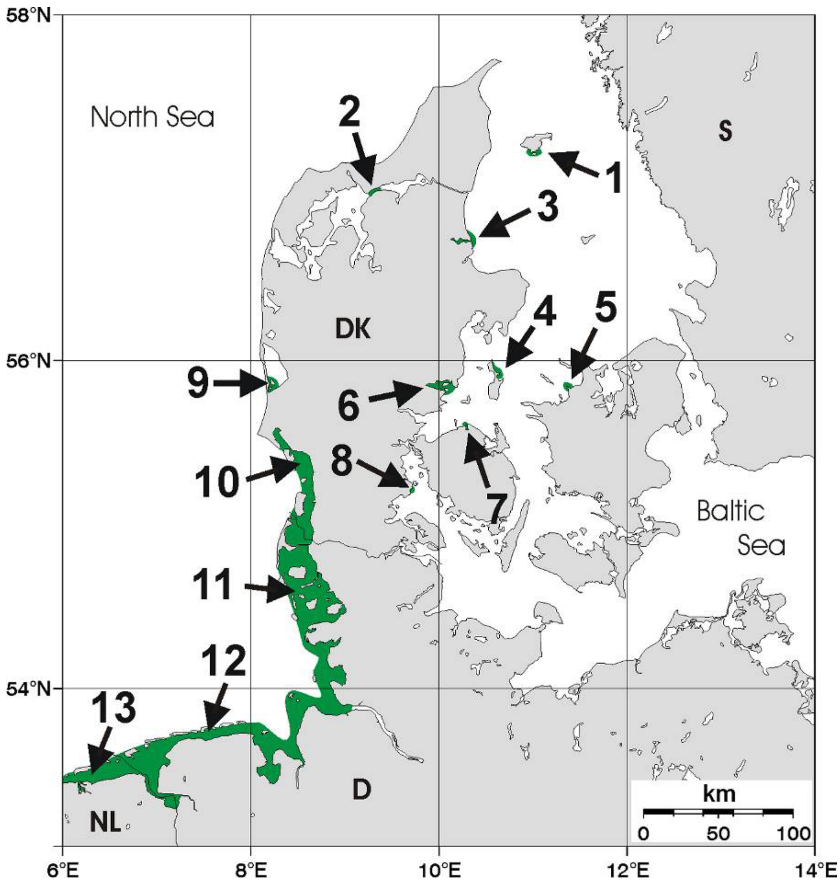

Fig. 5. *Spartina anglica* along the North Sea coast and the Kattegat coasts.

1. Hornfiskerøn, Læsø. Spontaneous spread. 2. Aggersborg in the Limfjord. Unsuccessful planting. 3. Mouths of Randers Fjord and Mariager Fjord. Successful large scale plantings and spread from these. 4. Stavns Fjord, Samsø. Small scale planting, allegedly uprooted, but intensive spread in the area. 5. Korevlen, Sejerø Bugt. Small scale planting, some spread. 6. Horsens Fjord. Small scale planting on Alrø, spread to other islets and mainland coast. 7. Nærå Strand. Spontaneous spread. 8. Bankel Nor near Haderslev. 9. Ringkøbing Fjord. Unsuccessfull planting. 10. Danish Wadden Sea, 11. German North Frisian Wadden Sea, 12. German East Frisian Wadden Sea, and 13. Dutch Wadden Sea. Many large scale plantings along the mainland coasts and on the islands. *Spartina* is common along the entire coastline not exposed directly to the North Sea.

Country	Not found	Not established	Rare	local	Common	Very common	Not known
Denmark					X		
Estonia	X						
European part of Russia	X						
Finland	X						
Faroe Islands	X						
Germany						X	
Greenland	X						
Iceland	X						
Latvia	X						
Lithuania	X						
Norway	X						
Poland	X						
Sweden	X						

Table 1. The frequency and establishment of *Spartina anglica*, please refer also to the information provided for this species at www.nobanis.org/search.asp. Legend for this table: **Not found** –The species is not found in the country; **Not established** - The species has not formed self-reproducing populations (but is found as a casual or incidental species); **Rare** - Few sites where it is found in the country; **Local** - Locally abundant, many individuals in some areas of the country; **Common** - Many sites in the country; **Very common** - Many sites and many individuals; **Not known** – No information was available.

