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Contents

Summary

This report describes a risk assessment of the alien Prairie cordgrass (*Spartina pectinata*) for the European Union (EU). This plant species has recently been identified in a horizon scan as a potential invasive alien species that currently has a very limited distribution in the EU. The species is native to North America and grows in different types of wetlands and poorly drained soils. *S. pectinata* is a sod forming C4-grass that reaches heights of one to three metres. The root system contains highly branched woody rhizomes. The roots grow more or less vertically to a depth of 2.4 to 3.3 m. In its native range, the species forms dense stands in which almost no other plant species are found. The ability of the species to rapidly grow and reproduce vegetatively with rhizomes indicates that this alien species could become invasive.

The present risk assessment is based on a detailed risk inventory of *S. pectinata*, which includes a science based overview of the current knowledge of the species including taxonomy, habitat preference, introduction and dispersal mechanisms, current distribution, ecological impact, socio-economic impact, and consequences for public health. A team of experts used this information to assess and classify the (potential) risks of spread, invasiveness and impact of *S. pectinata* in the EU using the Harmonia^{+} and Invasive Species Environmental Impact Assessment (ISEIA) protocols. The report also includes a risk assessment of *S. pectinata* that is focussed on the Netherlands.

The species has become established at several locations in Germany, Great Britain and Ireland, and is also recorded in the Netherlands, Belgium and France. The risk of introduction to the EU is scored as medium and the risks of establishment, spread and environmental impact are scored as high considering the climate and habitat match of the species, its high potential growth rate and capacity for vegetative reproduction. The climate and habitat characteristics of the core of the native range of *S. pectinata* suggest that areas most endangered by the species in the EU are likely to be wetlands and banks of rivers and streams, including the Natura 2000 habitat types 6430 (Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels) and 6250 (Pannonic loess steppic grasslands) present in Eastern EU member states.

The capacity of *S. pectinata* to disperse within the EU by natural means is scored as low, but it is intentionally introduced through ornamental planting in gardens. Subsequent distribution from gardens into the wild may occur due to improper disposal of garden waste. Establishment of these populations in the EU seems to have resulted from escapes from cultivation. Records of the species in eastern EU member states were not found during this study, but the climate and habitat match for these states is even better than that derived for north-western EU member states.

Moreover, the species is offered for sale in these regions. Inventory and monitoring of populations in eastern EU member states is required to assess the current distribution of the species.

The expert team allocated *S. pectinata* the total risk score “**high**”. The total risk score refers to the ecological risks to the EU derived using the Harmonia^{+} and ISEIA protocols. The total risk score implies that *S. pectinata* should be added to the **alert list** of the BFIS-list system for the current situation (class A1). Future climate change (defined as a 2 °C increase over current temperatures), and unchanged EU and national policies for *S. pectinata*, are expected to have no effect on its ecological risk.

1. Introduction

1.1 Background and problem statement

Recently, several horizon scanning reports have been published to identify potential invasive alien species (IAS) that may be introduced or currently have a very limited distribution in the Netherlands or the European Union (EU) (Matthews et al. 2014, 2015, 2017, Roy et al. 2014a, 2014b, Gallardo et al. 2016). Prairie cordgrass (*Spartina pectinata*) was one of the species that received a high ecological risk score for the Netherlands and larger areas of the EU in these reports, and is currently present on a limited scale in the EU. Therefore, the Office for Risk Assessment and Research of the Netherlands Food and Consumer Product Safety Authority (NVWA) requested to perform a scientific risk assessment for this species.

S. pectinata is native to North America. It is a perennial plant with a very rapid root development of up to 2.5 cm per day, particularly in disturbed soil. This growth rate is only exceeded by the root development of cultivated crops. A few populations have been recorded in multiple EU member states. Most of these populations seem have resulted from escapes from cultivation. As *S. pectinata* is sold in garden centres in many European countries, new introductions are likely to occur. To date, *S. pectinata* has not proved to be a problematic invasive species in the EU (Chapter 3). However, according to Matthews et al. (2015), the potential for the species to become invasive in the EU is high.

This report presents a risk assessment of *S. pectinata* for the EU. Additionally, appendix 2 presents a risk assessment of the species for the Netherlands. The assessments are based on a detailed risk inventory. The analyses of available data and risk classifications of the species have been performed by a team of experts using the Harmonia$^+$ and Invasive Species Environmental Impact Assessment (ISEIA) protocols.

1.2 Research goal

The goal of this study is to conduct a risk assessment of alien *S. pectinata* for the EU that complies with the criteria for listing IAS of EU concern as described in Regulation 1143/2014. This assessment focusses on the probability of introduction, establishment, spread, colonisation of high conservation value habitats, (potential) ecological and socio-economic effects, and impact on public health of the species.

1.3 Outline and coherence of the research

The coherence between various research activities and outcomes of the study are visualised in Figure 1.1.

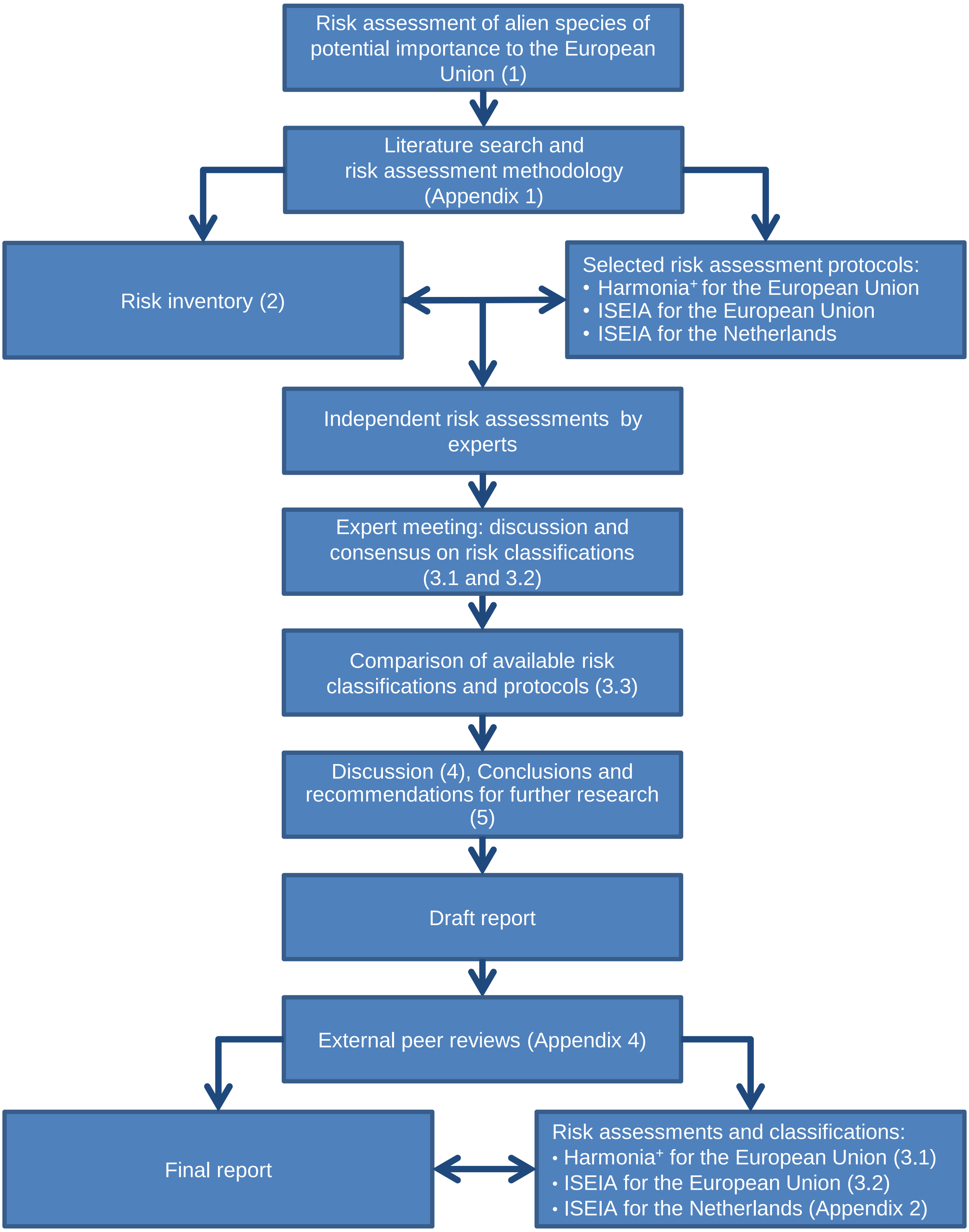


Figure 1.1: Flow chart visualising the coherence of various research activities (chapter numbers are presented between brackets; ISEIA: Invasive Species Environmental Impact Assessment protocol).

The present chapter describes the problem statement, goals and research questions in order to assess and classify the risks of *S. pectinata* in the EU. Chapter 2 describes the results of the risk inventory, which includes a science based overview of the current knowledge on taxonomy, habitat preference, introduction and dispersal mechanisms, current distribution, ecological impact, socio-economic impact and consequences for public health of the species. A team of experts used the information provided in the risk inventory to assess and classify the (potential) risks of spread, invasiveness and impact of *S. pectinata* in the EU using the ISEIA and Harmonia$^+$ protocols. Chapter 3 includes the results of these risk assessments and classifications. Moreover, in this chapter results of other available risk classifications are summarized and compared with the results of the risk assessments contained in this report. The uncertainties in the risk assessments, relevant knowledge gaps and differential outcomes (risk classifications) of available risk assessments are discussed in chapter 4. Chapter 5 draws conclusions. Appendix 1 describes the methods used for the inventory (including literature review and data acquisition), and the assessment and classification of the risks of the introduction and spread of this species. Appendix 2 summarizes the results of the risk classification of *S. pectinata* for the Netherlands using the ISEIA protocol. Appendix 3 includes an overview of the current distribution of *S. pectinata* in the EU. Finally, details on the outcomes of the peer review procedure for this report are summarized in appendix 4.

2. Risk inventory

2.1 Species description

2.1.1 Nomenclature and taxonomical status

The nomenclature and taxonomical status of *S. pectinata* are summarized in Table 2.1.The species is clearly a single taxonomic entity which can be distinguished from other species of the same genus by the longer awns of its upper glumes and the relative length of its lower glumes (see §2.1.2).

Table 2.1: Nomenclature and taxonomical status of Prairie cordgrass (*Spartina pectinata*).

Scientific name: *Spartina pectinata* Bosc ex Link

Synonym: *Spartina michauxiana* Hitchc.

Taxonomic tree

According to Naturalis Biodiversity Center (2016):	According to Encyclopedia of Life (2016), DAISIE (2016):
Domain: Eukaryota Kingdom: Plantae Phylum: Tracheophyta Class: Spermatopsida Order: Poales Family: Poaceae Genus: *Spartina* Species: *Spartina pectinata*	Domain: Eukaryota Kingdom: Plantae Phylum: Magnoliophyta Class: Liliopsida Order: Poales Family: Poaceae Genus: *Spartina* Species: *Spartina pectinata*
According to CABI (2016):	**According to USDA (2016):**
Domain: Eukaryota Kingdom: Plantae Phylum: Spermatophyta Subphylum: Angiospermae Class: Monocotyledonae Order: Cyperales Family: Poaceae Genus: *Spartina* Species: *Spartina pectinata*	Kingdom: Plantae Subkingdom: Tracheobionta Superdivision: Spermatophyta Division: Magnoliophyta Class: Liliopsida Subclass: Commelinidae Order: Cyperales Family: Poaceae Genus: *Spartina* Species: *Spartina pectinata*

Preferred Dutch name: Not yet determined. ‘Hoog slijkgras’ has been proposed lately and will probably be accepted.

Preferred English name: Prairie cordgrass

Other Dutch names: Not available

Other English names: Freshwater cordgrass, Tall marshgrass and Sloughgrass (the last name is also used as a common name for *Beckmannia* spp.)

Native range: North America, including central and eastern Canada and Mexico

2.1.2 Species characteristics

S. pectinata is a sod forming C4-grass. The firm or wiry culms reach heights from one to three metres. The spikes are four to eight cm long and each plant has 10 to 20 spikes. The leaves are glossy dark green in colour, turning yellow in autumn, and feature sharp edges. The root system contains coarse and woody rhizomes that are highly branched. The roots develop from the rhizomes and from the base of clumps, growing more or less vertically to a depth from 2.4 to 3.3 m (US Forestry Service 2016, Matthews et al. 2015, Missouri Botanical Garden 2016). In its native range *S. pectinata* is known as a polyploid species comprising three ploidy levels with tetraploids, hexaploids and octoploids (Kim 2012).

Figure 2.1: Prairie cordgrass (*Spartina pectinata*) (© Photo: J. Anderson, USDA-NRCS PLANTS Database).

Differences with visually similar species

S. pectinata might be confused with other *Spartina* species, but can be distinguished by the longer awns of its upper glumes (2-12 mm in length) and the relative length of its lower glumes, which are about the same length as the lemmas (7-10 mm). Other *Spartina* species have shorter awns and their lower glumes are shorter than their lemmas (Encyclopaedia of Life 2016).

Figure 2.2: Prairie cordgrass (*Spartina pectinata*) flowering. (© Photo: J. Hilty, Illinois Wildflowers).

Reproduction

S. pectinata reproduces by both sexual and vegetative means. In North America most reproduction occurs vegetatively through rhizomes. Seedlings are shade-intolerant and only establish in bare areas (Weaver 1954, US Forestry Service 2016). Rhizomes form an open network in part or all of the upper 30 cm of soil (Weaver 1958). In its native range, reproduction from rhizomes results in complete coverage and almost no other plants are found in dense stands (Weaver 1960a).

Because of (partial) self-incompatibility and insect predation, viable seed production is often low (Illinois Wildflowers 2016, Prasifka et al. 2012). In controlled storage, seeds remain viable for about 3 years, but decreases when seeds are stored under high temperatures and humidity (USDA NRCS 2016b).

Figure 2.3: Prairie cordgrass (*Spartina pectinata*) spikes (© Photo: J. Hilty, Illinois Wildflowers).

