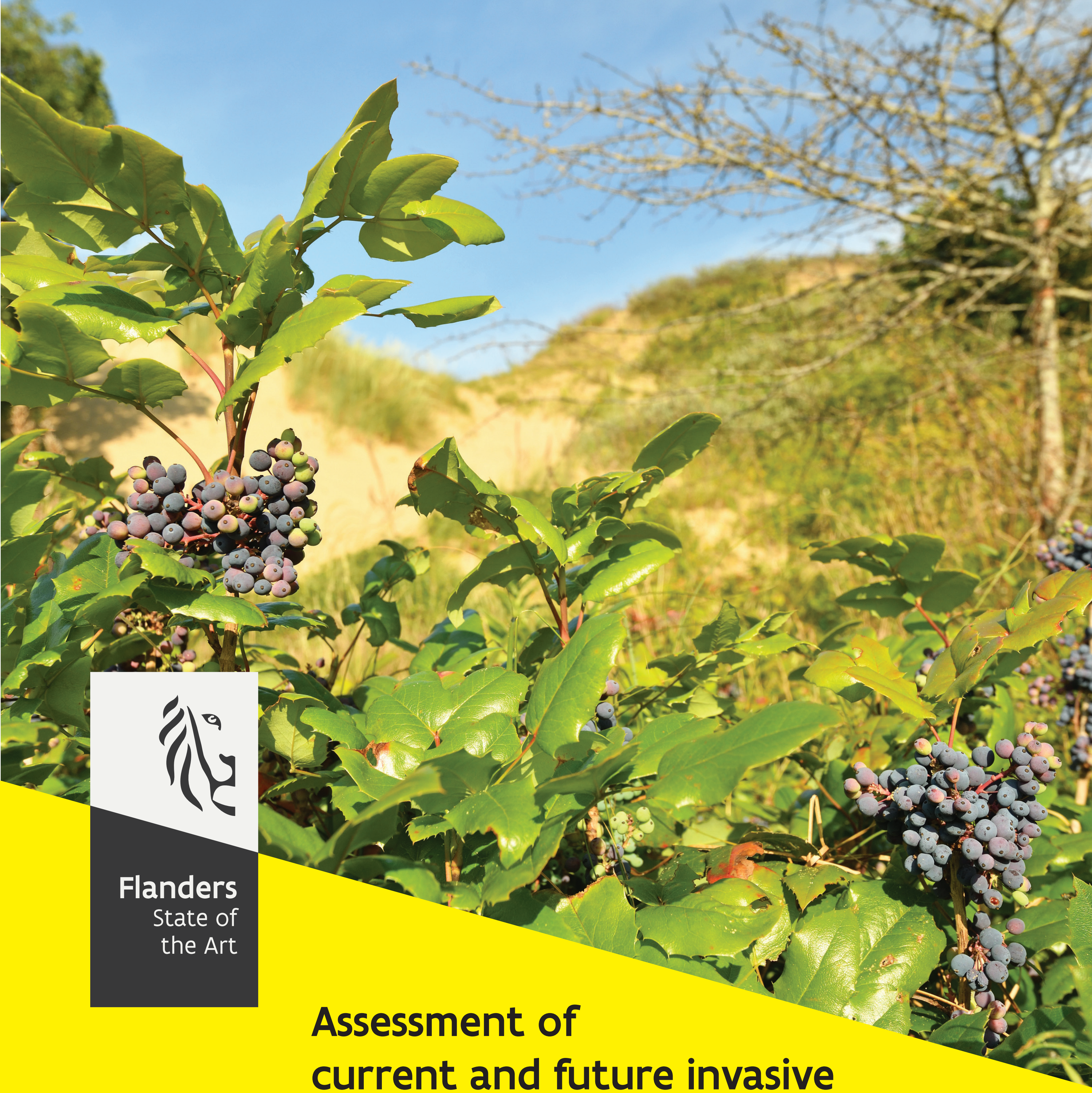

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Assessment of current and future invasive plants in protected dune habitats of the Atlantic coastal region

Including management accounts of selected species for the LIFE DUNIAS project (LIFE20 NAT/BE/001442)

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ASSESSMENT OF CURRENT AND FUTURE INVASIVE PLANTS IN PROTECTED DUNE HABITATS OF THE ATLANTIC COASTAL REGION

Including management accounts of selected species for the LIFE DUNIAS project (LIFE20 NAT/BE/001442)

Tim Adriaens, Bram D'hondt, Jasmijn Hillaert, Sander Carael, Debby Deconinck, Sander Devisscher, Indra Jacobs, Johannes Janssen, Patrik Oosterlynck, Reinhardt Strubbe, Wouter Van Gompel, Wouter Van Landuyt, Edward Vercruysse, Robbe Paredis, Toon Westra, Sam Provoost

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Abstract

Atlantic coastal dune systems in Europe are vulnerable to invasions by invasive plants, a continuous process driven by trends in urban plantings, escapes from gardens and range expansion of already established alien species. Early warning for invasive alien species and the sharing of practical experience with their management was identified as one of the key topics to address in Atlantic coastal dunes. This requires a good understanding of the potential ecological risk associated with alien species introductions and quick and robust prioritisation.

Here, we report on a systematic risk screening performed within the framework of LIFE DUNIAS in Belgium. Contrary to other horizon scans, we followed a more data-driven approach focused on protected habitats of the NATURA2000 regime. Using a variety of data sources, we drafted a longlist of over 1,300 alien taxa present in the Atlantic coastal region. This list was downsized through a quick relevance check performed by experts. The resulting list of about 250 species was assigned to ecoseries of NATURA2000 Annex I habitats (salty, sandy and woordy dune) according to the susceptibility of those habitats. We then performed moderated expert assessments in a consensual workshop format to assess the risk of introduction, establishment, spread and the potential (or realized) ecological impact. The resulting risk scores were combined with distribution data to identify emerging "horizon scan" species as well as high impact established species. We refined these lists for specific Annex I dune habitats, and present true horizon scan lists for the different countries of potential invaders that are not established yet. For a small selection of the species qualitative risk management assessment was performed at the workshop, evaluating the feasibility or eradication from protected habitats in the Atlantic coastal region.

Using the resulting lists and the results of monitoring in the framework of Article 17 reporting, we discuss the current way of performing conservation status assessments for coastal dune habitats and make recommendation on how to better deal with invasive alien species across the legislative regimes of the Habitat Directive and the invasive alien species Regulation. We present a list of (potentially) problematic alien species per Annex I habitat. The resulting prioritized list of potentially invasive plants represents an important step towards a more harmonized approach for tackling alien species in Atlantic coastal dunes across Europe.