Ecology

Habitat description

Spartina anglica is a plant of the intertidal zone. Because of its phenotypic plasticity, the species can tolerate a wide range of environmental conditions (Gray *et al.* 1991). The plant occurs on a variety of substrates, including clays, fine silts, organic muds, sands, and shingle (Gray *et al.* 1991). *S. anglica* can tolerate inundation for nine hours or more, which is long in comparison with other telmatic species (NWCB 2005). As result, *S. anglica* can occupy the seaward edge of salt marshes where there is little or no competing vegetation (Gray *et al.* 1991). On bare mud seedlings of the common cord-gras may grow densely, occurring at densities up to 13,000/m^2. Densities are lower in meadows (up to 9,750/m^2), with many of the seedlings dying. In most cases, meadows are maintained by rhizome formation and tillering, rather than seedling establishment (Gray *et al.* 1991).

In the Wadden Sea *S. anglica* grows as a pioneer plant in the upper tidal zone. At lower elevations, the distribution of this alien species may be limited by wave action; the species is more successful in sheltered sites, possibly because wave action uproots seedlings. It occurs in coherent swards at the seaward front of salt marshes and in patches on the tidal flats between the spring and neap high tide line. Often, a conspicuous, almost monotypic, belt of *S. anglica* is formed (Reise *et al.* 2005).

In the Kattegat area many clones establish themselves on coarser substrate, and *Spartina* sometimes often establishes itself in reed swamp of *Phragmites australis* or *Schoenoplectus tabaernaemontani*. Christiansen and Møller (1983) report that Spartina does not grow below +5 cm sea level in Northern Kattegat.

Reproduction and life cycle
Spartina anglica sprouts in the spring. In November, it produces wintering buds in the leaf axils, which is followed by rhizome development in response to short days. *S. anglica* has unpredictable production, viability and germination of its seeds. Seed production of *S. anglica* is quite variable both temporally and spatially. In the Wadden Sea, flowers emerging from July through October ripen seeds within approximately 12 weeks. In late fall the flowering culms generally die. However, flowering may extend to the following year during mild winters. Pioneer populations often produce few seeds, but seed production increases with marsh development. Low soil temperature can delay or suppress flowering and reduce seed production. It appears that high seed production is associated with warm, late summers, which probably facilitate both the breakdown of the self-incompatibility mechanism and the ripening of seed. *S. anglica* can produce up to 5 million spikelets per hectare. Less than 5% of these spikelets are likely to produce viable seed. The seeds are relatively short-lived, so this alien species does not have a persistent seed bank. In England seeds are only viable for one season under field conditions, with germination rates of 0.6 to 5 percent. Laboratory studies have indicated that seeds stored at 4° C in a refrigerator remained viable for at least four years. Maximum germination occurred in the dark, with the germination rate increasing as temperatures increased from 7° to 25° C. Seeds buried between 1 and 3 cm have the best chance of establishing. At shallower depths, seeds are subject to desiccation, while deeper burial may result in decreased viability. In the Stavns Fjord on Samsø, spontaneous seed plants have been documented (see figure 5, number 4).
The spread of *S. anglica* occurs in different phases; initial invasion and establishment, and then expansion of tussocks by radial clonal growth (up to 30 cm per year). Spreading tussocks fuse to form clumps which finally coalesce to form swards that can expand into extensive meadows. The formation of clumps, swards and meadows is not always a rapid or continuous process. Christiansen and Møller (1983) reported a mean annual area increase from 1959 to 1966 of 14.3% and from 1974 to 1978 of 2.7% in planted stands in Mariager Fjord (Northern Kattegat)
S. anglica tolerates salinities ranging from 5-40 PSU. However, many of the early transplants failed or appeared to be held at the tussock phase. The known reasons for failure include inappropriate site conditions. This phenomenon occurs most frequently in badly drained, waterlogged marshes that have highly anaerobic soils, a high proportion of fine particles, and a high sulphide content. Hypersalinity conditions as well as toxic levels of sulfide and anoxia in rhizomes have been implicated in the death of these plants. Particularly at the northern edge of the species' range, the death of transplants by frost has been recorded.
Unlike most temperate grasses *S. anglica* has a C_4 photosynthetic pathway. At optimal temperatures C_4 species have greater nitrogen and water use efficiency than comparable C_3 species, which may help explain the high salinity tolerance of *S. anglica*. In addition, *S. anglica* can maintain photosynthetic rates at 5° to 10° C that are equivalent to C_3 rates. Therefore, it does not have the temperature constraints that limit other C_4 plants to lower latitudes.
Key references: König 1948, Gray *et al.* 1991, Hammond *et al.* 2002, SFEISP 2005, ISSG 2005, NWCB 2005.