Seeds germinate readily in wet soil, and seedlings develop rapidly (Weaver 1958). Germination of seeds from five different collections ranged on average from 38.5% to 84.5% (Williams 2001). Stratification has no impact on germination success, viable seeds germinate readily with or without stratification (Williams 2001). Two greenhouse experiments in North America, that both applied optimum germination temperatures (30^{o}C), yielded different results. Shipley & Parent (1991) demonstrated that *S. pectinata* germinates at a rate of 41 percent, whilst Eddleman & Meinhardt (1981) observed a rate of between 70 and 91 percent in their experiment. Eddleman & Meinhardt (1981) observed that seedling survival was high after four weeks of moisture stress conditions, although a reduction in growth rates did occur.

Reproduction of *S. pectinata* has been observed in the Netherlands, Ireland and Great Britain (NDFF Verspreidingsatlas 2016, Stace 2015). However, it is unknown if this reproduction was vegetative or sexual. No information was found on the reproduction of the species in Belgium, Germany and France during the literature search.

S. pectinata has probably established as a garden escape at most sites where it has been recorded in Europe. Most sites in Europe are probably mono-clonal because only a limited number of clones are traded in the EU. Seed set on these sites will probably be low due to self-incompatibility and protogynous flowering (stigmas exerted prior to anthers), assuming the clones are not apomictic.

S. pectinata is known as a polyploid species in its native range, comprising three ploidy levels with tetraploids (2n = 40), hexaploids (2n = 60), and octoploids (2n = 80) based on a chromosome number of 10. Tetraploid populations extend from the north-east central to north-eastern regions of the USA, while the octoploid cytotypes occupy the north-western part of this range (Kim 2012). It is unclear whether seed set can result from self-pollination or from apomixes. Further studies examining potential self-compatibility and potential apomixis within various *S. pectinata* strains are underway (Gedye et al. 2012).

Life cycle

S. pectinata is a perennial plant. The roots develop very rapidly and their growth rate is only exceeded by those of cultivated crops. Growth is limited by the exceedingly strong competition for light, water, and nutrients that occurs in undisturbed grassland, but development is very rapid in disturbed areas where the sod formed by roots and rhizomes is broken. Under these conditions the roots of seedlings may reach a depth of 1.2 m at the age of three months, a growth rate of 2.5 cm per day.

Tillers appear when the plant is four to five weeks old. Simultaneously, adventitious roots develop that supply these tillers with water and nutrients. Once the plant has fully grown, the roots can remain functional for many years.

The development of shoots from perennial sod is also rapid. The foliage reaches a height of 60 to 90 cm by the beginning of June, and often reaches heights of 150 to 210 cm in midsummer. The leaves turn yellow in autumn.

Flowering stalks do not appear until the plant is at least two years old. The plant flowers from June to October, but the maximum floral production occurs in August and September. During the growing season, the stems become woody and coarse (Weaver 1954, US Forestry Service 2016).

S. pectinata features awned spikelets that cling to the fur of animals or clothing facilitating seed dispersal to new locations (Illinois Wildflowers 2016).

S. pectinata produces rhizomes that facilitate establishment in suitable habitats. In North America, reproduction from rhizomes can produce dense stands resulting in complete coverage. Few, if any other plant species are found in these dense stands. To date, dense monospecific stands have not been described in Europe, however, the species is reported to be expanding at some European sites (see §2.3).

In conclusion, characteristics that may facilitate the establishment of *S. pectinata* are rapid growth, vegetative reproduction from rhizomes, and an ability to compete which leads to the production of dense stands in which almost no other plants are found.

2.2 Probability of introduction

S. pectinata is sold in garden centres and is planted as an ornamental plant in gardens and public green areas (Plantago 2016). The species was first recorded in Ireland in 1967, in Great Britain in 1970, in Germany in 1982, in Belgium in 1996, in the Netherlands in 2007, and in France in 2015. The first adventitious records in the Netherlands date from 2007, but some observers state that the species must have been present for a longer period at several locations (NDFF Verspreidingsatlas 2016). Most of these records seem to have originated from garden escapes (Dirkse et al. 2007, Alien Plants Belgium 2016, Online Atlas of the British and Irish Flora 2016, Floraweb 2016, Stace 2015).

New introductions are likely to occur as *S. pectinata* is sold in garden centres in many European countries. The cultivar *S. pectinata* 'Aureomarginata' (syn. *S. pectinata* 'Variegata') is particularly popular. The results of our Google search show that the species is sold in Belgium, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Italy, Lithuania, the Netherlands, Poland, Serbia and the United Kingdom (Appendix 3).

Quantitative figures on trade of *S. pectinata* are not available. The species is traded in relatively small volumes at two large Dutch trade centres (FloraHolland, Aalsmeer; Plantion, Ede). Figures on the volume traded and the market value of *S. pectinata* are not recorded separately. The species is allocated together with other garden plants to the category “other plants”. The species is not listed among the top 25 most popular retail species by the international market leader FloraHolland (FloraHolland 2014) meaning that less than 2 million units are sold for less than €4 million yearly by FloraHolland.

Biomass production trials indicate that *S. pectinata* has a high potential for biomass production (Boe et al. 2009, Matthews et al. 2015). However, no European data relating to the areas cultivated with this species as a bioenergy crop could be found. According to Alien Plants Belgium (2016), *S. pectinata* has not yet been grown in biomass production trials in Belgium.

2.3 Probability of establishment

2.3.1 Current global distribution

S. pectinata is native to Canada, the USA and Mexico (USDA 2016, US Forestry Service 2016). The introduced range of the species extends to Australia and several countries in north-western Europe. The species is included in the list of species introduced to Australia. According to Randall (2007), the species is not naturalised here. In contrast, USDA-ARS (2016) state that the plant is naturalised in Australia. Figure 2.4 shows the global distribution of *S. pectinata.*

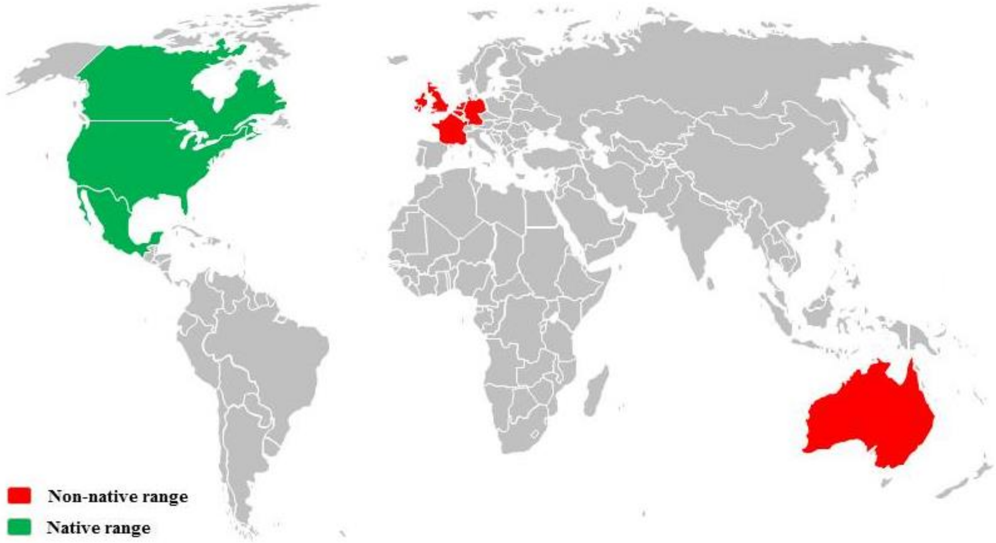


Figure 2.4: Global distribution of Prairie cordgrass (*Spartina pectinata*). Entire countries or states are coloured based on published records (Sources: USDA 2016, US Forestry Service 2016, GBIF 2016, DAISIE 2016, NDFF Verspreidingsatlas 2016, Randall 2007).

2.3.2 Current distribution in the EU

S. pectinata has been recorded in the Netherlands, Belgium, Germany, France, Great Britain and Ireland (GBIF 2016, NDFF Verspreidingsatlas 2016, DAISIE 2016). According to DAISIE (2016), the species is alien and established in Germany, Great Britain and Ireland, and alien but not established in Belgium. Only a few populations are recorded in these countries. Most populations seem to have resulted from escapes from cultivation (Alien Plants Belgium 2016, Online Atlas of the British and Irish Flora 2016, Floraweb 2016, Stace 2015). In Germany, records have been made in Bayern, Hessen, Brandenburg and Thüringen (Floraweb 2016, Flora-de 2016). On the British Isles, persistent and growing populations have been observed along the banks of a fresh water lake near Costello Lodge in County Galway (Ireland) since 1967, near a lake at Seaton Burn in South Northumberland since 1970, and in a quarry in North Hampshire since 1986 (Scannel & Jebb 2000, Stace 2015, Cope & Gray 2009). The species was probably first seen in Belgium in 1996 at an industrial area in Sint-Truiden, and has also been recorded at Hingene in 2000 and Oudenaarde in 2005. In the Netherlands, the species has been recorded at five locations since 2007 (NDFF Verspreidingsatlas 2016) and is increasing in at least two of these locations (Dirkse et al. 2007). The species probably arrived here as a result of planting or the dumping of garden waste contaminated with root fragments. One population of *S. pectinata* was recorded in 2015 in the French department of Tarn (Tela Botanica 2016, GBIF 2016).

2.3.3 Habitat description and physiological tolerance

Habitats

S. pectinata is usually found in wetlands and occasionally in other habitat types (Hansen et al. 1988, US Forestry Service 2016). The species grows around ponds and on the wet banks of slow flowing streams (Weaver 1960b). The plant has also been recorded on low-lying, poorly drained soils of wet prairies and alkaline fens, floodplains, till plains (Betz 1978, Weaver 1960a, US Forestry Service 2016), along prairie drainage channels and around prairie marshes (US Forestry Service 2016). *S. pectinata* may also be found in roadside ditches, low-lying areas along railroads, along field edges, and in poorly drained areas of vacant lots (Encyclopaedia of Life 2016). *S. pectinata* grows on the upland edges of salt marshes in the coastal regions of the north-eastern part of the USA. This zone is only incidentally flooded during extreme astronomical tides or by wind driven tidal inundations (Drociak 2005).

In the eastern part of its native range, *S. pectinata* is associated with tall rushes (*Scirpus* spp.), reed grasses (*Phragmites* spp.), sedges (*Carex* spp.), Canada wildrye (*Elymus canadensis*) and Switchgrass (*Panicum virgatum*) (Weaver 1960b, US Forestry Service 2016). On the upland edge of salt marshes it is accompanied by plant species such as *Phragmites australis*, *Convolvulus sepium*, *Panicum virgatum*, *Myrica pensylvanica*, *Solidago sempervirens*, *Toxicodendron radicans* and *Rosa rugosa* (Drociak 2005).

In its native range, *S. pectinata* colonizes wetlands and the banks of rivers and streams. Some of the European versions of these habitats are vulnerable and protected by the European Habitat Directive. It is not clear in which natural habitats *S. pectinata* will establish within Europe. The coastal regions where *S. pectinata* grows in the north-eastern part of the USA is probably comparable with EU habitat 6430: Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels. Prairie habitats are probably comparable with relatively moist areas within EU habitat 6250 Pannonic loess steppic grasslands.

Light and temperature

S. pectinata seeds germinate readily in wet soil, which is followed by rapid seedling development (Weaver 1954, US Forestry Service 2016). The seedlings are shade-intolerant and only establish on areas of bare ground (Weaver 1954, US Forestry Service 2016). Optimum temperatures for germination have been reported to range from 20 °C at night to 30 °C during day time (Eddleman & Meinhardt 1981, US Forestry Service 2016) (Table 2.2.). In greenhouse experiments, seedlings tolerated moisture stress conditions with high survival for up to four weeks but with reduced growth rate (Eddleman & Meinhardt 1981, US Forestry Service 2016). *S. pectinata* rhizomes are tolerant of cold winter conditions. At an experimental field site in Ontario (Canada) winter temperatures corresponding to 50% rhizome mortality (LT50) in November and February was near -24 °C and in late April -10 °C (Friesen et al. 2015). Moreover, *S. pectinata* leaves remained viable to -9 °C (Friesen et al. 2015).

Soil

S. pectinata tolerates most soil textures from fine clays to silt loams, and is tolerant of high groundwater levels but intolerant of prolonged flooding (Hansen et al. 1988, US Forestry Service 2016). The plant has been recorded at elevations of 640 to 2,134 m in the USA (Dittberner & Olson 1983, US Forestry Service 2016).

Table 2.2: Physiological conditions tolerated by *Spartina pectinata*.

Parameter	Data origin	Occurrence	References
Temperature (germination optimum °C)	Greenhouse	20-30	Eddleman & Meinhardt (1981) US Forestry Service (2016)
Temperature (LT50 November and February °C)	Canada	-24	Friesen et al. (2015)
Temperature (LT50 April °C)	Canada	-10	Friesen et al. (2015)
Altitude (m)	USA	640-2134	Dittberner & Olson (1983); US Forestry Service (2016)
Soil texture	North America	fine clays to silt loams	Hansen et al. (1988); US Forestry Service (2016)

Species associations

The larvae of the moth *Aethes spartinana* (Lepidoptera, Tortricidae) feed on *S. pectinata* in its native range. The larvae bore through the glumes and feed on the florets inside. A single larva generally feeds on a series of consecutive spikelets. In a later stage they tunnel into the stem. Other oligolectic moths (Noctuidae) that feed on *S. pectinata* are *Resapamea stipata*, *Photedes enervata* and *Photedes inops* (Prasifka et al. 2012).

Several species of leafhoppers (Hemiptera, Cicadellidae) feed on *S. pectinata*: *Destria fumidus*, *Neohecalus magnificus* and *Cicadula smithi*. Other insect species that feed on *S. pectinata* include: *Ischnodemus falicus* (Hemiptera, Lygaeidae), *Trigonotylus tarsalis* (Hemiptera, Miroidea), *Sphenophorus pertinax* (Coleoptera, Curculionoidea), *Pseudopomala brachyptera* (Orthoptera, Acrididae) and *Haplothrips shacklefordi* (Thysanoptera, Phlaeothripidae) (Illinois Wildflowers 2016).

The rhizomes of *S. pectinata* are eaten by Canada goose (*Branta canadensis*) and Muskrat (*Ondatra zibethicus*). The seed heads of the plant are occasionally eaten by

Black duck (*Anas rubripes*), Mallard (*Anas platyrhynchos*), and other ducks (Illinois Wildflowers 2016).