Lastly, the report provides detailed management accounts, species profiles and distribution maps for a number of invasive species with knowledge gaps on effective management methods. The list of species discussed should be seen in the context of the LIFE DUNIAS project which aims to manage these species in Belgian coastal dunes. Nonetheless, the accounts represent evidence-based mini-reviews and we hope they can be inspirational to the wider community working on coastal dune management and nature protection in dune systems. We provide some practical recommendations and heat maps of highly invaded areas to inform management planning.

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1 INTRODUCTION

Coastal areas are characterised by strong natural and social dynamics. On the Belgian coast, tourist development caused a metamorphosis of the landscape that led to a strong deterioration of ecological and landscape values in the course of the 20th century. From the 1990's onwards, the Flemish government has pursued an active nature conservation policy. A first important step was the official protection of the coastal dunes under the spatial planning regime of the Dune Decree (decree of 14 July 1993 containing measures for the protection of coastal dunes) (Kuijken et al. 1993, Kuijken & Provoost 1994). The systematic acquisition of dunes by the Flemish government followed. An ecosystem vision was developed to guide the management of dunes, mudflats and salt marshes (Provoost & Hoffmann 1996a & b), and these were followed by the drafting of several more detailed coastal zone management plans (e.g. Provoost et al. 1993, Hoffmann et al. 1999, Hoys et al. 1996a, Hoys et al. 1996b, Cosyns et al. 2013, Cosyns et al. 2015, Zwaenepoel 2009, Van der Biest et al. 2017a,b). Alongside, the knowledge base on coastal dune systems and their ecological functioning was sensibly increased and several monitoring initiatives were developed and implemented to guide restoration efforts and to plan and evaluate management interventions. These include the development of a network of groundwater monitoring in nature reserves, research on distribution and population ecology (Provoost & Bonte 2004), landscape and vegetation research (Provoost et al. 2002, 2004; Provoost et al. 2011), research related to dealing with invasive alien species (Adriaens et al. 2019), possible applications of remote sensing in the mapping of dune vegetation (Kissiyar et al. 2005, Provoost et al. 2005) and, more recently, the management monitoring projects Permanent Inventory of Coastal Nature Reserves (PINK I, Provoost et al. 2010 and PINK II, Provoost et al. 2014) and the follow-up project Coastal Management Evaluation (BEK I, Provoost et al. 2020). The mapping of alien plant species and the evaluation of invasive species management is an important part of these monitoring projects and the alien species data of these detailed surveys are used in the framework of the exercise described in this report.

Over the past two decades, numerous large nature restoration and development projects were carried out in Belgian coastal dunes, in many cases with European co-funding (LIFE programme, European Commission 2017), and the nature areas were given appropriate management. These include, for example, LIFE Flemish And North French Dunes Restoration (FLANDRE, LIFE+12 NAT/BE/000631) and LIFE Zwinduinen Ecologische NatuurOntwikkeling (ZENO, LIFE06 NAT/B/000087) & Zwin Tidal Area Restoration (ZTAR, LIFE09 NAT/BE/000413). Despite these positive evolutions and initiatives, major challenges remain for coastal nature conservation. One of these is the expansion of a range of invasive alien plant species (Adriaens et al. 2019).

Sustainable management of invasive alien plant species is one of the major challenges for conservation management, especially in the dynamic systems coastal dunes represent. The arrival, introduction, establishment and spread of alien species is an ongoing process driven by continuous import of new species (e.g. from urban plantings or garden escapes) and the range expansion of alien species from southern or neighbouring countries. Coastal managers need effective early warning tools to rapidly be aware of newly naturalised problem species, up to date information and data on managed invasive species in dunes and good knowledge on effective, sustainable management techniques. International cooperation and exchange of knowledge is essential to increase invasive species awareness across administrative boundaries. In Atlantic coastal dunes, **early warning for IAS and the sharing of practical experience with their management** was identified as one of the key topics of the "Dune Roadmap" for networking which was developed at a series of workshops coordinated by the European

Commission through the Natura 2000 biogeographical process (Houston 2020). More specifically, the dune roadmap describes the following actions with respect to the IAS topic (Houston 2022):

- Development of a 'black list' for Atlantic dunes,
- Best practice examples of control of IAS,
- Specific review of experience in the control of *Rosa rugosa* with details of costs and development of national programmes.

This report and the DUNIAS workshop presentations and outcomes want to make a contribution in these fields.

On 1 January 2015 Regulation 1143/2014 on the prevention of the introduction and spread of invasive alien species (IAS) entered into force, representsing a first European biosecurity instrument for biodiversity. It sets a common standard for combating IAS across political jurisdictions at a multinational scale. Although the absence of a dedicated funding mechanism to support comprehensive implementation has been highlighted as a shortcoming, the EU Regulation creates impetus for many conservation initiatives on tackling invasive alien species and provides legal backing for stakeholders active in invasion management. Its successful implementation depends however on national enforcement and resource allocation, as well as the delivery of concrete conservation projects such as LIFE projects. The EU IAS Regulation includes a list of IAS of Union concern, IAS whose negative impacts require joint action by Member States. Three distinct types of measures are envisaged, which follow the approved hierarchical approach of the Convention on Biological Diversity (CBD) to combating IAS: prevention of new introductions through trade bans and pathway action plans, early detection and rapid eradication to prevent establishment, and management to contain established species and mitigate their impact.

The selection of EU-list species is based on risk assessments. The list currently (since 2 August 2022) has 88 species. It contains eastern baccharis *Baccharis halimifolia* which is known to behave invasive in coastal ecosystems and dunes, giant rhubarb *Gunnera tinctoria* which can invade coastal cliffs, as well as invasive macrophytes like Nuttall's waterweed *Elodea nuttallii* and curly waterweed *Lagarosiphon major* which are known to occur in coastal and dune ponds (e.g. Provoost and Adriaens 2011). However, the selection of species for the list of Union concern follows specific criteria set out in the Regulation. More widespread notorious invasive plant species of coastal and dune ecosystems (e.g. hottentot fig *Carpobrotus edulis*., Japanese rose *Rosa rugosa*) lack the typical profile of Union List species and are lacking from the list. The risk screening exercise described in this study aimed to provide a more comprehensive overview of (potentially) problematic plant species, considering in particular the susceptibility of protected coastal dune habitats (Annex I habitats of the Habitats Directive) of the Atlantic coastal area in Europe.