Dispersal and spread
Spartina anglica spreads via seeds, rhizomes, tillering, and rhizome fragments. Dispersal may occur by water currents, humans, shipping, or by the feet of waterfowl (Adsersen 1974, Gray *et al.* 1991, Eno *et al.* 1997). According to Reise (1998) residual currents along the Wadden Sea coast rarely exceed 0.1 m s^{-1}, but since a drifting seed of *S. anglica* can remain viable for weeks it could theoretically travel several thousand km before it settles down. However, the observed spread towards areas outside the surroundings of the plantations occurred at a much slower rate (König 1948). The factors affecting establishment are imperfectly understood up to now. Above all, critical interaction between mudflat elevation, and hence hydrodynamic stability, and seed burial depth

seem to determine seedling emergence and growth (Gray *et al.* 1991, Hammond *et al.* 2002). The stands on Læsø are almost certainly due to spontaneous long distance dispersal (> 50 km over open sea). The spread could be mediated by floating (both spikelets with seeds and inflorescence blanches float) or by mud on waterfowl.

Impact

Affected habitats and indigenous organisms
Spartina anglica has been intentionally introduced to coastal and estuarine mudflats throughout the world. The species has proven to be highly invasive in many parts of the world and there is much concern about its spread on the Pacific coast of North America, in East Asia, New Zealand and Australia (incl. Tasmania). For example, by the mid-1960s, more than 12,000 ha of salt marsh in Great Britain, about a quarter of the total, were dominated by *S. anglica* (Gray and Raybould 1997). This is why *S. anglica* has been nominated by the World Conservation Union (IUCN 2000) as among 100 of the "World's Worst" invaders. As this species proliferates the results can be serious. *S. anglica* traps sediment with their large root masses. It experiences a wide range of sediment accretion rates, generally varying from 3 mm year^{-1} to as much as 20 cm year^{-1} (Gray *et al.* 1991, NWCB 2005). *S. anglica* has high productivity. Growth and death result in a large amount of energy and organic matter entering the ecosystem. *S. anglica* may form the basis of many food webs and is a possible food source for many grazers as geese, ducks and other water birds and wildlife (ISSG 2005). Significant harmful ecological impacts of *S. anglica* are described in general as follows:

1. A loss of valuable habitat for endobenthic invertebrates and for migrating shorebirds and waterfowl;
2. A loss of rearing habitat for fish;
3. Replacement of native plants and more diverse native plant communities; and
4. Alteration the course of succession.