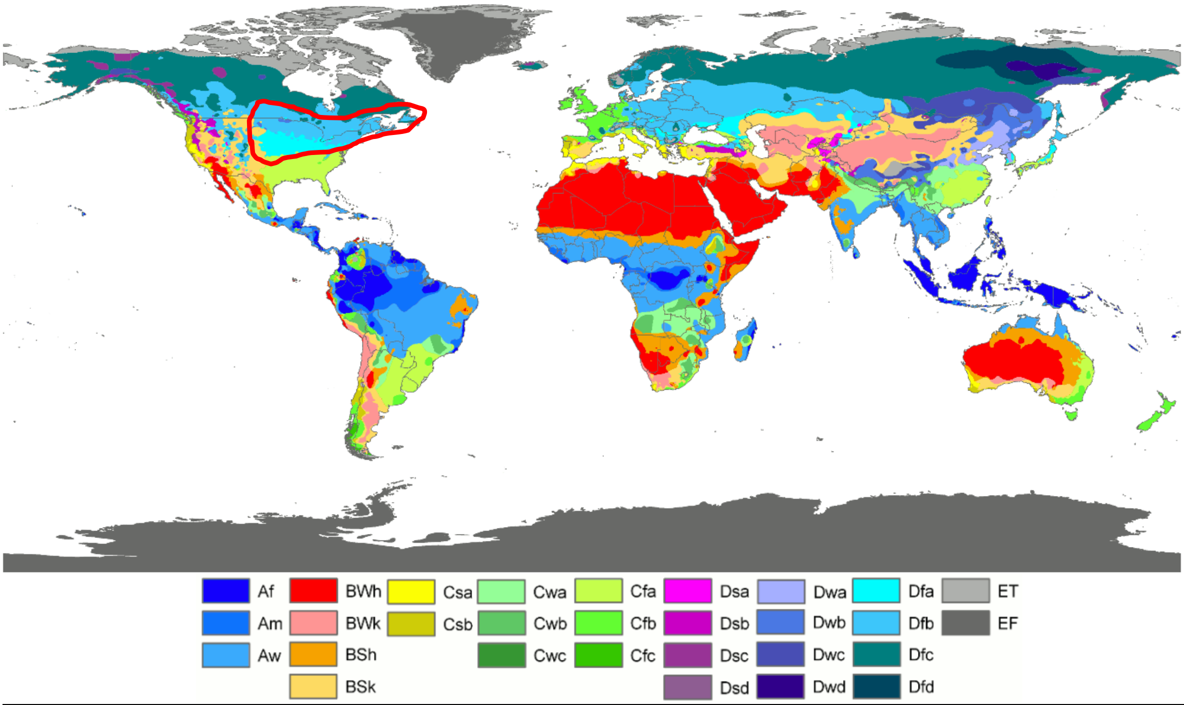
The rust fungi *Puccinia seymouriana* and *Puccinia sparganioides* occur on *S. pectinata* in the USA and Canada (Davelos et al. 1996).

2.3.4 Climate match and bio-geographical comparison

The core area of the native range of *S. pectinata* matches with the following Köppen-Geiger regions (Figure 2.5):

- **Dfa** - *Humid continental hot summer, wet all year*: mid and north-eastern USA;
- **Dfb** - *Humid with severe winter, no dry season, warm summer*: north-eastern USA, mid and south-eastern Canada;
- **Bsk** - *Dry Semiarid (Steppe), average temperature less than 18 °C*. Prairie zone in mid-western USA.

In addition, the **Cfa** region is included in the native range (*mild with no dry season, hot summer, subtropical*; south-eastern USA), but the species is more sparsely distributed here. This climate region is not present in Europe, but there is a climate match to a certain extent with the European **Cfb** region (warm instead of hot summer), that covers Western Europe: France, Belgium, the Netherlands, UK, Ireland, Denmark, northern Spain and Portugal, and the western part of Germany.



Main climate		Precipitation		Temperature		
A: equatorial	D: snow	W: desert	s: dry summer	h: hot dry	b: warm summer	f: polar frost
B: dry	E: polar	S: prairie	w: dry winter	k: cold dry	c: cool summer	t: polar tundra
C: warm		f: fully humid	m: monsoon system	a: hot summer	d: extremely continental	

Figure 2.5: Climate zones according to the Köppen-Geiger climate classification (Adapted from Peel et al. 2007). The core area of the native range of *S. pectinata* is circled in red.

Dfa, **Dfb** and **Bsk** climate regions also occur in Europe. Region **Dfb** covers southern Scandinavia (southern Sweden and central Norway) and a large part of Eastern Europe. Region **Dfa** covers relatively small parts of Eastern Europe and region **Bsk** covers parts of Spain. The **Dfa** and **Bsk** regions match with the Steppic biogeographic region of Europe (Figure 2.6). Eastern and south-eastern Europe feature the most extensive climate match with *S. pectinata*'s native range.

The European garden flora hardiness code applicable to *S. pectinata* is H2 (Walters et al. 2003), indicating that the species is hardy to -15 to -20 °C and is, therefore, able to withstand central European winters (Figure 2.7).

Figure 2.8 shows locations of suitable habitats for *S. pectinata* in the climate regions Dfb, Dfa and Bsk in the EU. These climate regions match the core area of the native range of the species in North America (Figure 2.5). The Natura 2000 habitat types in which *S. pectinata* is most likely to establish are 6430 (Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels) and 6250 (Pannonic loess steppic grasslands; §2.3.3). The risk of establishment of *S. pectinata* is highest in these locations and they could, therefore, be considered to be the most endangered areas in the EU. The potential high risk areas are quantified in Table 2.3.

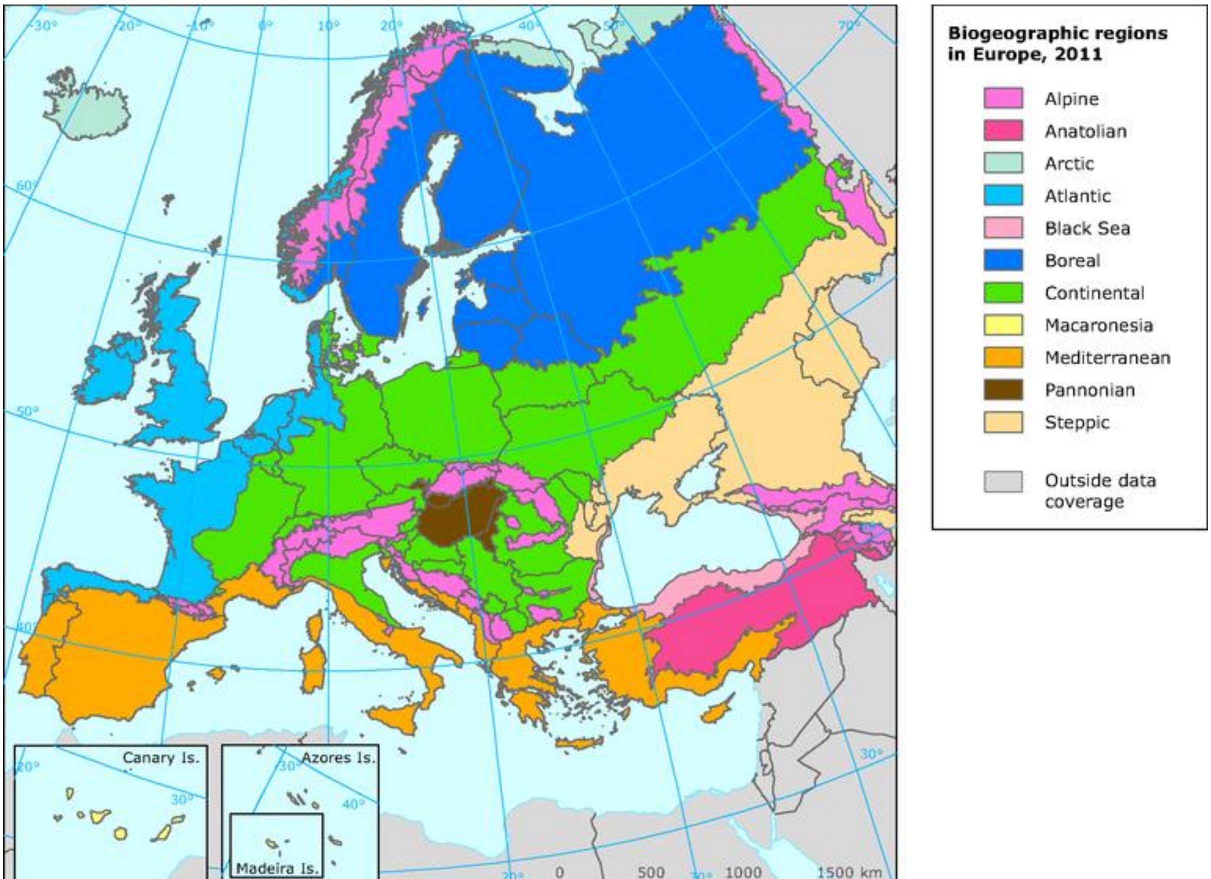


Figure 2.6: Biogeographic regions in Europe (European Environment Agency 2012).

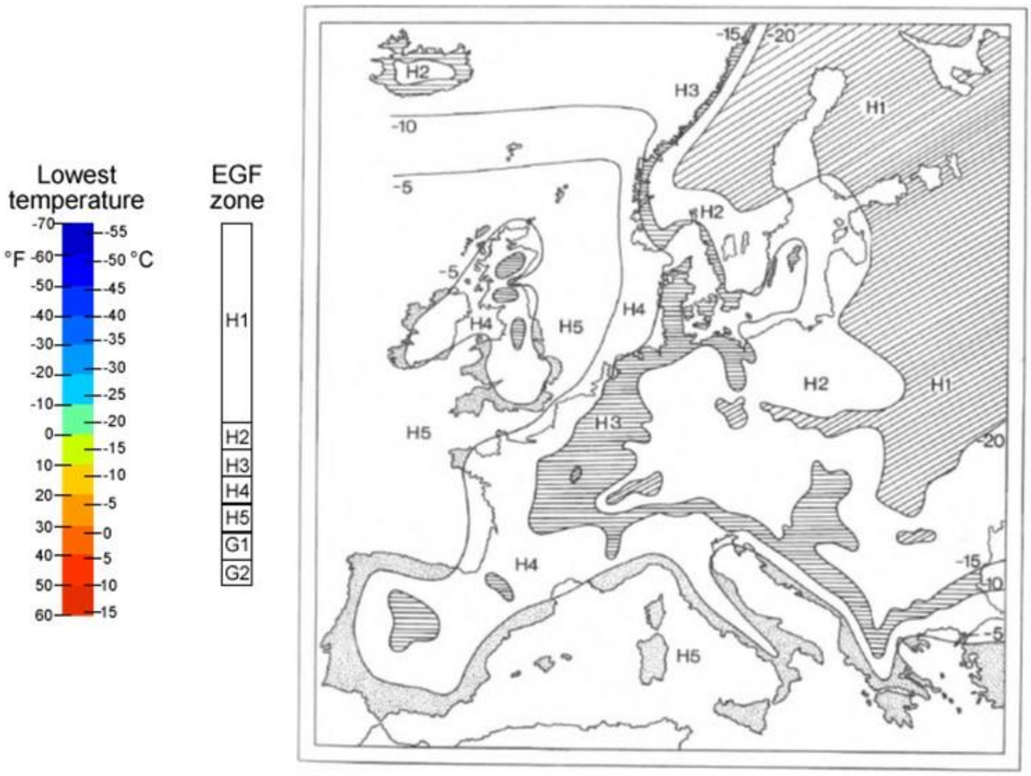


Figure 2.7: Minimum temperatures tolerated by plant species classified under the European Garden Flora (EGF) zones (left) and mean minimum January isotherms for Europe (hardiness codes; right) (Grey-Wilson 2011, Cullen et al. 2011).

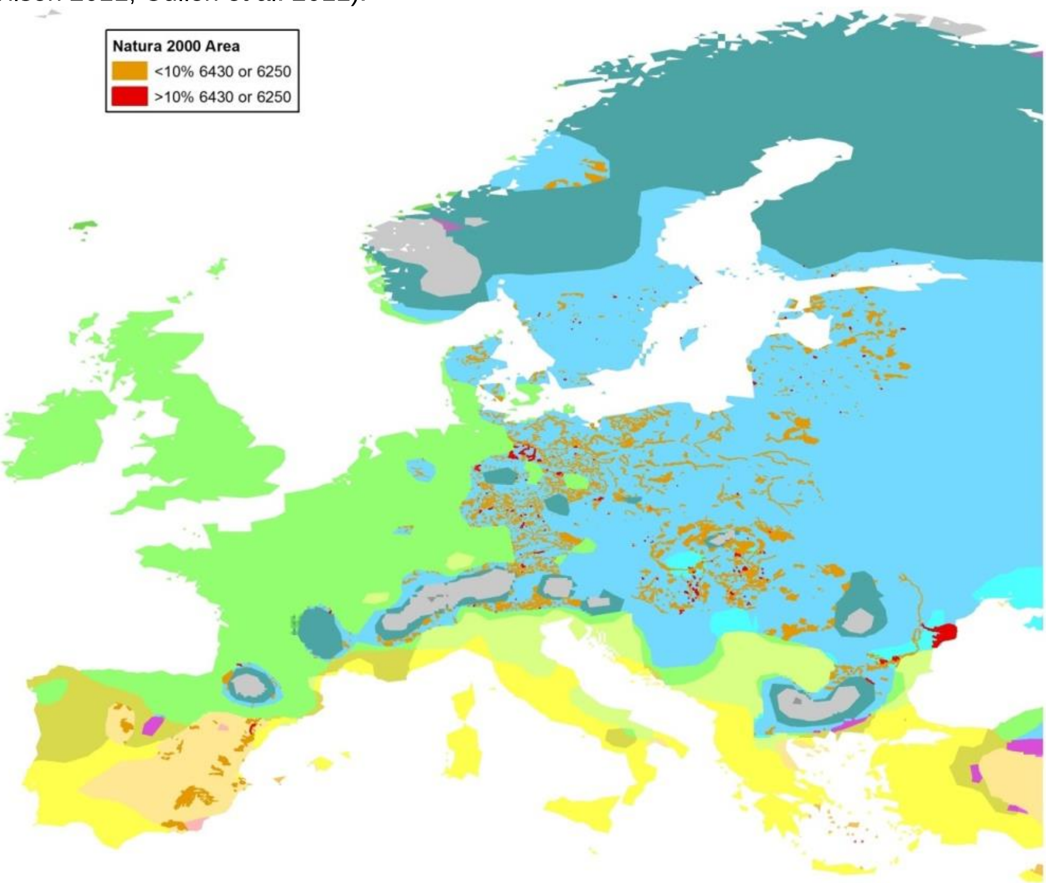


Figure 2.8: Presence of habitat types 6430 or 6250 in Natura 2000 area's within the Köppen-Geiger climate zones Dfb (blue), Dfa (sea blue) and Bsk (camel) (Köppen-Geiger map: Peel et al. 2007b; Natura 2000 database and shapefile: European Environment Agency 2015).