Through the European **LIFE project DUNIAS (DUNe restoration by tackling Invasive Alien Species, LIFE20 NAT/BE/001442)**, a consortium of partners under the coordination of the Agency for Nature and Forest (ANB) works on the management and large-scale removal of invasive plant species in the Flemish coastal dunes. During the project, exotic shrub species are removed, communication and awareness raising actions are performed with various target groups, such as networking events and workshops on invasive alien species and their management. One of these workshops was aimed at experts on invasive plants and the coastal environment. The workshop aimed to conduct a **risk screening for (potentially) invasive alien plant species**, and to exchange experiences and expertise on good and best management practices. For species that are present only to a very limited extent, this screening also classifies as a **horizon scan**. This report presents a summary of the methodology and the main outcomes of that workshop.

The list of species resulting from this risk screening exercise will be used in various ways by the LIFE DUNIAS project. First, it will guide increased surveillance for absent and newly occurring alien species in the dunes by implementing this alert list in the early warning portal on the citizen science platform www.waarnemingen.be/exoten, and the LIFE RIPARIAS (LIFE19 NAT/BE/000953) early alert tool (https://alert.riparias.be/). Second, it will serve as a basis to make risk management decisions e.g. which emerging alien species need a rapid response and which established, high-impact species should be managed. Third, it wants to provide baseline information on the threats alien species pose to European protected habitats, thereby **increasing the complementarity between juridical instruments for protection such as the EU Habitats Directive and the EU IAS Regulation**. To this end, the resulting list is confronted with the criteria for Article 17 reporting on habitat conservation status. Finally, it aimed to streamline alien species interventions in dunes of the European Atlantic coastal region and to promote exchanges with other LIFE projects on management.

This report further collects accounts on the management of a selection of invasive alien plant species. These are species for which the Agency for Nature and Forest (ANB) needs extensive information in light of the planned actions within the LIFE DUNIAS framework. These qualitative descriptions of potential management options follows as much as possible the guidelines for the drafting of best management practices developed by Adriaens et al. (2015).

2 METHODS

2.1 RISK SCREENING

Considering the multitude of species and the continuous changes in invasion pressure, which is subject, for example, to a variety of trends and market mechanisms in horticulture, gardening and landscaping, there is a need for simple yet robust rapid screening methods for selecting the highest-priority species. Conducting comprehensive risk analyses that can substantively estimate the probability of arrival, introduction, establishment, spread and the magnitude of ecological and other impacts, for example using species dispersal models, is expensive and time-consuming.

A commonly used method for identifying future high-risk introductions of alien species is to conduct **risk screenings**. When these screenings are focused on species that are currently absent from the assessed region, or present only to a limited extent, such screenings can be considered as **horizon scans**. In both cases, these refer to the systematic examination of potential threats and opportunities. The method has long been used in social and medical sciences but has been increasingly used in ecology over the last decade (Sutherland et al. 2008). It is now well established and often used to identify prospective (potentially invasive) alien species. Often, risk screening are applied in a two-step approach whereby priority potential problem species identified by a first screening undergo a detailed risk analysis. A good example is the European horizon scan by Roy et al. (2015, 2019), which still serves as the basis for the selection of species undergoing risk analysis for inclusion in the European list of alien species of concern to the Union sensu the IAS Regulation (EU 1143/2014). As another example, recent horizon scan initiatives in European countries are used as a basis for national lists of regulated alien species (e.g. Greece in prep., Bertolino et al. 2020 for mammals in Italy; D'hondt & Adriaens 2022).

2.2 CONSENSUS METHOD

For conducting risk screenings or horizon scans, there are many possible approaches but typically they consist of a **combination of gathering available scientific evidence and a moderated process for capturing expert knowledge**, also and especially where scientific studies are lacking. To carry out the screening for LIFE DUNIAS, we used a methodology based on Roy et al. (2014) (Figure 1). This methodology consists of the following steps:

- the collection of data, literature and expert knowledge to establish an initial longlist of candidate (potentially invasive) alien species;
- a systematic scoring exercise conducted by several experts (scientists and managers) based on objectified criteria and taking into account the confidence on the statements made by the experts;
- a consensus workshop (*Assessment of current and future Invasive Alien Species in European coastal dune ecosystems*, 19-20 May 2022, De Panne, Belgium) where different opinions were confronted, and impact and confidence scores were adjusted to finally obtain a prioritised list (Figure 1).

The expert judgements can be supported to a greater or lesser extent with scientific material provided along with them to equalise the knowledge base before the start of the exercise. At the same time, the consensus workshop offers experts the opportunity to share new insights with each other, which is a learning process. Of importance is a balanced composition of the expert panels and the provision of clear guidelines for the scoring exercise to exclude interpretation problems or linguistic uncertainty as much as possible.

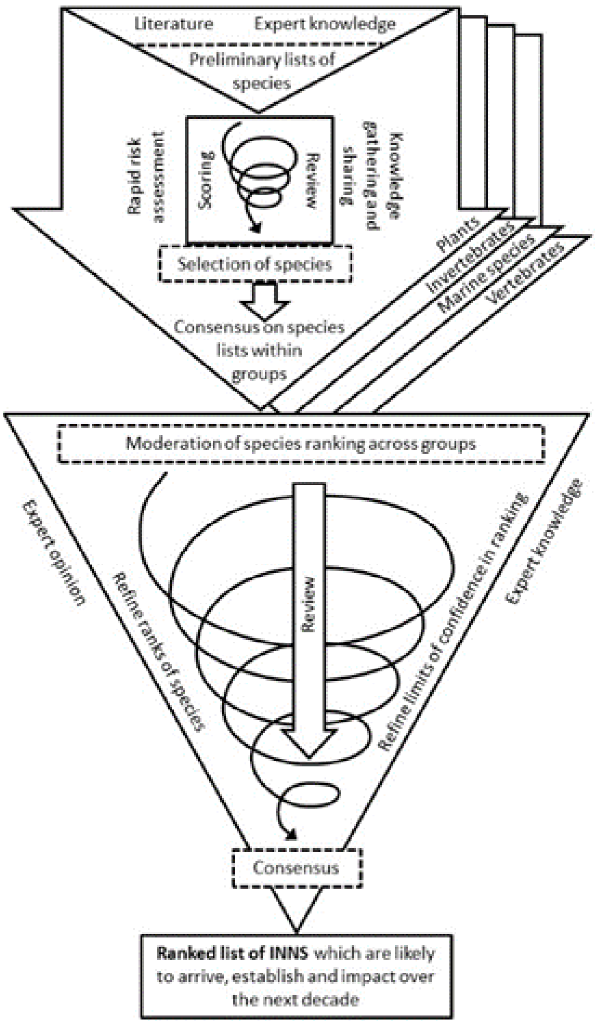

Figure 1. The process of horizon scanning for alien species, from Roy et al. (2014).