However, for the most part detailed studies have not been conducted on the specific impacts of *S. anglica* in the German and Danish Wadden Sea. Nevertheless, the first results and findings show that in the Wadden Sea *S. anglica* invades former native salt marsh grass-dominated vegetation, and is perceived as a threat to salt marsh conservation (Gettner *et al.* 1998). Today a dynamic mosaic often develops in the lower salt marsh zone where *S. anglica* patches may alternate with those of native salt marsh species (*Halimione portulacoides, Puccinellia maritima* or *Artemisia maritima* and others). On upper tidal flats the cord-grass displaces the glasswort (*Salicornia stricta*), the small seagrass (*Zostera noltii*), the lugworm (*Arenicola marina*) and associated species (König 1948, Reise 1994, Loebl 2002, Reise *et al.* 2005). Investigations from the Dutch Wadden Sea indicate that the polychaete *Neries diversicolor* (clam worm), the amphipod *Corophium volutator* (mud shrimp), and part of the microbenthos disappear when *Spartina* marsh spread into mud flats (Gribsholt and Kristensen 2003). Mesocosm experiments indicates that *Spartina* under Kattegat conditions strongly influences the biogeochemical turnover in the sediment, maybe because of its strong ability to transport oxygen to the substratum (Gribsholt and Kristensen 2002).
In conclusion, *S. anglica* should be regarded as a threat to the authentic biodiversity of the Wadden Sea (Nehring and Hesse 2006). And, the *Spartina* population in the Wadden Sea and Kattegat may benefit from global warming and may become more abundant (Nehring 2003, Loebl *et al.* 2006). Most of the infested areas in Denmark are protected (Natura 2000, Ramsar) e.g. Stavns Fjord on Samsø (see figure 5, number 4).

Genetic effects
The invasiveness of *Spartina anglica* has a demonstrable genetic cause. Even this case is special, in

that the 'mutation' was a doubling of the genome, not a point mutation in a single gene. Allopolyploidy clearly had immediate effects in *S. anglica*, as indicated by its ecological success. Although the species underwent a severe genetic bottleneck at the time of its formation in England, and despite its low level of inter-individual genetic variation, considerable morphological variability is encountered among native populations (Gray *et al.* 1991). Heterosis and dosage effects in duplicated genomes are likely to increase the metabolic plasticity of the duplicated genes, thereby affecting the fitness of the newly formed species (Salmon *et al.* 2005). *S. anglica* is known for having rapidly invaded habitats previously unoccupied by its parental species. This species displays higher physiological tolerance that may facilitate colonization of extensively flooded zones of the low marshes (Salmon *et al.* 2005).
In *S. anglica* there is some potential for the generation of variation by either the breakdown of preferential pairing or by backcrossing with one or the other parental species (Gray *et al.* 1991). However, no 'new' *Spartina* species has been observed in the Wadden Sea yet.

Human health effects
No significant human health effects have been recorded (Starfinger and Kowarik 2004). However, the leaves of *Spartina anglica* are sharp and stiff. It appears likely that the process of global warming may have a major effect on the future spread of *S. anglica* (Nehring 2003, Loebl *et al.* 2006). A further increase of the *Spartina* population in the Wadden Sea is expected, probably combined with an increase of cut injuries among walkers and swimmers (Nehring and Hesse 2006).