Table 2.3: Estimated potential area of Natura 2000 habitats (km^2) in which *Spartina pectinata* could establish in the EU derived by matching Natura 2000 habitats 6430 and 6250 with the Köppen-Geiger climate zones Dfb, Dfa and Bsk (European Environment Agency 2015, Peel et al. 2007b)[a].

Country	Bsk	Dfa	Dfb	Country	Dfa	Dfb
Bulgaria		644	1974	Italy		6997
Czech Republic			3959	Lithuania		1295
Germany			11035	Luxembourg		13
Denmark			1538	Latvia		5828
Estonia			5348	Netherlands		1
Spain	14654		740	Poland	<1	23106
Finland			476	Romania	1835	12270
France			1539	Sweden		5247
Greece		29	331	Slovenia		723
Hungary		546	10149	Slovakia	1641	8112

[a] No information was available for Austria.

Endangered areas

Based on current climatic conditions and habitat requirements, *S. pectinata* could establish EU member states, in particular in central and eastern member states. The most endangered areas are different types of wetland and poorly drained soils, like hydrophilous tall herb fringe communities (Natura 2000 habitat type 6430) and Pannonic loess steppic grasslands (habitat type 6250; §2.3.3) in Austria, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Italy, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia, Sweden, and Spain (Table 2.3). Greece, United Kingdom, Ireland, Finland, Belgium, the Netherlands and Portugal are on the limit of the area of potential establishment according to climate. When (summer) temperature increases due to climate change, the potential area of establishment will expand northward (Finland, Sweden) and westward (Belgium, France, Germany, The Netherlands).

2.3.5 Influence of management practices

S. pectinata has a high resistance to grazing, but decreases in biomass may occur with intensive application. *S. pectinata* is usually grazed during the spring, before the plant stems become coarse and woody, or in the autumn after other foraging material has dried. Late autumn grazing at moderate stocking rates of 2.2 animals per ha induces an increase in biomass. The species is often cut for hay before it becomes coarse. Cutting two or three times a year prevents coarseness (US Forestry Service 2016).

S. pectinata features deep rhizomes that allow it to survive fires. Survival is increased if burning occurs during the wet season because of water that is present on the topsoil. Fires occurring in dry stands of this grass are hot enough to kill any trees or shrubs. *S. pectinata* stands with accumulated litter are very fire prone. In south-western Minnesota four successive years of annual burning, with low to moderate intensity from mid to late April, caused an increase in cover of *S. pectinata* (US Forestry Service 2016).

2.4 Pathways and vectors for dispersal

2.4.1 Dispersal potential by natural means

Natural dispersal occurs by sexual or vegetative means. The awned spikelets with seeds can be dispersed in the fur of animals (Illinois Wildflowers 2016, US Forestry Service 2016). No information was found on other modes of dispersal, but dispersion in running water seems likely.

2.4.2 Dispersal potential by human assistance

S. pectinata is planted as an ornamental in gardens and may be used for biomass production trials (Table 2.4). Most records of *S. pectinata* in Europe originate from garden escapes (Alien Plants Belgium 2016, Online Atlas of the British and Irish Flora 2016, Floraweb 2016, Stace 2015, Dirkse et al. 2007). The seeds are also dispersed following attachment to clothing (Illinois Wildflowers 2016).

Table 2.4: Active (A) and potential future (F) pathways and vectors which contribute to the spread of *S. pectinata* in the European Union.

Category	Subcategory [a]	A	F	Examples and relevant information	Reference [b]
Escape from confinement	2.1 Agriculture (including biofuel feedstocks)	?	X	The species might be used for biomass production trials	1-4
Escape from confinement	2.9 Ornamental purposes other than horticulture	X	X	The species has been planted in gardens and public green areas	1-3

[a] As described by UNEP (2014); [b] 1. Cope & Gray (2009), 2. Stace (2015), 3. Alien Plants Belgium (2016), 4. Scannel & Jebb (2000).

2.5 Impacts

2.5.1 Environmental effects: biodiversity and ecosystems

S. pectinata has a stiff stem and vigorous rhizomes that enable it to provide good shoreline cover, and contribute to wave energy dissipation. The species tolerates moderate cover up of its stands with soil deposits, as the pointed shoots can push their way through 30 cm of sand or silt deposits (US Forestry Service 2016).

In its native range, *S. pectinata* is able to develop dense coverage locally and to outcompete other plant species (Encyclopaedia of Life 2016, Weaver 1960b, US Forestry Service 2016). According to CABI (2016), *S. pectinata* is not invasive anywhere in the world. However, according to Matthews et al. (2015), *S. pectinata* poses a potentially high ecological risk.

S. pectinata colonizes wetlands and the banks of rivers and streams in its native range. Many of the European equivalents of these habitats are vulnerable and are protected by the Habitat Directive in Europe. Many rare and vulnerable species depend on these habitats. Although *S. pectinata* has not been recorded in N2000 areas or other protected or vulnerable areas within Europe, the species is likely to have effects once it is introduced and records indicate that the population is increasing. *S. pectinata* may outcompete native species in the event that it develops dense coverage in Europe.

Eastern and south-eastern Europe feature the most extensive climate match with *S. pectinata*'s native range (§2.3.4). It is likely that the species will thrive better in these areas once it is introduced.

In the USA, thick stands of *S. pectinata* occur around marshes, providing good cover for game and song birds, and small mammals. The plant also provides shade and refuge for larger wildlife (US Forestry Service 2016).

S. pectinata hybridizes with *S. patens* on the east coast of the USA and Canada forming the hybrid species *Spartina x caespitosa* A.A. Eaton (Mcdonnell & Crow 1979). When growing in coastal habitats hybridization of *S. pectinata* (2n=40, 60 or 80) with other European *Spartina* species, such as *S. anglica* or *S. maritima,* probably cannot be ruled out completely. In the past, native American *S. alterniflora* (2n=62) hybridized with European *S. maritima* (2n=60) producing the sterile hybrid *S. x townsendii* (2n=62). Subsequently, *S. x townsendii* transformed into the fertile allopolyploid *S. anglica* (2n=120, 122, 124) following chromosome doubling (Cope & Gray 2009, IPCN 2016). As a result, *S. anglica* outcompeted and replaced the native *S. maritima* on West European coasts.

2.5.2 Effects on cultivated plants

S. pectinata is known as an agricultural weed in Australia (Randall 2007), but no further information regarding the effects of this species on cultivated plants in Australia or any other countries was found in the available literature.

2.5.3 Effects on domesticated animals

No information regarding effects of *S. pectinata* on domesticated animals was found in the available literature.

2.5.4 Effects on public health

No information regarding effects of *S. pectinata* on public health was found in the available literature.

2.5.5 Socio-economic effects

No information regarding negative socio-economic effects of *S. pectinata* was found in the available literature. It is likely that costs will be incurred in the event that the species is introduced to protected habitats and becomes invasive. There are no European management plans available as yet.

Table 2.5. Effects of *S. pectinata* on ecosystem services (+ = positive effect, - = negative effect, 0 = no effect, ND = no data).

Service	Sub-category	Effect
	Provisioning Services	
Food	Crops	0
	Livestock	0
	Capture fisheries	0
	Aquaculture	0
	Wild plant and animal food products	0
Fibre	Timber	0
	Cotton, hemp, silk	+
	Wood fuel	+
Genetic resources		0
Bio-chemicals, natural medicines, and pharmaceuticals		ND
Fresh water		0
	Regulating Services	
Air quality regulation		0
Climate regulation	Global	0
	Regional and local	0
Water regulation		0
Erosion regulation		+
Water purification and waste treatment		0
Disease regulation		0
Pest regulation		0
Pollination		0
Natural hazard regulation		+
	Cultural Services	
Cultural diversity		0
Spiritual and religious values		0
Knowledge systems		0
Educated values		0
Inspiration		0
Aesthetic values		-
Social relations		0
Sense of place		0
Cultural heritage values		0
Recreation and ecotourism		0
	Supporting services	
Soil formation		+
Photosynthesis		0
Primary production		+
Nutrient cycling		0
Water cycling		0

2.5.6 Effects on ecosystem services

The potential effects of *S. pectinata* on ecosystem services are summarized in Table 2.5. Due to lack of information, these scores are mainly based on the best professional judgement of the authors.

Provisioning services
No evidence of the species being used as food for humans or livestock was found in available literature. No data was found on any plant contents of *S. pectinata* that can be used as bio-chemicals, natural medicines, or pharmaceuticals. However, the species may possibly be used to produce fibre, and may be used as a biomass crop for fuel (Matthews et al. 2015).

Regulating services
S. pectinata has proven useful in preventing erosion on earth fill dams, spillways and drainage channels in North America (Cope & Gray 2009, USDA NRCS 2016a). In this respect, the species may regulate natural hazard, e.g. by preventing erosion due to flooding and waves.

Cultural services
The species may have a negative effect on aesthetic values of the vegetation or landscape if it changes the characteristics of vegetation by forming dense mono-specific stands and outcompetes native (flowering) plants.

Supporting services
S. pectinata may have a positive effect on soil formation by increasing sedimentation, although the natural vegetation of the invaded habitat may often have a dense vegetation structure as well. In some situations the species may be more productive than the natural vegetation and thereby increase primary production. However, no data on these issues was found during the literature search.

2.5.7 Influence of climate change on impacts
No information regarding the influence of climate change on impacts was found in the available literature.

2.5.8 Positive effects
S. pectinata is a potential biomass crop (Matthews et al. 2015). The species has proven useful in preventing erosion on earth fill dams, spillways and drainage channels in North America (Cope & Gray 2009, USDA NRCS 2016a). Therefore, the species may regulate natural hazard (e.g., by preventing erosion due to flooding and waves).

3. Risk assessment

3.1 Risk assessment and classification with the Harmonia+

3.1.1 Classification for the current situation

Table 3.1 presents an overview of the risk assessment of *S. pectinata* with the Harmonia+ protocol. The expert team exchanged arguments for the risk scores and came to a consensus. Evidence for this risk classification is explained in more detail in the following paragraphs.

Species introduction

To date, the species has been recorded outside gardens and public green areas in at least six countries in the EU and is sold in at least fourteen EU member states. The probability of new introductions of individuals of *S. pectinata* into the wild of EU member states from outside the EU via natural pathways within the time span of a decade is scored as low. Introductions via natural pathways are expected to occur less than once every 30 years, because other, non EU, native and introduced ranges exist in North America and Australia. The probability for the species to be introduced into the EU's wild from outside the EU by unintentional human actions is also scored as low (≤ 1 event expected per decade), as it is highly unlikely that the species will enter the EU via activities like earth-moving. There is no evidence of introductions of *S. pectinata* into the wild by intentional human actions. Therefore, experts judged the probability of introduction based on the present-day occurrence in EU member states. The probability that the species will be introduced into the EU's wild from outside the EU by intentional human actions is scored medium (between 1 and 9 events per decade).

Establishment

Both climate and habitat are scored as optimal for establishment, in particular in central and eastern EU member states. The climatic requirements of the species are expected to be fully met in a large part of the EU as the species' native range (North America, including Canada) and a large part of the EU are in the same climate zones (§2.3.4). Rhizome mortality was 50% (LT50) at an experimental field site in Ontario, Canada with temperatures near -24 °C in November and February, and -10 °C in late April. In addition, *S. pectinata* leaves remained viable to -9 °C. Thus, winter temperature does not limit the species' propagation and growth in the EU. The habitat requirements of the plant are also expected to be fully met because in its native and introduced range, *S. pectinata* grows in different types of wetlands and poorly drained soils of most textures from fine clays to silt loams.

Table 3.1: Consensus risk scores for *Spartina pectinata* with the confidence levels for both the current and future situation in the European Union with the Harmonia[+] protocol.