Specifically, in the context of DUNIAS, we used an adapted version of this methodology (below). The approach differs in the explicit focus on impacts of alien species on different European protected habitat types of coastal dunes, and in a more data-driven workflow for drafting the longlist of species to consider, by using the Global Biodiversity Information Facility (GBIF).

2.3 FOCUS: PROTECTED HABITATS

Risk screenings for potentially invasive species may differ in their scope(s):

- *geographic scope*, e.g. for a collection of countries (Matthews et al. 2014, 2017 for the Netherlands; Roy et al. 2015, 2019 for Europe; Roy et al. 2014 for Great Britain; Peyton et al. 2019, 2020 for Cyprus) or specific transboundary regions (e.g. Gallardo et al. 2016 for the project area of the Interreg 2Seas project RINSE; NOBANIS 2015 for the Northern European and Baltic region);
- *species group* (taxonomic) scope (e.g. Swart & Robinson 2019 for alien crabs, Thomas 2010 for terrestrial plants, Parrot et al. 2009 for animal species, Bertolino et al. 2020 for mammals);
- *domain of impact* of alien species (e.g. Peyton et al. 2019 for biodiversity, Peyton et al. 2020 for human health and economy);
- *types of ecosystems* (e.g. Tsiamis et al. 2020 for marine exotic species; Thomas 2010 for terrestrial ecosystems; all other references above for both terrestrial, marine and freshwater systems).

For DUNIAS, we have put the focus of the horizon scan on protected habitats. This focus already inherently constitutes a first means of prioritisation within the broader pool of alien species with potential biodiversity impacts. Also, impact on the quality of protected nature in itself represents a forms of impact that would score higher on the impact scale. Also, for eventual use and application of the resulting prioritised list, this focus offers advantages, in particular through the application of the criteria around alien species for assessing local conservation status of habitats (Art 17 reporting).

A logical classification we followed for protected habitats are the **Annex I habitats of the European Habitats Directive** (European Commission 2013). For the purpose of the DUNIAS workshop, the habitats were grouped in three "ecoseries", i.e. groups of habitats that share an affinity with regard to abiotic conditions, dynamics, or location within the broader coastal ecosystem (Table 1). These ecoseries were nick-named as comprising the “salty”, “sandy” and “shrubby” habitats.

Table 1. Protected NATURA2000 dune habitats relevant to Atlantic coastal dunes that were the subject of thematic working groups at the DUNIAS workshop.

Ecoseries	Annex I habitat considered for DUNIAS
Tidal salt marshes (“salties”)	1110 - Sandbanks
	1130 - Estuaries
	1140 - Mudflats and sandflats
	1210 - Annual vegetation of drift lines
	1230 - Vegetated sea cliffs of coasts
	1310 - Annuals colonising mud and sand
	1320 - *Spartina* swards
	1330 - Atlantic salt meadows
Embryonic dunes, mobile sand dunes and dune graslands (“sandies”)	2110 - Embryonic shifting dunes
	2120 - Shifting dunes along shoreline (white dunes)
	2130 - Fixed coastal dunes with herbs (grey dunes)
	2140 - Decalcified dunes with *Empetrum*
	21A0 - Machairs
	2150 - Atlantic decalcified fixed dunes
	2190 - Humid dune slacks
Dune scrub and woodland (“shrubbies”)	2160 - Dunes with *Hippophae rhamnoides*
	2170 - Dunes with *Salix repens* ssp. *argentea*
	2180 - Wooded dunes of the Atlantic region

Picture 1. Collage of pictures illustrating protected dune habitats considered in the risk screening.

1110 – Sandbanks *(Vildaphoto, Yves Adams)*

1130 – Estuaries

1140 - Mudflats and sandflats

1210 - Annual vegetation of drift lines *(Saxifraga, Jan van der Straaten)*

1230 - Vegetated sea cliffs of coasts

1310 - Annuals colonising mud and sand

1320 - *Spartina* swards

1330 - Atlantic salt meadows

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2110 - Embryonic shifting dunes


2120 - Shifting dunes along shoreline (white dunes)


2130 - Fixed coastal dunes with herbs (grey dunes)


2140 - Decalcified dunes with *Empetrum*


21A0 - Machairs


2150 - Atlantic decalcified fixed dunes


2190 - Humid dune slacks


2160 - Dunes with *Hippophae rhamnoides*

2170 - Dunes with *Salix repens* ssp. *argentea* *(Vildaphoto, Yves Adams)*

2180 - Wooded dunes of the Atlantic region *(Kris Decleer)*

2.4 DRAFTING A LIST OF SPECIES OF CONCERN

2.4.1 The longlist

As our undertaking was to narrow down a very wide set of taxa in consecutive steps, we break down the workflow according to a series of lists: (1) the longlist, (2) the workshop list and (3) the shortlist.

The **longlist** refers to the full list of plant species that are considered alien to the Atlantic coastal dune region, and thus worthy of closer examination. This is the list that was shared with contributors, to request for their individual input prior to the workshop.

To compile the longlist, we used a **data driven approach**. First, we compiled and standardized alien species checklists, selecting tracheophytes, bryophytes and marchantiophytes at the rank of species, subspecies or varieties (for brevity referred to as 'species' or 'taxa') from:

- The GRIIS (Global Register of Introduced and Invasive species, https://griis.org/, [Pagad et al. 2018, 2022]) checklists of EU countries with Atlantic coastal dunes (Belgium, France, Ireland, Netherlands, Spain, Denmark, Germany, Portugal), including also the United Kingdom given its central position within the Atlantic region. Hence, the following GRIIS checklists were mined for their alien plants:
    - GRIIS Belgium (Desmet et al. 2021)
    - GRIIS France (Thevenot et al. 2022)
    - GRIIS Ireland (O'Flynn et al. 2020)
    - GRIIS Netherlands (van Delft et al. 2022)
    - GRIIS Spain (Dana et al. 2022)
    - GRIIS United Kingdom (Roy et al. 2020)
    - GRIIS Denmark (Møller et al. 2020)
    - GRIIS Germany (Gollash et al. 2022)
    - GRIIS Portugal (Marchante et al. 2020)
- The species list of Giulio et al. (2020: Annex S7) comprising alien plant species across European coastal dunes of the Atlantic, Baltic, Black Sea and Mediterranean coasts of Europe.
- An ad hoc list of 101 invasive non-native plant species in sand dunes in the United Kingdom, compiled within the framework of this exercise by a group of UK and international colleagues (Peyton et al. unpublished).

We then excluded species that were to be considered synonyms according to the GBIF taxonomic backbone and only retained accepted names of taxa.