Economic and societal effects (positive/negative)
Spartina anglica has the potential to be used for economic benefits. Under natural conditions on tidal marshes vigorous stands of this alien species will absorb wave energy (Gray *et al.* 1991). Therefore *S. anglica* has been used world-wide as an agent for coastal protection and stabilization. Because of its ability to trap sediment *S. anglica* has been used to stabilize mudflats and reduce the source area for channel silting. In addition, agricultural interests have planted *S. anglica* for estuary reclamation (Gray *et al.* 1991). Experience from around the world indicates a wide variety of livestock (*i.a.* cattle, goat) will eat *S. anglica* (Ranwell 1967). *S. anglica* is also used as green manure in China; 50 kg of this alien species are approximately equivalent to 0.5 kg of urea (NWCB 2005).
A secondary negative impact of increased sediment accretion may be changes in water circulation patterns. Large, dense populations of *S. anglica* at or in river mouths may cause particular problems by decreasing flow and leading to increased flooding, especially during periods of heavy precipitation and/or above normal tides (NWCB 2005). The spread of *S. anglica* also threatens the economic interests of commercial oyster fisheries (WSDE 2003). Changes associated with *Spartina* also impact recreation. Therefore, activities such as fishing, hunting, boating, bird watching, botanizing, and shellfish harvesting that are dependent on the extant intertidal ecosystem could be negatively impacted by the continued spread of *S. anglica* (Ranwell 1967, Gray *et al.* 1991, NWCB 2005).
In the German and Danish Wadden Sea most of the impact of *S. anglica* on other sea areas is probably insignificant. In Germany common cord-grass was planted in the 1920s and 1930s for several years because the expected effects regarding sedimentation and stabilization of mudflats did not satisfy expectations (König 1948). *S. anglica* has been more modestly invasive in the Wadden Sea, which is the northern limit of its distribution, as compared with much of the Southwestern Netherlands and Southern England. König (1948) stresses that besides temperature the absence of shelter is a second important key factor. The salt marshes in the German and Danish Wadden Sea generally are too exposed to wave action to enable *S. anglica* to form extensive dense vegetation. In Denmark *Spartina* has been planted as a reclamation aid also after world war II and with some success in the Mariager Fjord – Randers Fjord area. The species may develop higher abundances

mainly in sheltered places and in enclosed basins (Dijkema 1983) Along the Kattegat coast there are many shallow bays and inlets where it may form dense stands. The salinity in the water is suboptimal to *Puccinellia maritima* and *Salicornia* but apparently suitable for *Spartina*, so it may fill a partially empty niche here. The impacts of *S. anglica* on sedimentation and erosion actions in the Wadden Sea area and Kattegat are not quantified yet. The species may benefit from global warming and may become more abundant in the near future and be associated with complex interactions in hydromorphodynamics and with unknown effects on coastal protection.
Along the Kattegat coast some of the establishments occur on sandy beaches that are attractive to tourists. Formation of large swards would change the aspect of the beach and create a belt with unattractive sedimentation.

Management approaches

Prevention methods
In Germany and in Denmark *Spartina anglica* was planted at the beginning of the 20th century, when there were no legal regulations. In Germany today the introduction of alien species into the landscape must be authorised, according to the Federal Conservation Act (excluding their use in agriculture or forestry) (Klingenstein *et al.* 2004). However, no agreed guidelines for regional authorities or accepted procedures e.g. for risk assessments exist. On the basis of the Guiding Principles of the Convention on Biological Diversity, the preparation of a national strategy on alien species is in progress (Klingenstein *et al.* 2004). Because of the high potential for natural dispersal of introduced aquatic species, and many human vectors for secondary dispersal along European coasts, adequate precautionary measures are needed beyond an international management plan. A decision not to introduce *S. anglica* for plantation would have merely postponed the invasion, unless the same decision would have been made for European coasts outside the Wadden Sea (Nehring and Klingenstein 2005).

Eradication, control and monitoring efforts
In Germany and Denmark no eradication or control programme has so far been carried out to reduce the wild stock of *Spartina anglica*. However, if a need should arise in future, various experiences from other coastal areas are available.
The best way to control *S. anglica* is early detection. Digging is, however, only successful on *Spartina* clumps smaller than 50 cm in diameter (after Hammond and Cooper 2002). Smothering with plastic sheeting, burying and repetitive burning have achieved killing rates of over 90%. These methods are, however, more costly than herbicides and have practical problems e.g. sheeting may become dislodged by tidal currents, and are therefore only suitable for use on small areas (ISSG 2005). Bi-weekly stimulated horse trampling over a period of one year reduced above-ground *Spartina* biomass only by 55% (after Hammond 2001). Trampling of mixed salt marsh vegetation by students failed to have any impact on common cord-grass cover (after Hammond 2001).
Herbicide application is the most frequently used control method due to its practical ease of use and cost effectiveness (Hammond and Cooper 2002). However, Ranwell and Downing (1960) reported the complete recovery of *S. anglica* within sprayed areas two years after Dalapon application. The herbicides Fluazifop and Haloxyfop both regularly achieve over 90% efficiency after one application. However, a complete eradication would require repeated applications of eradication treatments, possibly on many occasions (Hammond and Cooper 2002). Other possible control methods being researched include biological control using an insect (*Prokelisia* spp.) (ISSG 2005).
In Germany and Denmark there are no coordinated monitoring programmes to document the spreading and impacts of *S. anglica*. Thus, it is still a challenge to act on this alien species. Therefore, existing management initiatives and instruments as well as the implementation of new