Risk category	Risk	Confidence
Context		
A01. Assessor(s)	**Consensus scores of six experts**	
A02. Species name	**Prairie cordgrass (*Spartina pectinata*)**	
A03. Area under assessment	**European Union**	
A04. Status of species in area	**Alien and established within the area's wild**	
A05. Potential impact domain	**Environmental domain**	
Risk category	**Risk**	**Confidence**
Introduction		
A06. Probability of introduction by natural means	Low	High
A07. Probability of introduction by unintentional human actions	Low	High
A08. Probability of introduction by intentional human actions	Medium	Medium
Establishment		
A09. Climate for establishment	Optimal	High
A10. Habitat for establishment	Optimal	High
Spread		
A11. Dispersal capacity within the area by natural means	Low	Medium
A12. Dispersal capacity within the area by human actions	High	Medium
Impacts: environmental targets		
A13. Effects on native species through predation, parasitism or herbivory	Inapplicable	High
A14. Effects on native species through competition	High	High
A15. Effects on native species through interbreeding	Low	Medium
A16. Effects on native species by hosting harmful parasites or pathogens	Low	Medium
A17. Effects on integrity of ecosystems by affecting abiotic properties	High	Medium
A18. Effects on integrity of ecosystems by affecting biotic properties	High	Medium
Impacts: plant targets		
A19. Effects on plant targets through herbivory or predation	Inapplicable	High
A20. Effects on plant targets through competition	Low	Medium
A21. Effects on plant targets through interbreeding	Inapplicable	High
A22. Effects on integrity of cultivation systems	Low	Medium
A23. Effects on plant targets by hosting harmful parasites or pathogens	Low	Medium
Impacts: animal targets		
A24. Effects on animal health or production through parasitism or predation	Inapplicable	High
A25. Effects on animal health or production by properties hazardous upon contact	Very low	High
A26. Effects on animal health or production by parasites or pathogens	Inapplicable	High
Impacts: human health		
A27. Effects on human health through parasitism	Inapplicable	High
A28. Effects on human health by properties hazardous upon contact	Very low	High
A29. Effects on human health by parasites or pathogens	Inapplicable	High
Impacts: other targets		
A30. Effects by causing damage to infrastructure	Very low	High
Ecosystem services		
A31. Effects on provisioning services	Moderately positive	Medium
A32. Effects on regulation and maintenance services	Moderately positive	Medium
A33. Effects on cultural services	Moderately negative	Medium
Effects of climate change		
A34. Introduction	No change	Medium
A35. Establishment	Increase moderately	Medium
A36. Spread	No change	Medium
A37. Impacts: environmental targets	No change	Medium
A38. Impacts: plant targets	No change	Medium
A39. Impacts: animal targets	No change	Medium
A40. Impacts: human health	No change	Medium
A41. Impacts: other targets	No change	Medium

Spread

The capacity of *S. pectinata* to disperse within the EU by natural means is scored low. This score is allocated because the species does not easily disperse over larger distances, the production of viable seed in the EU is probably low and, similarly to North America, the primary mode of reproduction in the EU will be vegetative. *S. pectinata*'s high capacity for vegetative reproduction will enable the species to invade habitats where it is planted or stowed away as garden waste. The probability for the species to be spread by human actions, like disposal of garden waste, is scored high (more than 10 events per decade). This score is given due to the historical introductions and present-day occurrence of *S. pectinata* in EU member states, and its popularity in garden centres in many European countries. This score was, however, allocated with medium confidence, as there are no data on the volume of trade of *S. pectinata* or on the number of events of spread that occur as a result of dumping of the species as garden waste.

Environment: biodiversity and ecosystems

The criterion for effects of *S. pectinata* on native species, through predation, parasitism or herbivory is inapplicable. The effects on native species through competition are scored high. This is with respect to the species' rapid growth rate and its ability to form dense mono-specific stands and thus significantly limit the growth and alter the habitat conditions of native plant and animal species. These effects may be similar to those of *S. anglica*, which has outcompeted and replaced native *S. maritima* in West European coastal habitats (§2.5.1). The potential for effects through interbreeding with native *Spartina* species is allocated a low risk score since *S. maritima* is almost extinct and only occurs along the coast in Western Europe. However, hybridization of *S. pectinata* with other European *Spartina* species if it were to grow in coastal habitats cannot be ruled out completely. This risk was scored with medium confidence due to data deficiency for the EU. The species is expected to have a low effect on native species through the hosting of pathogens or parasites that are harmful to them. This classification was assessed with a medium level of confidence as no information on this issue was found in the available literature.

If it is assumed that *S. pectinata* becomes widespread in the EU, the risk of adverse effects on ecosystem integrity through impacts on abiotic and biotic properties is estimated to be high. *S. pectinata* has the ability to outcompete native herb and grass species and is able to form dense mono-specific stands. This will change the species composition, and possibly also the vegetation structure and microclimate of habitats. Although dense stands are also formed by native species in vegetation types in which *S. pectinata* can potentially become invasive, such a change in species composition caused by the alien *S. pectinata* will likely have a negative effect on the presence of host plants for native herbivores. The species can form dense stands and roots deeply making these changes difficult to reverse. A medium level of confidence was allocated to the risk scores relating to effects on the abiotic and biotic properties of ecosystems due to a lack of data on these issues. These risks have been estimated mainly by applying the best professional knowledge of the expert panel.

Plant crops
The consequences of *S. pectinata* invasion on plant crops, pastures and horticultural stock through herbivory, parasitism and interbreeding are inapplicable. Competition of *S. pectinata* is expected to have a low effect on the integrity of cultivation systems. This classification was assessed with a medium level of confidence. No details were found in the available literature on this aspect. The risk of effects to cultivated plants through the hosting of pathogens or parasites that are harmful is classified as low with a medium confidence level. This is because no information on shared pathogens was found in the literature consulted during the risk inventory. If such pathogens or parasites were present, they would likely be described in literature.

Domestic animals
The effects of *S. pectinata* on domestic animals through parasitism or predation and by parasites or pathogens are not applicable. The risk of effects on animal health resulting from properties of *S. pectinata* that are hazardous upon contact is scored as very low, with a high level of confidence. No effects are expected and no information regarding the effects of *S. pectinata* on domesticated animals was found in the literature consulted during the risk inventory.

Human health
Effects on human health through parasitism and by parasites or pathogens are not applicable. The risk of effects through properties that are hazardous upon contact is scored as very low with a high level of confidence. No effects are expected and no information regarding effects on human health was found in the literature consulted during the risk inventory. If such pathogens or parasites were present, they would likely be described in literature.

Infrastructure
The risk of damage to infrastructure is scored as very low with a high confidence as no information regarding negative socio-economic effects by *S. pectinata* was found in the available literature.

Ecosystem services
In line with the risk scores provided in the modules concerning impacts on plant crops and domestic animals, effects on provisioning, regulation and maintenance (or supporting) services were scored as moderately positive, with a medium level of confidence (see §2.5.6). Effects on cultural services are considered to be moderately negative, in view of the fact that this species may change the plant species composition and structure of natural vegetation. This score was also assigned with a medium level of confidence.

Risk classification

The invasion score is classified as medium due to the medium risk of introduction and the high establishment and spread scores (Table 3.2). The overall impact is scored high due to the high impact score for environmental targets. As a consequence, the overall risk score of *S. pectinata* is classified medium.

Table 3.2: Risk classification and maximum risk scores per risk category for *Spartina pectinata* with the confidence levels in the European Union obtained using the calculation method of the Harmonia[+] protocol (Note: the risk classifications and confidence levels for the current and future situations are the same).

Risk category	Risk classification	Risk score	Confidence	Confidence score
Introduction[1]	Medium	0.50	High	1.00
Establishment[1]	High	1.00	High	1.00
Spread[1]	High	1.00	Medium	0.50
Impacts: environmental targets[1]	High	1.00	High	1.00
Impacts: plant targets[1]	Low	0.25	Medium	0.50
Impacts: animal targets[1]	Low	0.00	High	1.00
Impacts: human health[1]	Low	0.00	High	1.00
Impacts: other targets[1]	Low	0.00	High	1.00
Invasion score[2]	Medium	0.50	NA	NA
Impact score	High	1.00	NA	NA
Risk score (Invasion x impact)	Medium	0.50	NA	NA

1: maximum score per risk category; 2: introduction x establishment x spread; NA: not applicable.

3.1.2 Classification for the future situation

The expert team expects that climate change (2 °C increase by 2050 with unchanged management policies on alien species in the EU) will have no substantial effect on the ecological risks of the species. The risk of establishment may increase moderately, especially in areas where the climate match is currently sub-optimal. Therefore, the risk scores for the current and future situations are the same (Table 3.1 and 3.2).

3.2 Risk assessment and classification with the ISEIA-protocol

3.2.1 Classification for the current situation

The expert team exchanged arguments with respect to the risk scores of *S. pectinata* and came to the following consensus. The experts allocated a “medium” risk classification for the section dispersion potential and a “high” classification for the other sections (Table 3.3). The total score for the environmental risk of this species is 11, out of a maximum score of 12.

The species is currently present in isolated populations within the EU. Therefore, the species is classified as an A1 species in the BFIS list system for the current situation (Figure 3.1). According to the BFIS list system, *S. pectinata* qualifies for the black list. The evidence for this risk classification is explained in more detail in the following paragraphs.

Table 3.3: Consensus risk scores and risk assessment for Prairie cordgrass (*Spartina pectinata*) for the current and future situations in the European Union obtained using the ISEIA-protocol.

Risk category		Consensus scores
Dispersion potential or invasiveness		**2**
Colonisation of high conservation value habitats		**3**
Direct or indirect adverse impacts on native species		**3**
1. Predation/herbivory	NR	
2. Interference, exploitation competition	3	
3. Transmission of parasites and diseases	1*	
4. Genetic effects (hybridisation / introgression with natives)	1*	
Direct or indirect alteration of ecosystem functions		**3**
1. Modification of nutrient cycling or resource pools	2	
2. Physical modifications of habitat	3	
3. Modification to natural succession	2	
4. Disruption to food webs	1*	
Total score		**11**
Range of spread		**Isolated populations**
Risk Classification		**A1**

NR: not relevant; *: uncertainty due to data deficiency.

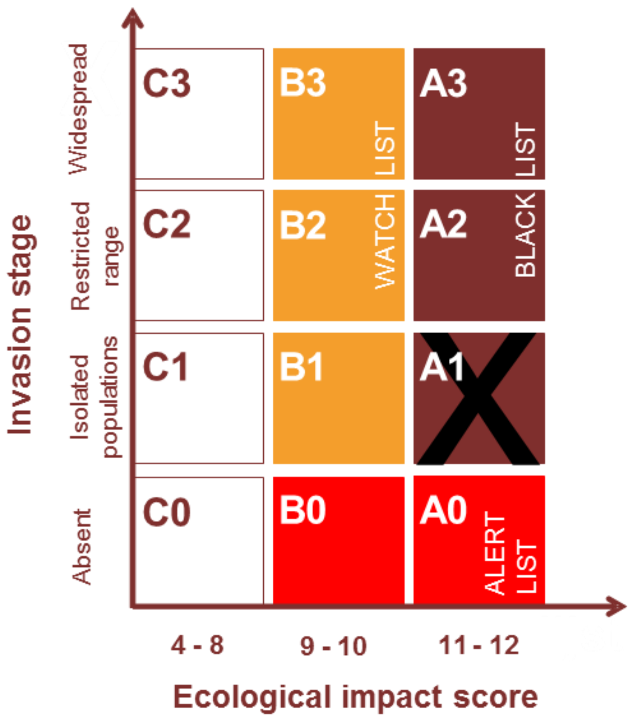


Figure 3.1: The risk classification of *Spartina pectinata* for the current situation in the European Union according to the BFIS list system.

Dispersion potential or invasiveness

Risk score 2 (**medium**). The species does not easily disperse over larger distances in the EU because the production of viable seed is probably low. However, the species has a high capacity for vegetative reproduction, temperature tolerance and has been recorded in several EU member states. Therefore, the species poses a moderate risk of dispersal and invasiveness in the EU. In its native range in North America, most reproduction occurs vegetatively through rhizome production.

Production of viable seeds is often low because of (partial) self-incompatibility and insect predation. Seedlings are shade intolerant and only establish in bare areas. Most records of *S. pectinata* in Europe are probably the result of garden escapes. *S. pectinata* is sold as ornamental plant in many European countries so new introductions from gardens to the wild are likely to occur. Most European stands of *S. pectinata* are probably mono-clonal because only a limited number of clones are traded. Seed set is probably low due to self-incompatibility and protogynous flowering.

Colonisation of high conservation value habitats
Risk score 3 (**high**). The species is able to easily invade through vegetative reproduction when source populations are present in the vicinity of high conservation value habitats that meet the species habitat requirements, or if garden waste is dumped in such habitats. In its native range, *S. pectinata* colonizes wetlands and the banks of rivers and streams. This suggests that there is a high risk of colonisation of similar high conservation value habitats in the EU, especially in south-eastern EU member states because of the better climate match and presence of suitable habitat (§2.3.4). The risk of invasion is probably higher for disturbed and species poor sites. These locations may not be designated as Natura 2000 habitat, but they may also, at the time of or following recovery from disturbance, be of high conservation value.

Adverse impacts on native species
Risk score 3 (**high**). The species can grow rapidly, forming mono-specific stands with 100% ground coverage and thus significantly limit the growth and population size of native plant and animal species, and significantly alter the habitat conditions for native species. These effects are difficult to reverse due to the depth of root development of the species. In its native range, *S. pectinata* colonizes wetlands and the banks of rivers and streams growing in dense stands and spreading over wide areas at some locations. Some European equivalents of these habitats are vulnerable and protected by the Habitat Directive in Europe (§2.3.3). The risk assessment criterion predation/herbivory is not relevant for this species, and information on genetic effects and transmission of parasites and diseases is lacking.

Alteration of ecosystem functions
Risk score 3 (**high**). The species has a high impact on ecosystem processes and structure as a result of its capacity to form mono-specific stands with 100% ground coverage over wide areas. The species will affect the nutrient cycling and resource pools of the invaded habitat, and make physical modifications of the habitat by forming dense stands thereby modifying natural succession. There is insufficient data available to assess whether the species will disrupt food webs. Resulting changes in plant species composition will likely affect the occurrence and abundance of herbivorous species, but no information was found in the available literature on the extent of this effect on the abundance, biomass or species diversity of herbivores, detritivores and higher trophic levels.

3.2.2 Classification for future situation

Similarly to the risk assessment and classification obtained using the Harmonia$^+$ protocol (§3.1), the risk scores for the current and future situation are the same. This is because climate change is not expected to affect the ecological risks of the species to a high degree. Only the risk of establishment may increase moderately, especially in western and northern EU member states, where the climate match is currently sub-optimal. Therefore, the species is classified as an A species also for the future situation in the EU.

3.3 Other available risk assessments

No formal risk assessments were discovered during the literature search. A horizon scan of biomass crops for the Netherlands concluded that *S. pectinata* has a high potential for invasiveness (Matthews et al. 2015).

4. Discussion

4.1 Classification and rating of risks

The expert team classified *S. pectinata* as an alien with a high risk of environmental impact. Although there are no data proving that the species is currently invasive and has much impact in Europe, the species has the potential to become problematic due to its high growth potential and vegetative reproduction via rhizomes. The species develops locally dense coverage in its North American native range, outcompeting other plant species. This strongly indicates that, in areas of suitable habitat, species native to the EU may be outcompeted, causing severe population declines and reductions of species richness. According to Encyclopaedia of Life (2016), *S. pectinata* may become weedy or invasive in some regions or habitats and may displace desirable vegetation if not properly managed.