Also, taxa native to (any part of) Europe were excluded, mostly using native range and origin information from GBIF and GRIIS Belgium (Desmet et al. 2021). As these data were hard to retrieve, a conservative approach was taken, by retaining doubtful species at this point (for quality control, see below).

The resulting compilation at this point consisted of 5.309 unique plant taxa.

Second, we harvested post-1950 occurrences (human observations and observations) for all these taxa from GBIF. We then retained only those taxa with **at least one occurrence in the Atlantic coastal zone**. This zone was integrated in the analysis as a grid of cells of 10 × 10 km^2 (Figure 2).

As a result, the longlist ended at **1.317** plant taxa. This list was then circulated as a spreadsheet via e-mail to potential participants and interested contributors to the workshop. These were either people active in the management of alien species in coastal dunes, botanists or experts in invasive species (Annex 2).

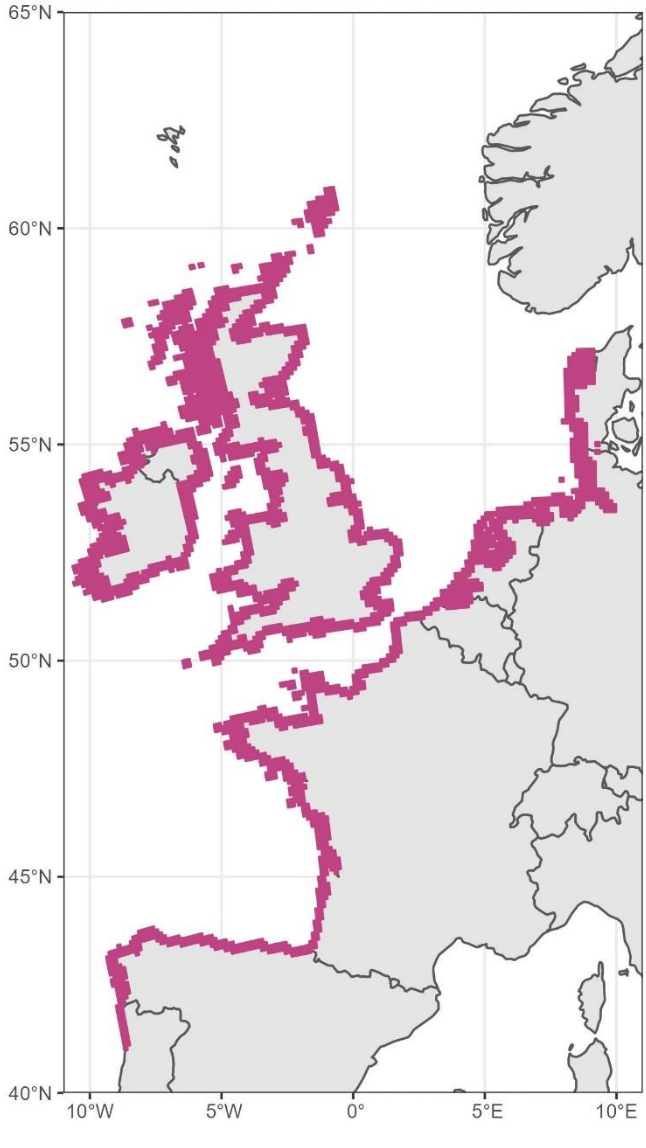


Figure 2. The selection of 10 × 10 km^2 squares considered as the European Atlantic coastal zone, as used for the selection of occurrences of alien plants in the screening.

2.4.2 The workshop list

The contributors were asked to individually examine the longlist over the course of a pre-workshop period (28 April to 16 May). The input gathered from them would be used to compile the **workshop list**.

Spefically, the contributors were asked to assess the following aspects from the longlist (Figure 3):

1. perform quality control on the native status (native to Europe). Any native species was to be flagged, for omission in further analysis.

2. add any species to the list that they thought was missing (thus focusing on species alien to Europe, but occurring in the Atlantic coastal area). Any such species should be taken along in further steps.
3. provide their opinion on the relevance of the species for further scoring. For this, species were flagged with any of the following three marks (blank if the species was unknown to them):
    - 1 = ecological impact unknown,
    - 2 = no relevant ecological impact,
    - 3 = (potential) ecological impact. The contributors were informed that this mark meant as much as: “I think this species should be looked at in depth”.
4. ONLY for the species that contributors marked as having a (potential) ecological impact (mark = 3), they were asked to flag those habitats (see 0) where the species would be expected to grow in.
5. ONLY for the species that contributors marked as having a (potential) ecological impact (mark = 3), they were asked to indicate the mechanisms through which the species could exert a (potential) impact (see 5.1.1).
6. Transversally, contributors were asked to provide evidence or statements for any modification to the spreadsheet, so as to document the process as best as possible and follow an evidence-based approach. This could be done through the comments box.

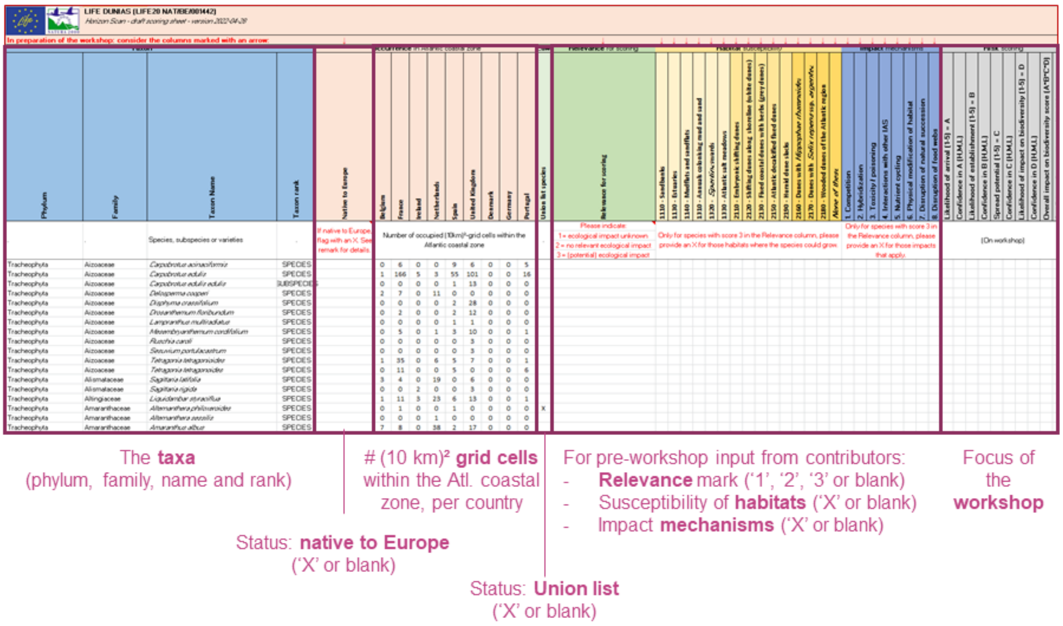


Figure 3. A sample from the longlist, in spreadsheet format, as circulated to contributors pre-workshop.