and relevant ones, must be observed carefully (Nehring and Klingenstein 2005).

Information and awareness
Today the occurrence of *Spartina anglica* in Germany and Denmark is generally accepted by various institutions and experts and is not the subject of public attention. However, a relevant information platform has not yet been installed. Education and awareness-raising initiatives are needed.

Knowledge and research
Knowledge about establishment mechanisms as well as about ecological and economic impacts of *Spartina anglica* in the German and Danish part of the Wadden Sea and Kattegat is limited. Today no specific research programme is in place. However, it is likely that the occurrence of *S. anglica* has relevant effects and should be investigated. So much more as this alien species may benefit from global warming and may become more abundant in the near future.

Recommendations or comments from experts and local communities
Until now the introduction, establishment and spreading of alien species in the Wadden Sea is perceived only on a descriptive level in some ways. A purposeful alien strategy for dealing with the protection and conservation of the Wadden Sea is missing. The development of an alien species plan on the level of the Trilateral Cooperation on the Protection of the Wadden Sea is essential (Nehring and Klingenstein 2005). Analyses about the potential economic effects are also needed.

References and other resources

Contact persons
Stefan Nehring (DE) AeT umweltplanung, Bismarckstraße 19, D-56068 Koblenz, Germany; Phone: +49 261 1330398; E-mail: nehring@aet-umweltplanung.de

Henning Adsersen (DK) Biologisk institut, Universitetesparken 15, DK-2100 København Ø, Denmark; Phone: +35 32 12 52; E-mail: adser@bi.ku.dk

Melanie Josefsson (SE) Swedish Environmental Protection Agency, SE-106 48 Stockholm, Sweden; Phone: +46 18 67 31 48, fax: +46 18 67 31 56; E-mail: Melanie.Josefsson@snv.slu.se

Dora Jakobsdottir (IS) Reykjavik Botanic Garden, Laugardalur, IS-104 Reykjavik, Iceland; E-mail: dora.jakobsdottir@reykjavik.is

Christina Birnbaum (EE) Estonian University of Life Sciences, Institute of Agriculture and Environmental Sciences, Kreutzwaldi 64, EE-51014 Tartu, Estonia; E-mail: chbirnbaum@yahoo.com

Links

Species Fact Sheet - *Spartina anglica* in Germany - Internet-Handbook "Neoflora" of the Bundesamt für Naturschutz Bonn
Global Invasive Species Data Base - *Spartina anglica*, a world overview - ISSG - Invasive Species Specialist Group
Species Fact Sheet - *Spartina anglica* in Great Britain - JNCC - Joint Nature Conservation Committee
Information board - *Spartina anglica* in USA - NWCB - The State Noxious Weed Control Board.
Information services - aquatic alien species in Germany - AeT umweltplanung Koblenz

References

Adsersen, H. 1974. *Spartina* (Vadegræs) i Horsens Fjord. - Flora og Fauna 80: 37-42.

Christiansen, C. and Møller, J.T 1983. Rate of establishment and seasonal immersion of Spartina in Mariager Fjord, Denmark.- Holarctic Ecology 6: 315-319.

Dijkema, K.S. 1983. The salt-marsh vegetation of the mainland coast, estuaries and halligen. - In: Dijkema, K.S. and Wolff, W.J. (eds.), Flora and vegetation of the Wadden Sea island and coastal areas. Final report of the section "Flora and vegetation of the islands" of the Wadden Sea Working Group. Leiden: 185-220.