Several populations of *S. pectinata* are recorded in north-western Europe. These are likely to have mainly resulted from garden escapes or improper disposal of garden waste. No data on populations in (south) eastern EU member states were found in this study. However, the climate of (south) eastern EU member states is better matched to *S. pectinata*'s native range than north-western Europe. Therefore, populations of this species are likely to be present in south-eastern European states. Moreover, new introductions are likely to occur, as *S. pectinata* is sold in garden centres in many European countries (see also Appendix 2). Most records encountered during this study feature the location (ranging between rough descriptions to detailed coordinates), date and sometimes the number of individuals only. Information about the species' habitat, vitality/viability, impacts and mode of dispersion in Europe is scarce. No information was found concerning sites of *S. pectinata* in areas of high nature conservation values, but the species has the potential to expand in high conservation value areas. Some of the current European populations are persistent and increasing in numbers of individuals. However, no invasive behaviour or other kinds of effects resulting from S. pectinata establishment have been recorded in Europe as yet. This is despite some populations being present in Europe for decades, such as the populations in Ireland and Great Britain. However, invasive behaviour may be delayed due to a time-lag of several decades that may occur between the establishment of a species and its geographic range expansion (Bean 2015).

4.2 Knowledge gaps and uncertainties

S. pectinata has the potential to become a problematic species. The European equivalent for its native habitat in the coastal regions of north-eastern USA is probably EU habitat type 6430: Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels. The relatively moist or wet areas within EU habitat type 6250 Pannonic loess steppic grasslands will probably provide a suitable habitat in Eastern Europe. The plant may also be present in high conservation value habitats. To date, *S. pectinata* has not been recorded in high conservation value habitats in Europe. No data on populations in (south) eastern EU member states were found in this study. However, the climate of (south) eastern EU member states is better matched to *S. pectinata*'s native range than north-western Europe. Populations of *S. pectinata* are likely to be present in south-eastern European states. This is because the species is offered for sale as an ornamental plant in these states and garden escapes are therefore likely. Inventory and monitoring of populations and the viability and impact of the species in these member states is lacking, or data are not published.

The propagation mode of strains introduced to the EU is unknown. It is not clear whether introduced strains are indeed self-incompatible or if self-compatible or even apomictic strains are also present. The species is considered to be self-incompatible and within a single self-incompatible clone no viable seeds will be formed. If apomictic clones are present, viable seeds can be formed within a single clone.

There are no figures available for the volume of trade of *S. pectinata* within the EU.

4.3 Management

No information was found on potential management measures for the eradication or control *S. pectinata*. The species forms deep roots and has a high vegetative reproduction capacity. Therefore, effective eradication measures should ensure that the root system is removed entirely and that the proper disposal of all plant material is carried out. However, the removal of soil and root systems has proven very ineffective in the management of other species because small parts of the root system are often missed. These subsequently develop into new plants. The impact of removal of such deep root systems on the ecosystem is huge, and may even result in improvements in habitat suitability for the species. In this situation biological or even chemical measures (systematic working agents) are far more effective, and will likely have less impact on the environment than mechanical removal (personal communication R. Pot). No information on the effectiveness of control management measures such as mowing or grazing was found during the literature survey.

5. Conclusions

Current presence in the EU

- *S. pectinata* has been recorded as established at several locations in Germany, the Netherlands, Great Britain and Ireland, and is also recorded in Belgium and France. It is currently offered for sale as an ornamental plant in many EU member states.

- As *S. pectinata* is used as an ornamental plant, the social and economic benefits of the species are related to the horticultural and plant trade.

Probability of introduction

- The species is intentionally introduced to the EU through planting as an ornamental plant in gardens. Subsequent dispersal from gardens into the wild may occur due to improper disposal of garden waste. In view of the history of introductions of the species, the probability of introduction via this pathway is classified as medium.

Probability of establishment

- Most current populations in the EU seem to have resulted from escapes from cultivation. The climatic requirements of *S. pectinata* are met in the EU and in particular in Eastern Europe.

- The habitat requirements of *S. pectinata* are expected to be fully met in the EU because the plant grows in different types of wetland and poorly drained soils, and is able to establish in most soil textures from fine clays to silt loams in its native and introduced ranges.

- The expert team expects that there is a high risk of establishment especially in eastern EU member states because of the better climate match, probable availability of more suitable habitats, and the fact that the species is offered for sale as an ornamental plant.

- Future climate change is expected to moderately increase the risk of establishment, especially in northern and western EU member states.

Probability of spread

- The potential for *S. pectinata* to disperse within the EU by natural means is scored low, but the risk that the species will spread within the EU by human actions is scored high. Reasons for this high score are the characteristics of historical introductions of the species, and its high capacity for vegetative reproduction.

- Climate change will probably not change the risk of spread within the EU.

Probability of impact

- The impact on native species is classified as high because *S. pectinata* can grow rapidly and forms dense mono-specific stands, thus significantly limiting the growth or distribution of native plant and animal species and significantly altering habitat conditions for native species.

- The impact of *S. pectinata* on ecosystem functions is expected to be high in view of the potential of the species to form dense mono-specific stands and its high growth potential.

Risk classification

- The application of both the Harmonia^{+} and the ISEIA protocols resulted in the expert team allocating *S. pectinata* the total risk score of "**high**" for ecological risk especially in central and eastern EU member states. The species is currently and will probably remain present in isolated populations within the EU in the future. Therefore, the species is classified as an A1 species in the BFIS list system and thus qualifies for the **black list**. Climate change is expected to have no effect on the ecological risks of this species.

- Expert classification of *S. pectinata* based on available knowledge using the Harmonia^{+} protocol resulted in the following risk scores :
  - Introduction risk: **Medium** (Confidence: high)
  - Establishment risk: **High** (Confidence: high)
  - Spread risk: **High** (Confidence: medium)
  - Environmental impact risk: **High** (Confidence: high)
  - Risk of effects on plant cultivation: **Low** (Confidence: medium)
  - Risk of effects on domesticated animals and livestock: **Low** (Confidence: high)
  - Risk of effects on public health: **Low** (Confidence: high)
  - Other risk effects: **Low** (Confidence: high)

Knowledge gaps

- Several knowledge gaps were encountered during this risk assessment and classification. Records of the species in eastern EU member states were not found during this study. However, the climate, and probably also habitat match with *S. pectinata*'s native range are better for eastern than western EU member states and the species is offered for sale in both regions. Data are lacking on the costs of (recurrent) control measures and the potential loss of income from the plant trade that would occur if the species were banned. No information on the effectiveness of eradication and control measures was found. Information on these issues is required to underpin management decisions.

- The propagation mode of strains introduced to the EU need to be assessed to better determine the potential for reproduction following escape.

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	http://waarnemingen.be/soort/view/137954
Bulgaria	http://eea.government.bg/bg/soer/2010/biodiversity-nem/biologichno-raznoobrazie-natsionalna-ekologichna-mrezha-1
Croatia	NA
Czech Republic	http://www.preslia.cz/P122Pysek.pdf
Cyprus	NA
Denmark	http://ign.ku.dk/formidling/publikationer/rapporter/filer-2014/pathways-for-non-native-species-in-DK.pdf
Germany	http://floraweb.de/pflanzenarten/artenhome.xsql?suchnr=7035&
Estonia	https://www.riigiteataja.ee/akt/12828512
Finland	http://vieraslajit.fi/
France	http://www.tela-botanica.org/bdtfx-nn-82460-synthese
Greece	NA
Hungary	http://www.termeszetvedelem.hu/_user/downloads/invazios_fajok/invazivfajok.pdf
Ireland	http://www.botanicgardens.ie/glasra/aliens/282_301.pdf
Italy	http://www.minambiente.it/sites/default/files/archivio/biblioteca/protezione_natura/dpn_flora_alloctona.pdf
Latvia	NA
Lithuania	http://www.corpi.ku.lt/nemo/
Luxemburg	NA
Malta	NA
The Netherlands	http://waarneming.nl/soort/view/137954
	http://www.verspreidingsatlas.nl/8009
	http://plantago.nl/plantindex/plant/BO/S/1/spartina-pectinata/8139.html
	http://plantago.nl/plantindex/plant/BO/S/1/spartina-pectinata-aureomarginata/8140.html
Poland	http://www.iop.krakow.pl/ias/gatunki
	http://www.wigry.org.pl/ros_obce_cz1a.pdf
Portugal	http://invasoras.pt/
Romania	NA
Slovakia	http://www.preslia.cz/P122Medvecka.pdf
Slovenia	NA
Spain	http://www.magrama.gob.es/es/biodiversidad/temas/conservacion-de-especies/especies-exoticas-invasoras/ce_eei_flora.aspx
	http://www.anthos.es/index.php?lang=en
Sweden	http://artfakta.artdatabanken.se/taxon/265211
United Kingdom	http://www.nonnativespecies.org/factsheet/factsheet.cfm?speciesId=3347
EU candidate countries	
Albania	NA
Former Yugoslav Republic of Macedonia	NA
Montenegro	NA
Serbia	NA

Turkey	NA
Other European countries	
Norway	http://www.artsdatabanken.no/file/689/alien%20species
Switzerland	https://www.infoflora.ch/de/assets/content/documents/neophytes/neophytes_divers/Schwarze%20Liste_Watch%20Liste_2014.pdf
Global and European sites	
CABI	http://www.cabi.org/isc/datasheet/117272
DAISIE	http://www.europe-aliens.org/speciesFactsheet.do?speciesId=4841
EOL	http://www.eol.org/pages/1114695/overview
EPPO	https://gd.eppo.int/taxon/SPTPE
EU LIFE projects	http://ec.europa.eu/environment/life/publications/lifepublications/lifefocus/documents/life_ias.pdf
GBIF	http://www.gbif.org/species/5290030
GISIN	http://www.gisin.org/cwis438/Websites/GISINDirectory/GISIN_ScientificName_List.php?WebSiteID=4
GRIN	https://npgsweb.ars-grin.gov/gringlobal/taxonomydetail.aspx?70746
ISSG	http://www.issg.org/index.html
IUCN	http://www.iucngisd.org/gisd/
Nobanis	https://www.nobanis.org
Observado	http://observado.org/waarnemingen_v7.php?groep=10
Plant list	http://www.theplantlist.org/tpl1.1/record/kew-443817
Q-bank	http://www.q-bank.eu/Plants/

Glossary

Term	Description
Adventitious record	Plant occurring outside its native range due to non-natural cause
Adventitious roots	Roots developing in an unusual position; roots that grow from a stem
Anemochory	Seed dispersal by wind
Anther	Part of the stamen containing the pollen grains
Apex	Relating to the apex or tip of a pyramidal or pointed structure
Apomixis	Reproduction by seed not as a result of a sexual fusion
Awn	A stiff bristle-like projection from the tip or back of the lemma in grasses
Biomass crop	Crops grown specifically for use as fuel that offer high productivity per hectare with low inputs
C4 photosynthesis	C4 carbon fixation is one of three biochemical mechanisms used in carbon fixation, along with C3 and CAM photosynthesis. It is named after the 4-carbon molecule present in the first product of carbon fixation in the small subset of plants known as C4 plants, in contrast to the 3-carbon molecule products in C3 plants. C4 plants are able to more efficiently fix carbon in drought, high temperatures, and limitations of nitrogen or CO_2.
Culm	The hollow stem of a grass or cereal plant, especially the one that bears the flower
Cytotype	Different cytotypes within a species differ in karyotypes (chromosomes, structure and numbers: ploidy), or in genomes (mitochondrial chloroplast)
Fecund	Producing or capable of producing an abundance of offspring or new growth; highly fertile
Glumes	Each of two membranous bracts surrounding the spikelet of a grass (forming the husk of a cereal grain) or one surrounding the florets of a sedge
Heptaploid	Having seven times the monoploid number of chromosomes
Hexaploid	Having six times the monoploid number of chromosomes
Hybridization	A cross between parents that are genetically dissimilar
Hydrochory	Dispersal by water
Invasive species	Alien species which spread quickly and become dominant in newly colonized areas
Lemma	A part of the spikelet of grasses (Poaceae). It is the lowermost of two chaff-like bracts enclosing the grass floret.
Octoploid	Plants that have eight sets of chromosomes in their nuclei
Naturalized	Plants established as a part of the flora of a locale other than their place of origin
Alien	Species not native, originating from elsewhere
Perennial	Living for more than two years and usually flowering each year
Ploidy	The number of sets of chromosomes in a cell, or in the cells of an organism
Propagation	The reproduction or spreading of something
Protogynous	Ovary maturing before the stamens
Rhizomes	A continuously growing horizontal underground stem which puts out lateral shoots and adventitious roots at intervals
Spikelets	The basic unit of a grass flower, consisting of two glumes or outer bracts at the base and one or more florets above
Stigma	Receptive surface of the gynoecium to which the pollen grains adhere
Stratification	Seed dormancy is usually overcome by this process which is characterised by seeds spending time in the ground through a winter period which weakens the seed coat and triggers the seed’s embryo
Tetraploid	A plant having four sets of chromosomes in its nuclei
Vegetative	A type of asexual reproduction employed by plants wherein new independent individuals emerge from the vegetative parts, such as specialized stems, leaves, roots, and not from seeds or spores
Zoochory	Seed dispersal by animals

Appendix 1 – Materials and methods

A1.1 Risk analysis components

The present risk assessment of Prairie cordgrass (*Spartina pectinata*) in the EU includes analyses of the probability of introduction, establishment and spread within the EU. Also the available literature on the ecological and socio-economic effects, impact on public health, and availability of cost-effective options for risk management were analysed. The background information and data collected in the risk inventory are presented in chapter 2 and used as basis for the risk assessments and classification in chapter 3.

Subsequently, an ecological risk assessment and risk classification of the species in the EU was made using the Harmonia$^+$ protocol (D'hondt et al. 2015). The novel internet version of this protocol includes criteria for an ecological risk assessment as well as modules for the assessment of (potential) impacts on human health, infrastructure and ecosystem services, and a module to assess effects of climate change on the risks posed by alien species. The earlier version of Harmonia$^+$ was nearly compliant with criteria for risk assessment of IAS of EU-concern derived from Regulation 1143/2014 on the prevention and management of the introduction and spread of IAS (Roy et al. 2014b). We assumed that the current internet version of Harmonia$^+$ is compliant with these criteria due to the addition of modules concerning the impacts on ecosystem services and the potential effects of climate change on future impacts of alien species.

In addition, a risk assessment was performed using the Invasive Species Environmental Impact Assessment (ISEIA) protocol (Branquart 2009, Branquart et al 2009, Vanderhoeven et al. 2015).