The instructions deliberately stated that a rapid screening was sufficient at this point, and that contributors could base themselves on their ready knowledge.

When the longlists were returned to us, any line that had any change to it, relative to the integer longlist (i.e., marks that were added, or species that were added,...), was extracted and transferred to a master file. As such, we received 3.300 lines of feedback on 1.446 species. For about half of the species (731), there was input from two or more contributors (as compared to 715 species with input from only when contributor; Figure 4).

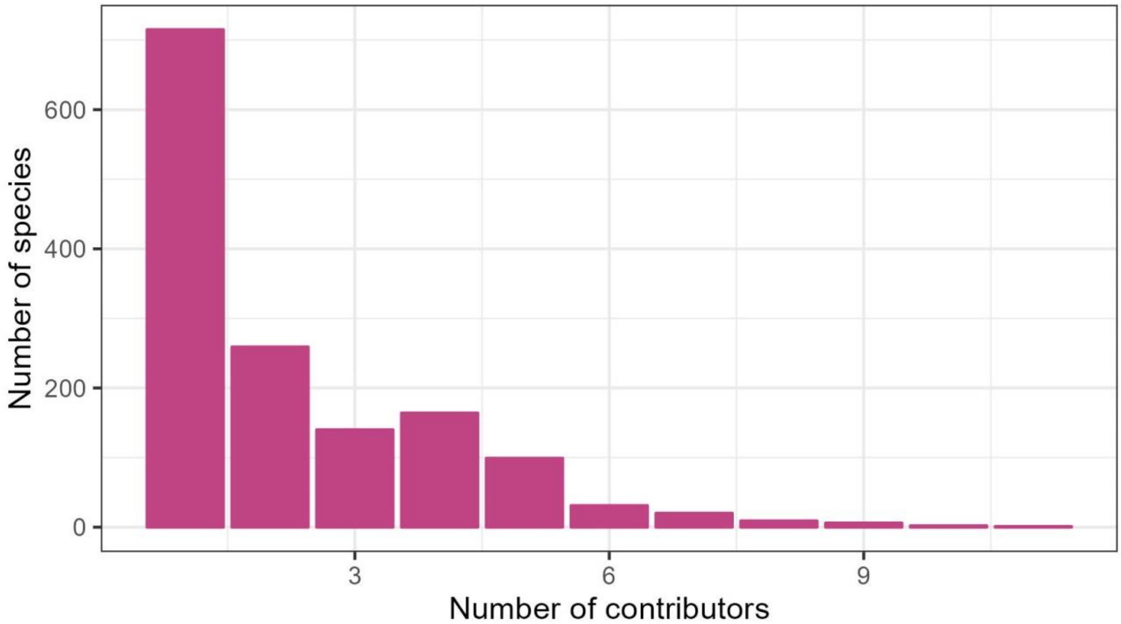


Figure 4. Frequency distribution of the number of species, given the number of contributors that provided input on that species.

Then, we filtered all species that were marked as having **(potential) ecological impact** (mark = 3) by **at least one contributor**, to take further to the next step. In case a species was marked as having an impact, but also as native to Europe (in an earlier step, or by another contributor in parallel), that species was kept within the list. This resulted in the **workshop list**, that ended at **344** plant taxa (Figure 5, Annex 5). These were the species that were taken to the workshop (19-20 May).

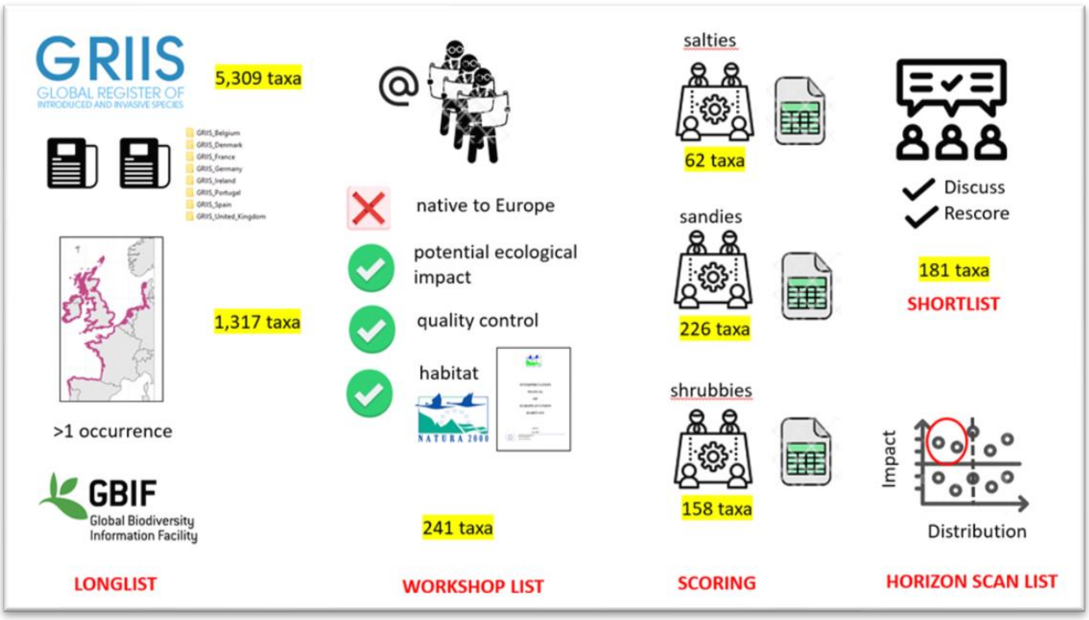


Figure 5. Schematic representation of the different steps in the process of prioritisation through risk screening.

2.4.3 The workshop (risk scoring)

The goal of the workshop was to assess the ecological risk of species and transform the resulting prioritized list into a **shortlist**, bringing together all the risk scores for species deemed relevant by participants. Here, we will provide further details on the workshop and the methods used for scoring. The results of the shortlist will be dealt with in chapter 3.