Eno, N.C., Clark, R.A. and Sanderson, W.G. 1997. Non-native marine species in British waters: a review and directory. - Joint Nature Conservation Committee, Peterborough: 152 pp.

Forschungsstelle Norderney 1973. Zur Ausbreitung und Gesellschaftsbildung von *Spartina townsendii* an der Ostfriesischen Küste. - Forschungsstelle Norderney, Jahresbericht 1972, Band 24: 219-239.

Gettner, S., Heinzel, K. and Dierßen, K. 1998. Veränderung der Salzmarschenvegetation. - In: Nationalpark Schleswig-Holsteinisches Wattenmeer and Umweltbundesamt (eds.), Umweltatlas Wattenmeer Bd. 1, Nordfriesisches und Dithmarscher Wattenmeer. Ulmer, Stuttgart: 88-89.

Gray, A.J., Marshall, D.F. and Raybould, A.F. 1991. A century of evolution in *Spartina anglica*. - Advances in Ecological Research 21: 1-62.

Gray, A.J. and Raybould A.F. 1997. The history and evolution of *Spartina anglica* in the British Isles. - In: Second International Spartina Conference Proceedings, Olympic Natural Resources Center, University of Washington: 5-8.

Gribsholt, B. and Kristensen, E. 2002. Effects of bioturbation and plant roots on salt marsh biogeochemistry: a mesocosm study. - Marine Ecology Progress Series 241: 71-87.

Gribsholt, B. and Kristensen, E. 2003. Benthic metabolism and sulphur cycling along an inundation gradient in a tidal *Spartina anglica* salt marsh. - Limnology and Oceanography 48: 2151-2162.

Hammond, M.E.R. 2001. The experimental control of *Spartina anglica* and *Spartina townsendii* in estuarine salt marsh. - University of Ulster, PhD: 147 pp.

Hammond, M.E.R. and Cooper A. 2002. *Spartina anglica* eradication and inter-tidal recovery in Northern Ireland estuaries. - In: Veitch, C.R. and Clout, M.N. (eds.), Turning the tide: the eradication of invasive species. IUCN SSC Invasive Species Specialist Group: 124-131.

Hammond, M.E.R., Malvarez, G.C. and Cooper A. 2002. The distribution of *Spartina anglica* on estuarine mudflats in relation to wave-related hydrodynamic parameters. - Journal of Coastal Research 36: 352-355.

ISSG 2005. Global Invasive Species Data Base - *Spartina anglica*. - Invasive Species Specialist Group. Web publication

IUCN 2000. 100 of the world's worst invasive alien species. - IUCN The World Conservation Union, http://iucn.org

Jørgensen, C.A. 1934. Plantningsforsøg med *Spartina Townsendii* i den danske Vesterhavsmarsk.- Botanisk Tidsskrift 42: 421-440.

Klingenstein, F., Eberhardt, D. and Kornacker, P. 2004. Invasive gebietsfremde Arten aus Sicht des Naturschutzes auf Bundesebene. - In: Senat der Bundesforschungsanstalten im Geschäftsbereich des BMVEL (ed.), Bedrohung der biologischen Vielfalt durch invasive gebietsfremde Arten - Erfassung, Monitoring und Risikoanalyse. Schriftenreihe des BMVEL, Reihe A, Angewandte Wissenschaft 498: 24-39.

Kolumbe, E. 1931. *Spartina townsendii* - Anpflanzungen im schleswig-holsteinischen Wattenmeer. - Wissenschaftliche Meeresuntersuchungen, Abt. Kiel, N.F. 21: 66-73.

König, D. 1948. *Spartina townsendii* an der Westküste von Schleswig-Holstein. - Planta 36: 34-70.

Loebl, M. 2002. Das Schlickgras *Spartina anglica* C.E. Hubbard - Ausbreitung und Habitatveränderungen im Sylter Wattenmeer. - Universität Kiel, Diplomarbeit: 123 pp.