A1.2 Risk inventory

An extensive literature review was carried out to compile a science based overview of the current knowledge on taxonomy, habitat preference, introduction and dispersal mechanisms, current distribution, ecological impact, socio-economic impact and consequences for public health of the species. In addition, data on the current distribution in EU member states were acquired. In this risk inventory internationally published knowledge in scientific journals and reports was described. If relevant issues mentioned in the format for this risk inventory could not sufficiently be supported by knowledge published in international literature, 'grey literature' or 'best professional judgement' was used. In the latter case, this has been indicated in the report to clearly identify which arguments may be open to discussion. Uncertainties and knowledge gaps are also addressed in the discussion. A glossary was added to the report with an explanation of botanical terms.

A1.2.1 Literature review

The internet was searched for information concerning *S. pectinata*. Consulted websites are listed in the references section and contain information on invasive species including information on their distribution at a global or national scale. The Web of Science was searched using the official scientific species name (The Plant List 2016) as a search term (Table A1.1). A quick-scan of the title or summary of all the articles was made to estimate their relevance. Google and Google Scholar were used to find references not accessible by the Web of Science. A combination of the scientific name "*Spartina pectinata*" and "buy plants" in several languages (i.e., Dutch, English, French, German and Spanish) were used as search queries in Google in order to estimate the scale of trade in *S. pectinata*. As soon as availability in a country was ascertained the search was stopped. Other available risk assessments and classifications of *S. pectinata* were retrieved using all combinations of the common or scientific name and the search terms risk assessment, risk analysis and risk classification.

Table A1.1. Literature search strategy.

Search engine	Search terms	Search date
Web of Science	*Spartina pectinata*	March 2016
Google Scholar	Idem	March 2016
Google	*Spartina pectinata* buy plants	March 2016
Web of Science	*Spartina pectinata*, Prairie cordgrass, risk, risk assessment, risk analysis, risk classification	July 2016
Google (Scholar)	Idem	July 2016

A1.2.2 Data acquisition on current distribution

Several online databases were used to acquire data on the current distribution of *S. pectinata*. These databases are reported in the reference section ('Websites consulted') and Appendix 3. Records in these databases are validated by photos or herbarium specimens.

A1.3 Risk assessment and classification

A1.3.1 Selection of risk assessment methods

One of the aims of this project is to provide insight into the risks of *S. pectinata* to biodiversity and ecosystems in the EU. Assessments of ecological risks were therefore required on ecological risks and it was decided to apply both the Harmonia$^+$ and the ISEIA protocols for this purpose. In the current study, the Harmonia$^+$ protocol was used as it includes the assessment of impacts on socio-economic aspects, public health, infrastructure and ecosystem services, as well as the effects of climate change on the establishment, spread, and impacts of alien species. Moreover, the Harmonia$^+$ protocol complies with the criteria of the EU regulation 1143/2014. The ISEIA protocol requires less detailed information on impacts to obtain a risk classification than Harmonia$^+$ and focuses on ecological impacts only. Additionally, this protocol was used to allow comparisons of our risk classifications for *S. pectinata* with those of other alien species assessed for the Netherlands. In the Netherlands, the ISEIA protocol has been most frequently used for the risk classification of alien species.

Harmonia$^+$ and ISEIA are protocols for risk screening and are primarily developed for assessing the negative effects of alien species. They do not consider positive effects, except the module on ecosystem services in the Harmonia$^+$ protocol. However, available information on positive effects of alien species has been included in the risk inventory (Chapter 2).

A1.3.2 Harmonia$^+$ ecological risk assessment protocol

The Harmonia$^+$ protocol includes procedures for the risk assessment of potentially invasive alien plant and animal species. This protocol stems from a review of the ISEIA protocol and incorporates all stages of invasion and different types of impacts. The online version of the Harmonia$^+$ protocol (D'hondt et al. 2015) was used for the risk assessment of *S. pectinata*. All risk scores were calculated using this online version. This risk assessment method comprises 41 questions grouped in the following modules:

A0. Context (assessor, area and organism);
A1. Introduction (probability of the organism to be introduced into the area);
A2. Establishment (does the area provide suitable climate and habitat);
A3. Spread (risks of dispersal within the area);
A4. Potential impact on the following subcategories:
- A4a. Environmental effects: wild animals and plants, habitats and ecosystems;
- A4b. Effects on cultivated plants;
- A4c. Effects on domesticated animals;
- A4d. Effects on human health;
- A4e. Effects on infrastructure;

A5a. Effects on ecosystem services;
A5b. Effects of climate change on the impact of the organism.

Each module contains one or more risk assessment questions and provides options for risk scores in each question. The protocol provides guidance for all questions and includes explanations and examples that serve as a reference for attributing risk scores.

Table A1.2 shows the formulas used for the calculation of various risk scores. The protocol allows the assignment of various weighing factors to impact categories (i.e., weighing risks within and between categories). In order to prevent averaging of risks and to keep the highest score of each risk category visible, the highest score was always used to calculate final effect scores for a specific impact category. This 'one out all out' principle has also been used in other risk assessments of alien species (e.g., in ISEIA and the EPPO prioritizing schemes) and other policy domains (such as ecological status assessments of water bodies according to the European Water

Framework directive). The default value 1 was always used for weighing various impact categories (i.e., equal weighing). The product of the introduction, establishment and spread was used to calculate the invasion score. The maximum of the different impact scores was used to calculate the aggregated impact score.

Table A1.2: Concepts and definitions for risk assessments and classifications of alien species with the Harmonia^{+} protocol (D'hondt et al. 2014).

<u>Conceptual framework</u>
Invasion= f(*Introduction*; *Establishment*; *Spread*; $Impact_{a\text{-}g}$)
Risk = *Exposure* x *Likelihood* x *Impact*

<u>Invasion = risk?</u>
Exposure ≡ f_1(*Introduction*;*Establishment*;*Spread*) = ***Invasion score***
Likelihood x *Impact* ≡ f_2($Impact_a$; $Impact_b$; $Impact_c$; $Impact_d$; $Impact_e$; $Impact_f$; $Impact_g$) = ***Impact score***
a: environment (biodiversity and ecosystems); b: cultivated plants; c. domesticated animals; d. human health; e: other; f: ecosystem services; g: climate change

Total risk = *Exposure* x *Likelihood* x *Impact* ≡ f_3(*Invasion score*; *Impact score*) = **Invasion**

<u>Mathematical framework</u>
f_1 : (weighed) geometric mean or product
f_2 : (weighed) arithmetic mean or maximum
f_3 : product

The degree of certainty associated with a given risk was scored as a level of confidence. The level of confidence of risk scores has been consistently reported using low, medium and high, in accordance with the framework of Mastrandrea et al. (2010, 2011). Harmonia^{+} attributes values of 0, 0.5 and 1 to low, medium and high confidence, respectively, to calculate confidence levels for various impact categories. The cut-off values for risk scores and confidence levels used for the risk classification of *S. pectinata* in the EU are summarized in Table A1.3.

Table A1.3: Cut-off values for risk scores and confidence levels used for the risk classification of the Prairie cordgrass (*Spartina pectinata*) in the EU, using the Harmonia^{+} protocol.

Colour code risk	Risk classification	Risk score (RS)*	Colour code confidence	Confidence	Confidence score (CS)*
	Low	<0.33		Low	<0.33
	Medium	0.33 ≤ RS ≤ 0.66		Medium	0.33 ≤ CS ≤ 0.66
	High	>0.66		High	>0.66

*: Arbitrary cut off values for distribution of risk scores between 0 and 1.

A1.3.3 ISEIA ecological risk assessment protocol

The ISEIA protocol assesses risks associated with dispersion potential, invasiveness and ecological impacts only (Branquart 2009). Definitions for risk classifications relating to the four sections contained within the ISEIA protocol are presented in Table A1.4.

The ISEIA protocol contains twelve criteria that match the last steps of the invasion process (i.e., the potential for spread establishment, adverse impacts on native species and ecosystems). These criteria are divided over the following four risk sections: (1) dispersion potential or invasiveness, (2) colonisation of high conservation habitats, (3) adverse impacts on native species, and (4) alteration of ecosystem functions. Section 3 contains sub-sections referring to (i) predation / herbivory, (ii) interference and exploitation competition, (iii) transmission of diseases to native species (parasites, pest organisms or pathogens), and (iv) genetic effects such as hybridization and introgression with related native species. Section 4 contains sub-sections referring to (i) modifications in nutrient cycling or resource pools, (ii) physical modifications to habitats (changes to hydrological regimes, increase in water turbidity, light interception, alteration of river banks, destruction of fish nursery areas, etc.), (iii) modifications to natural successions and (iv) disruption to food-webs, i.e., a modification to lower trophic levels through herbivory or predation (top-down regulation) leading to ecosystem imbalance.

Table A1.4: Definitions of criteria for risk classifications per section used in the ecological risk assessment protocol (Branquart 2009a).

1. Dispersion potential or invasiveness risk	
Low	The species does not spread in the environment because of poor dispersal capacities and a low reproduction potential.
Medium	Except when assisted by man, the species doesn't colonise remote places. Natural dispersal rarely exceeds more than 1 km per year. However, the species can become locally invasive because of a strong reproduction potential.
High	The species is highly fecund, can easily disperse through active or passive means over distances > 1km / year and initiate new populations. Are to be considered here plant species that take advantage of anemochory, hydrochory and zoochory, insects like *Harmonia axyridis* or *Cemeraria ohridella* and all bird species.
2. Colonisation of high conservation habitats risk	
Low	Populations of the alien species are restricted to man-made habitats (low conservation value).
Medium	Populations of the alien species are usually confined to habitats with a low or a medium conservation value and may occasionally colonise high conservation habitats.
High	The alien species often colonises high conservation value habitats (i.e., most of the sites of a given habitat are likely to be readily colonised by the species when source populations are present in the vicinity) and makes therefore a potential threat for red-listed species.
3. Adverse impacts on native species risk	
Low	Data from invasion histories suggest that the negative impact on native populations is negligible.
Medium	The alien species is known to cause local changes (<80%) in population abundance, growth or distribution of one or several native species, especially amongst common and ruderal species. The effect is usually considered as reversible.
High	The development of the alien species often causes local severe (>80%) population declines and the reduction of local species richness. At a regional scale, it can be considered as a factor for precipitating (rare) species decline. Those alien species form long standing populations and their impacts on native biodiversity are considered as hardly reversible. Examples: strong interspecific competition in plant communities mediated by allelopathic chemicals, intra-guild predation leading to local extinction of native species, transmission of new lethal diseases to native species.
4. Alteration of ecosystem functions risk	
Low	The impact on ecosystem processes and structures is considered negligible.
Medium	The impact on ecosystem processes and structures is moderate and considered as easily reversible.
High	The impact on ecosystem processes and structures is strong and difficult to reverse. Examples: alterations of physicochemical properties of water, facilitation of river bank erosion, prevention of natural regeneration of trees, destruction of river banks, reed beds and / or fish nursery areas and food web disruption.

Each criterion of the ISEIA protocol was scored by six experts (§A1.3.4). The scores range from 1 (low risk) to 2 (medium risk) and 3 (high risk). Definitions for low, medium and high risk, according to the four sections of the ISEIA protocol are given in Table A1.2. If information obtained from the literature review was insufficient for the derivation of a risk score, then the risk score was based on best professional judgement and / or field observation leading to a score of 1 (unlikely) or 2 (likely). If no answer could be given to a particular question (no information) then a score of 1 was given (DD - deficient data). This is the minimum score that can be applied in any risk category. In cases with data or knowledge limitations, periodical review of new literature and updates of risk scores will be recommended. Finally, the highest score within each section was used to calculate the total ISEIA risk score for the species.

Consideration was given to the future situation assuming no changes in management measures that will affect the invasiveness and impacts of this invasive plant. The risk assessment and classification of *S. pectinata* for the future situation was performed, with the assumption of a temperature increase of 2 °C in 2050, which reflects the IPCC scenarios for Climate Change (IPCC 2013) and unchanged policies on alien species in the EU member states.

Subsequently, the Belgian Forum Invasive Species (BFIS) list system for preventive and management actions was used to categorise the species of concern (Branquart 2009). This list system was designed as a two dimensional ordination (Ecological impact * Invasion stage; Figure A1.1). The BFIS list system is based on guidelines proposed by the Convention on Biological Diversity (CBD decision VI/7) and the EU strategy on invasive alien species.

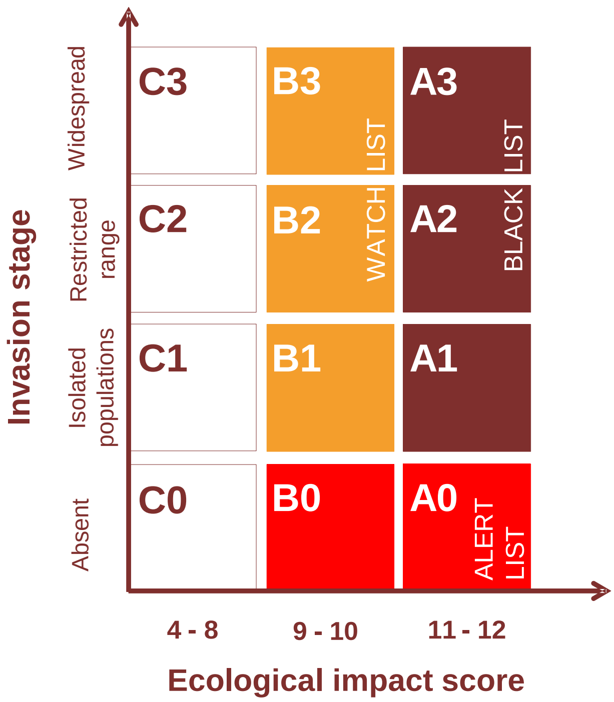


Figure A1.1: BFIS list system to identify species of most concern for preventive and mitigation action (Branquart 2009; score 4-8: low risk; score 9-10: medium risk; score 11-12: high risk).

Ecological impact of the species was classified into a group represented by the letters A, B or C, which was based on the total ISEIA risk score: low ecological risk score 4-8 (C), moderate ecological risk score 9-10 (B - watch list) and high ecological risk score 11-12 (A - black list) (Figure A1.1). This letter was then combined with a number representing the invasion stage: (0) absent, (1) isolated populations, (2) restricted range, and (3) widespread. A cross was used to indicate the risk classification of the assessed species within the BFIS system. A black cross indicates a species that should appear on either the watch, alert or black list of the BFIS system.