For the scoring part of the workshop, the participants were divided in three groups, following the three habitat groups recognized earlier (ecoseries: "salties", "sandies" and "shrubbies", Table 1). As such, the participants were asked to focus on the species relevant to their group. This relevance was based on whether at least one expert had previously flagged that species for at least one subsceptible habitat from that habitat group. Participants were presented with all the species from the workshop list, so changes to habitats (adding or removing a susceptible habitat for an alien species) could be made on-workshop. Also, species could be newly added to the list and had then to be considered and scored by each of the three groups.

The joint on-workshop assessment was based on a number of criteria relating to the different steps of the invasion process (Blackburn et al. 2011), and the potential invasion impact. Experts were asked to consider the LIFE DUNIAS timeframe when assessing species, which roughly corresponds to the next ten years. Before scoring was performed in break-out groups, guidance was provided on the methodology used for scoring. The scoring system used is largely based on Peyton et al. (2019).

In general, it was stressed that the scope for scoring was the species in the context of the protected habitats considered (Table 1, Picture 1). Experts had been given a presentation on those specific habitats and were asked to consider these throughout scoring, with the spatial and landscape context in which they occurred. Also, experts were reminded that the scoring exercise partly represents a horizon scan (i.e. impacts may have not yet manifested themselves), and thus requires them to embrace the notion of risk (likelihood). Also, they were asked to clearly disentangle the different invasion stages (e.g. score biodiversity impact irrespective of spread).

Picture 2. Before heading off into break-out groups, participants to the workshop received presentations on the highest impact IAS in the different countries, their impact mechanisms, as well as guidance on the criteria for scoring biodiversity impact.

For the scoring, experts were directed to a number of information sources, such as the GBIF (https://www.gbif.org/) and the GRIIS checklists of the different countries, the habitat manual (European Commission 2013), scientific and scholarly libraries (Web of Knowledge, Google scholar), the CABI Invasive Species Compendium (https://www.cabidigitallibrary.org/product/qi), the Manual of Alien Plants (https://alienplantsbelgium.myspecies.info/), Wikipedia etc. To provide reasoning behind scores or to document information sources, a comment field was available in the spreadsheet.

2.4.3.1 Likelihood of introduction

The likelihood of introduction was scored on a 5-point scale (1 = low likelihood; 5 = high likelihood). To assess this, experts were specifically asked to consider the likelihood that the species would arrive in the protected habitats (Table 1) within the European Atlantic coastal zone (Figure 2). Species that already arrived in the Atlantic coastal zone (as evidenced by the number of 10x10 km grid cells in which they occur in the different countries, see 5.1.1) do not necessarily have a high likelihood of introduction in protected areas. Experts were asked to consider this, taking into account specific introduction pathways such as ornamental trade, natural dispersal, transport commodities (Harrower et al. 2018), neighbouring populations, location and size of potential source populations (e.g. in gardens, urban areas, public greenery, ruderals), propagule pressure or introduction effort (number and frequency), the presence in ornamental garden trade or any other relevant consideration.

2.4.3.2 Likelihood of establishment

The likelihood of establishment in the protected habitats (Table 1) within the European Atlantic coastal zone (Figure 2) was scored on a 5-point scale (1 = low likelihood; 5 = high likelihood). Establishment is interpreted as the formation of sustainable, self-sustaining populations. We note that the establishment score is interpreted at the level of the specific habitat series considered, rather than at the level of the Atlantic coastal zone. For species that are already established in the Atlantic coastal zone (as evidenced by the number of 10x10 km grid cells in which they occur in the different countries, see 5.1.1) this does not necessarily mean the likelihood is high in protected areas. For instance, a halophytic species might be widespread in the Atlantic coastal zone, but it will score low in the habitat series embryonic dunes, mobile sand dunes and dune graslands (“sandies”) or dune scrub and woodland (“shrubbies”). Experts were asked to consider likelihood of establishment, taking into account the physiology of the species (e.g. halophyte, nitrogen fixing species), its reproductive biology (e.g. specific requirements such as pollinators, formation of seeds, cold tolerance, mechanism of vegetative reproduction), physiological constraints on establishment (e.g. germination requirements, dormancy) or biotic resistance of the habitats (e.g. available ecological niches, presence of competing species).

2.4.3.3 Likelihood of spread

The likelihood of spread in the protected habitats (Table 1) within the European Atlantic coastal zone (Figure 2) was scored on a 5-point scale (1 = low likelihood; 5 = high likelihood). Spread is defined as the expansion of the geographical distribution of an alien species within the protected habitats in the Atlantic coastal area. Experts were asked to score this based on data or knowledge on the species dispersal capacity (e.g. dispersal of berries by birds, wind or water dispersed seeds, vegetative spread), propensity for human-mediated (e.g. visitors, cars, intentional introductions for erosion control or dune stabilisation) spread or other.

2.4.3.4 Likelihood of biodiversity impact

In this assessment, specifically, we considered the impact on species and habitats of conservation concern, more specifically impact on legally protected habitats of the NATURA2000 regime. The likelihood of biodiversity impact in the protected habitats (Table 1) within the European Atlantic coastal zone (Figure 2) was scored on a 5-point scale (1 = minimal, 2 = minor, 3 = moderate, 4 = major, 5 = massive). To provide an equal baseline on the magnitude of impact, experts were provided guidance adapted from the risk assessment template used for drafting pest risk assessments for the Union List of the EU Regulation (European Commission 2022).

Table 2. Scores and criteria used for scoring the potential magnitude of biodiversity impact of species.

Score	**Biodiversity and ecosystem impact**
Minimal	The species (potentially) causes local, short-term population declines, but causes no significant ecosystem impact
Minor	The species (potentially) causes local, short-term population loss. Some ecosystem impacts are possible but these are mostly reversible changes.
Moderate	The species (potentially) causes measurable long-term damage to populations and ecosystems, but the damage is mostly local or regional and reversible, it does not cause extinction of native species.
Major	The species (potentially) causes long-term, irreversible ecosystem change, the impacts spread beyond the local level and are more widespread, the species (can) cause population loss or extinction of native species.
Massive	The species (potentially) causes widespread, long-term population losses or extinctions in native species, affecting several species with serious ecosystem effects.

2.4.3.5 Overall impact on biodiversity

The overall impact on biodiversity was calculated (for each of the three habitats groups separately, see 0) as the product of the scores for likelihood of introduction, establishment, spread and impact. Hence, the maximum score per habitat group was 625, the minimum score was 1.

$$\textbf{Introduction} \times \textbf{Establishment} \times \textbf{Spread} \times \textbf{Impact} = \textbf{Overall score}$$
$$[1\text{-}5] \times [1\text{-}5] \times [1\text{-}5] \times [1\text{-}5] = [1\text{-}625]$$

Picture 3. Photographic impression of the joint assessment of alien species at the LIFE DUNIAS workshop *Assessment of current and future Invasive Alien Species in European coastal dune ecosystems* (De Panne, Belgium, 19-21 May 2022). Here, the salties group are in action.