Loebl, M., Beusekom, J.E.E. van and Reise, K. 2006. Is spread of the neophyte *Spartina anglica* recently enhanced by increasing temperatures? - Aquatic Ecology 40: 315-324.

Meesenburg, H. 1972. Spartinas kolonisation og udbredelse langs Ho Bugt. - Geografisk Tidsskrift 71: 37-46.

Nehring, S. 2003. Alien species in the North Sea: invasion success and climate warming. - Ocean Challenge 13(3): 12-16.
Nehring, S. and Hesse, K.-J. 2006. The common cord-grass *Spartina anglica*: An invasive alien species in the Wadden Sea National Park. - Verhandlungen der Gesellschaft für Ökologie 36: 333.
Nehring, S. and Klingenstein, F. 2005. Alien species in the Wadden Sea - A challenge to act. - Wadden Sea Newsletter 31: 13-16.
NWCB 2005. Common cordgrass (*Spartina anglica* C.E. Hubbard). - The State Noxious Weed Control Board. Web publication
Pedersen, A. 1974. Gramineernes udbredelse i Danmark. - Botanisk Tidsskrift 68: 178-343.
Ramløv, M.B. 2006. *Spartina anglica* i Stavns Fjord på Samsø. - Master thesis, Institute of Biology, University of Copenhagen.
Ranwell, D.S. 1967. World resources of *Spartina townsendii* (*sensu lato*) and economic use of *Spartina* marshland. - Journal of Applied Ecology 4: 239-256.
Ranwell, D.S. and Downing, B.M. 1960. The use of Dalapon and substituted urea herbicides for control of seed-bearing *Spartina* (cord grass) in inter-tidal zones of estuarine marsh. - Weeds 8: 78-88.
Reise, K. 1994. Das Schlickgras: die Invasion einer neuen Art. - In: Lozán, J.L., Rachor, E., Reise, K., Westernhagen H. von and Lenz, W. (eds.), Warnsignale aus dem Wattenmeer. Blackwell Wissenschaftsverlag, Berlin: 211-214.
Reise, K. 1998. Pacific oysters invade mussel beds in the European Wadden Sea. - Senckenbergiana maritima 28: 167-175.
Reise, K., Dankers, N. and Essink, K. 2005. Introduced species. - In: Essink, K., Dettmann, C., Farke, H., Laursen, K., Lüerßen, G., Marencic, H. and Wiersinga, W. (eds.), Wadden Sea Quality Status Report 2004. Wadden Sea Ecosystem No. 19: 155-161.
Salmon, A., Ainouche, M.L. and Wendel, J.F. 2005. Genetic and epigenetic consequences of recent hybridization and polyploidy in *Spartina* (Poaceae). - Molecular Ecology 14: 1163-1175.
SFEISP 2005. Invasive *Spartina* project - Introduced *Spartina anglica* (English cordgrass). - San Francisco Estuary Invasive Spartina Project. Web publication
Starfinger, U. and Kowarik, I. 2004. *Spartina anglica* C. E. Hubbard (Poaceae), Salz-Schlickgras. - In: Internet-Handbuch “Neoflora” des Bundesamtes für Naturschutz Bonn. Web publication
Tranberg, H. 2006. Floristiske fund fra falderebets Fyns Amt 2005. - Urt 30: 13-17.
Vestergaard, P. 2000. Strandenge - en beskyttet naturtype. - Gads Forlag, København.
WAPMS 2004. *Spartina alterniflora* - Smooth Cordgrass - A problem aquatic plant in the Western USA. - The Western Aquatic Plant Management Society. Web publication
Wolff, W.J. 2005. Non-indigenous marine and estuarine species in The Netherlands. - Zool. Med. Leiden 79: 1-116.
WSDE 2003: Washington’s coast - *Spartina*. - Washington State Department of Ecology, Washington. Web publication

Date of creation/modification of this species fact sheet: 16-11-2006