A1.3.4 Expert meeting on risk classification

The risk assessments of *S. pectinata* have been performed by a team of six experts (Ir. R. Beringen, Dr. G.A. van Duinen, Dr. R.S.E.W. Leuven, Drs. B. Odé, Dr. G. van der Velde and Dr. Ir. J.L.C.H. van Valkenburg), using the ISEIA and Harmonia$^+$ protocols. Each expert thoroughly reviewed the risk inventory (knowledge document). Subsequently, experts independently assessed and classified current and future risks of *S. pectinata*, using both protocols. Future risks were determined with respect to the potential effects of climate change on the introduction, establishment, spread and impacts of the species.

Following the individual assessment of experts, the entire team met, elucidated differences in risk scores, discussed diversity of risk scores and interpretations of key information during a risk assessment workshop. Discussion during the workshop led to agreement on consensus scores and risk classifications relating to both protocols. The consensus scores, risk classifications and justifications for the scores were described in a draft report that was reviewed by the project team, assuring full agreement with the outcomes of the risk assessment.

A1.3.5 Other available risk assessments and classifications

A specific literature search using Web of Science and Google (Scholar) was performed to retrieve other available risk assessments and classifications of *S. pectinata*. Search terms applied were the scientific species name and English name combined with the following terms: risk, risk assessment, risk analyses and risk classification. The outcomes of these risk assessments and classifications were included in this report and compared for consistency with our risk classifications.

A1.4 Peer review by independent experts

The quality of this risk assessment was assured by an external peer review procedure. The final draft of this report was reviewed by two independent experts:

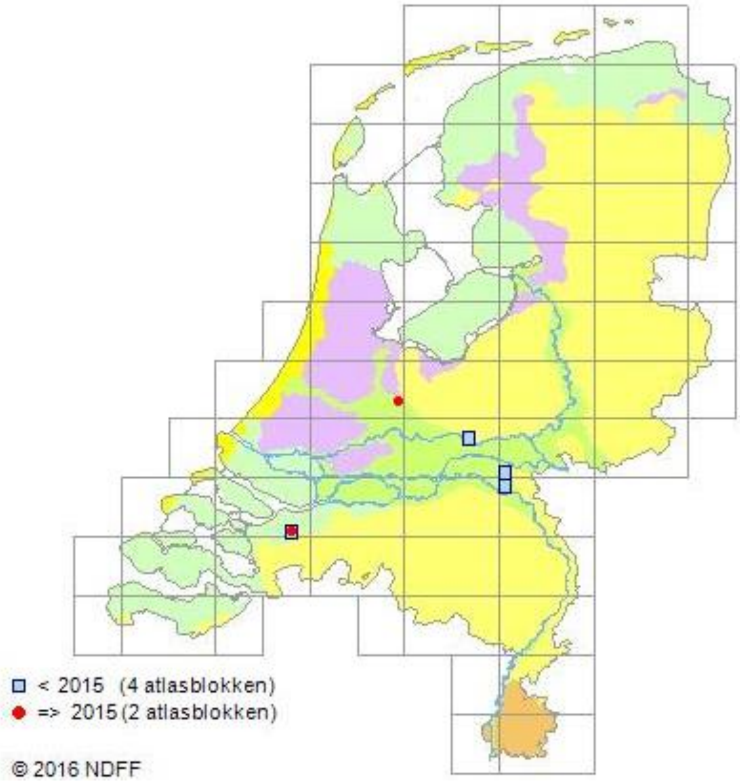
1. Drs. R. Pot (Roelf Pot Research and Consultancy, the Netherlands).
2. Dr. F. Verloove (Botanic Garden of Meise, Belgium).

Both experts critically reviewed the available data and information described in the risk inventory as well as the outcomes of the risk assessments. Special attention was focused on the justification of the risk classification and relevant scientific uncertainties. Appendix 4 summarizes how the remarks and suggestions of the reviewers were dealt with.

Appendix 2 – Risk assessment for the Netherlands

S. pectinata is in Nederland bekend op vijf locaties (Figuur A2.1, NDFF Verspreidingsatlas 2016):

- In een buitenwijk in Utrecht werden twee exemplaren gevonden in een bomenaanplant, waar de exemplaren waarschijnlijk werden geplant. Volgens de waarnemer zijn ze daar al minimaal vijftien jaar aanwezig.
- In het bedrijventerrein Winkelsteeg in Nijmegen is de soort aangeplant langs meerdere vijvers. De populatie bestaat uit meer dan 1000 stengels en neemt toe (Dirkse et al. 2007).
- In de Berendonck, een recreatiegebied tussen Nijmegen en Wijchen, werd een populatie van 100 stengels gevonden in een nat grasland in 2009. Volgens de waarnemer is de soort daar al meerdere jaren aanwezig.
- In 2009 werd *S. pectinata* gevonden in een zandafgraving in Rhenen.
- In een groen gebied tussen de snelweg A17 en afrit 24 Standdaarbuiten werd één aangeplant of adventief exemplaar waargenomen door verschillende waarnemers. Voor het eerst beschreven in 2013.



Figuur A2.1: Verspreiding van *Spartina pectinata* in Nederland (NDFF Verspreidingsatlas 2016).

Het deskundigenpanel heeft de risico's van *S. pectinata* voor Nederland en de gehele EU identiek geclassificeerd met behulp van het ISEIA protocol (Tabellen A2.1 en A2.2).

Tabel A2.1: Risicobeoordeling van *Spartina pectinata* voor de huidige en toekomstige situatie in Nederland met behulp van het ISEIA protocol.

Risicocategorie		**Consensus scores**
Dispersie potentieel / invasiviteit		**2**
Kolonisatie van waardevolle habitats		**2**
Directe en indirecte negatieve effecten op inheemse soorten		**3**
1. Predatie/begrazing	NR	
2. Verstoring en competitie	3	
3. Overdracht van parasieten en ziektes	1*	
4. Genetische effecten (hybridisatie / introgressie met inheemse soorten)	1*	
Directe of indirecte verandering van ecosysteem functies		**3**
1. Modificatie van nutriëntencycli of hulpbronnenvoorraad	2	
2. Fysieke modificatie van habitat	3	
3. Modificatie van natuurlijke successie	2	
4. Ontwrichting voedselketens	1*	
Totaal score		**10**
Verspreiding		**Geïsoleerde populations**
Risicoclassificatie		**B1**

NR: niet relevant; *: onzekerheid groot wegens data deficiëntie.

Het risico op verspreiding en invasiviteit is als matig (Score 2, Tabel A2.1) geclassificeerd, vanwege de hoge potentiële groeisnelheid van de soort en de goede vegetatieve voortplanting, maar de waarschijnlijk geringe zaadzetting en daardoor geringe kans op natuurlijke verspreiding over grotere afstand. Verder is er in Nederland weliswaar een klimaatmatch met het natuurlijke verspreidingsgebied van de soort, maar is deze match minder goed dan in Oost-Europa.

Het risico op kolonisatie van waardevolle habitats wordt eveneens als matig (Score 2) geclassificeerd. In Nederland wordt wel voldaan aan de habitat- en klimaateisen van de soort en zijn geschikte habitats aanwezig, maar in Oost-Europa is de klimaatmatch beter. Daarom is het risico op kolonisatie van waardevolle habitats voor de EU geclassificeerd met score 3 (§3.1) en voor Nederland met score 2. Het voorkomen op de huidige locaties is waarschijnlijk een gevolg van aanplant of het dumpen van tuinafval met daarin wortelstokken van de soort. Omdat zaadzetting gering is, is de kans op natuurlijke verspreiding naar waardevolle habitats zeer klein.

De risico's op negatieve effecten op inheemse soorten en op ecosysteemfuncties worden beide als hoog geclassificeerd, vanwege de sterke potentiële groei van de wortelstokken en de vorming van dichte bestanden, waarin nauwelijks andere soorten kunnen voorkomen. Bij deze scores is niet meegewogen dat de risico's op verspreiding en kolonisaties in Nederland matig zijn.

Klimaatverandering zal naar verwachting niet tot veranderingen in de ecologische risico’s leiden en de risicoscores voor de toekomstige situatie zijn daarom identiek aan de scores voor de huidige situatie (Tabel A2.1).

Appendix 3 - Current distribution in the EU

Country	Local name	Present	Source	Trade	For sale at websites
EU member countries					
Belgium	Slijkgras	Yes	waarnemingen.be, CABI, DAISIE	Yes	http://plantengids.willaert.be/nl/plantenfiche/sppaureo/
Czech Republic		NI		Yes	http://www.hruska-skolky.cz/prodejna-produkt/spartina-spartina-pectinata-aureomarginata
Denmark	Prærie-Vadegræs (Guldlistegræs)	NI		Yes	http://kridtvejsplanter.dk/graesser/2115-spartina-pectinata-aureomarginata-guldlistegraes.html
Germany	Prärie-Schlickgras	Yes	GBIF, CABI, DAISIE	Yes	http://shop.mein-schoener-garten.de/pflanzen/spartina-pectinata-aureomarginata-goldleistengras-ziergraeser-farne_pid_1431_1664.html
Estonia	Kamm-soohein	NI		Yes	http://www.seemnemaailm.ee/index.php?GID=11696
Finland	Raitamarskinheinä	NI		Yes	http://www.vihertaimisto.fi/heisan.html
France	Spartine pectinée	Yes	GBIF, Telabotanica	Yes	http://www.lumen.fr/lumen/0/boutique/44432/spartina_pectinata_aureomarginata.htm#.Vt7es_nhBhE
Hungary	Tarkalevelű prérizsinegfű	NI		Yes	http://www.disznovenywebaruhaz.hu/tarkalevelu-prerizsinegfu_spartina-pectinata-aureomarginata
Ireland	Spairtíneach chíre	Yes	GBIF, CABI, DAISIE	NI	
Italy	Spartina pectinata 'Aureomarginata'	NI		Yes	http://www.waterplantsitaly.com/prodotto/spartina-p-aureomarginata/
Lithuania	šukiškoji spartina	NI		Yes	http://www.sodospalvos.lt/Augalas-191-SPARTINA_MARGALAPE_FORMA
Netherlands		Yes	http://www.verspreidingsatlas.nl/8009#	Yes	http://www.plantago.nl/plantindex/plant/BO/S/1/spartina-pectinata/8139.html
Poland	Spartyna grzebieniasta	NI		Yes	https://sadzawka.pl/Spartina_pectinata_Aureomarginata-Spartina_grzebienista
United Kingdom	Prairie cord-grass	Yes	GBIF, CABI, DAISIE	Yes	https://www.shootgardening.co.uk/plant/spartina-pectinata-aureomarginata
EU candidate countries					
Serbia		NI		Yes	http://www.bastovanstvo.rs/index.php?topic=874.15

NI: No information.

Appendix 4 – Quality assurance by peer review

The quality of this risk assessment was assured by an external peer review procedure. The independent experts Drs. R. Pot (Roelf Pot Research and Consultancy, the Netherlands) and Dr. F. Verloove (National Botanic Garden of Belgium) reviewed the final draft of this report. They assessed the available information used for the risk assessments and the outcome of the assessments, including the justifications for the risk classifications and scientific uncertainties.

The external reviewers emphasised the thoroughness of the literature search and stated that, where applicable, the expert judgement was performed well by the expert panel.

The reviewers delivered useful comments and suggestions for improvement of the risk inventory and assessment. All remarks and suggestions of the reviewers were implemented in the final version of this report. Textual inconsistencies were corrected (e.g., country names, scientific names) and all references were correctly addressed in the reference list.

Two points require further attention: 1) the decision of choosing maximum risk scores to calculate the final effect scores for impact categories in the Harmonia$^+$ protocol, and 2) the scores allocated for the risks of establishment and effects on native species and ecosystem functioning.

According to one reviewer, we made one rather questionable decision with regard to the aggregation in the Harmonia$^+$ protocol. He argues that maximizing the score within every module would be a fundamental error since maximizing in both steps would result in an overestimation of the total risk. We therefore clarified our choices in the text. After consultation with the Office for Risk Assessment and Research of NVWA, the maximum risk scores per module were applied to maintain transparency. In order to prevent the averaging of risk scores and to keep the highest score within each risk category visible, the highest score was always used to calculate final effect scores for a specific impact category. This 'one out all out' principle has also been used in other risk assessments of alien species (e.g., in ISEIA and the EPPO prioritizing schemes) and other policy domains (such as ecological status assessments of water bodies according to the European Water Framework directive).

One reviewer commented that the scores allocated to the risks of establishment and effects on native species and ecosystem functioning were overestimated. The volume of trade of *S. pectinata* in the EU is unknown and probably not high. Therefore, the risk of introduction through garden escapes or improper dumping of garden waste was scored as medium instead of high, with medium confidence. As a result, the risk score for introduction and the invasion score in the Harmonia+ risk assessment were changed from high to medium.

The reviewer also commented that the species does not easily invade during all stadia of the habitat types, but merely the disturbed, species poor stands that have a lower conservation value than undisturbed stands in areas that qualify as Natura 2000 habitat types. This difference in the invasion risk of *S. pectinata* between disturbed and undisturbed stands is probably correctly observed. However, we argue that disturbed stands may also have conservation value, and that this value could be improved through restoration or natural succession with protection, e.g., within a Natura 2000 area. Assuming that *S. pectinata* is present at the edges of such areas or dumped in nearby suitable habitat, the species may, due to its high growth rate compared to native plant species, expand into high conservation value habitats. Indeed, mono-specific stands of *S. pectinata* with 100% coverage outcompete individual plants but are not expected to cause extinction of native plant species at regional scale. Moreover, independent of the protection status of the habitat, a negative effect on native plant species will occur anyway (decline of abundance), and some of the animal species that depend on these native plants will suffer similar effects. Furthermore, another species that is closely related to *S. pectinata* (*S. anglica*) outcompeted and replaced native *S. maritima* in west European coastal habitats (§2.5.1). Therefore, we still consider the risk of *S. pectinata* to native species through competition and the risk of colonisation of high conservation value habitats to be high, especially in the most suitable habitats located in eastern EU member states.