2.4.3.6 Scoring of confidence

Experts were asked to provide a confidence on their scoring for each of the different criteria (introduction, establishment, environmental impact) as well as on the overall score following Peyton et al. (2019) (Table 3). This confidence was used for the consensus building as well as to provide a general feel of the quality and amount of evidence available for the difference criteria.

Table 3. Score and descriptions for scoring the level of confidence on the assessments.

Score	Description
Low (L)	no direct observational evidence is available or evidence is difficult to interpret or considered low quality
Medium (M)	some direct observational evidence is available but may be ambiguous or difficult to scale within the specific geographic context
High (H)	direct observational evidence is available and straightforward to interpret without controversy and considered high quality

2.4.4 Post-workshop assessments

Given the depth at which species needed discussion, and the large number of species for discussion, not all species could be dealt with at the workshop. Particularly in the "sandy" and "shrubby" habitat group, some species were left unscored, though the group moderators made sure that the most relevant ones (based on e.g. the pre-workshop input) were discussed at that occasion.

To complete the scoring, the INBO project team (Annex 2) took the scoring further in group discussions (similar to the on-workshop discussions) after the workshop.

2.5 LIMITATIONS OF THE EXERCISE

We should reiterate that we started from a longlist of species with at least one GBIF occurrence in the Atlantic coastal region. Although this renders the exercise more data-driven (and therefore more efficient), and perhaps more realistic and more focused on recent invasion events, our risk screening was confined to alien plant species on the *not so distant* horizon. The LIFE DUNIAS project did not have the capacity to run climate matching algorithms (cf. D'hondt et al. 2022 for Union List species in Flanders using occurrence cubes using Oldoni et al. 2020a, 2020b, 2022a, 2022b, Vanderhoeven et al. 2017), to perform detailed species distribution models (e.g. https://trias-project.github.io/risk-maps/, or the procedure followed in EU pest risk assessments for the EU Regulation - Chapman et al. 2019) or to provide experts with a systematic literature review to assist in scoring. These could however considerably improve future exercises.

There are however many areas in the world with coastal grasslands, salt marshes and sand dunes, both in the Northern and Southern hemisphere (e.g. Martínez et al. 2004). Therefore, there might very well be species on the horizon that currently have no occurrences at all in the European Atlantic coastal region. These can be considered *'true' horizon scan species*. One such example is the Asiatic sand sedge (*Carex kobomugi*), a sedge species from sandy coastal areas of eastern Asia which has become an invasive species in similar habitats in the north-eastern United States and other parts of the world after being planted for stabilising sand dunes (CABI compendium, Kim 2005).

Also, we note that GBIF data are subject to publication biases (e.g. Groom et al. 2015), with some countries pushing more datasets to GBIF and differences in publication frequency between countries. Lastly, the GRIIS checklist of the different countries are heterogenous in the way they are composed and (if at all) maintained and updated (Reyserhove et al. 2020).

Finally, the risk screening we performed is sensitive to the amount of experts and the expertise that could be mobilized within the framework of one single two-day workshop with preliminary, non-remunerated work for experts to screen the longlist (Annex 2). At the DUNIAS workshop, in particular, representation from France, Denmark, Germany and the Mediterranean was rather poor.

2.6 MANAGEMENT FEASIBILITY

A second part of the workshop was devoted to a qualitative management prioritization exercise. To structure this, first, a number of management case studies were presented on various species (Annex 1). After that, guidance was provided on assessment of management feasibility and a survey was filled by the workshop participants to grasp their opinions on the feasibility of management of a number of high profile IAS.

To broadly assess management feasibility, we used an adapted version of the framework of Booy et al. (2017, 2020) that is used for assessing eradication feasibility using expert judgement. This methodology used the criteria effectiveness, practicality, cost, acceptability, non-target impacts, window of opportunity and likelihood of reintroduction for judging on an overall feasibility of an eradication strategy which should be clearly defined before such exercise is undertaken. Such a thorough assessment (cf. Adriaens et al. 2019), with predefined invasion scenarios and eradication strategies was impossible within the framework of a two-day event and without prior knowledge on the exact list of species that would come out of the prioritization. Also, proper expert elicitation would try to grasp the evidence base used by the experts, would rule out linguistic uncertainty by providing guidance and would assess uncertainty on the opinions by asking assessors for their confidence on statements and/or the quality of evidence. All of this was not part of the workshop.

Nonetheless, to structure the survey and to allow comparison of feasibility across the different species, participants had to answer the same question for every species: "*I believe eradicating the species from the Atlantic coastal area is feasible*". Note that for this assessment too, participants were asked to consider the specific protected habitats within the delimitation of the Atlantic coastal area considered for the exercise. Participants could choose only a single option out of the following categories of answers that were inspired by most of the criteria of Booy et al. (2017) except for practicality:

- I honestly have no clue
- Yes, totally, this should be the goal
- No, I think there are no effective methods available (effectiveness)
- No, I think this would be too costly (cost)
- No, I think this would face disapproval or resistance from individuals, groups or sectors (acceptability)
- No, I think management would do more harm than good (non-target impact of management)
- No, the species is already too widespread, it is already too late (~ window of opportunity)
- No, I think there would be instant recolonisation from other infected areas (likelihood of reinvasion)

To increase the chances of getting clear patterns as a basis for discussion, respondents were asked to hit either the don't know, yes or no (with multiple answers possible only within the "no" category). The resulting graphs were used to generate discussion among participants on management feasibility for some of the IAS under consideration.

3 RESULTS

In this part, we will first elaborate on the results from the **shortlist**, i.e. the list of species with risk scores assigned at the workshop (see 2.4.3). For details regarding the steps that preceded this selection (i.e. the longlist and the workshop list) we refer to the methodology. Second, we will present the results from the **management feasibility**, as assessed at the workshop (see 2.4.4).

3.1 SPECIES OF CONCERN

During the workshop, ten species were added to the workshop list (which was used as the initial input for the scoring assessment and counted 344 species; see above). On the other hand, a total of 113 species were not taken further for scoring, because (1) they had not been attributed to any of the coastal habitats prior to the workshop, nor on the workshop itself; or (2) they were agreed on to be native to Europe, thus falling out of scope. As a result, the shortlist with actual risk scores was ended at **241** plant taxa.

An overview of the scores (the product of the scores for introduction, establishment, spread and impact, range: 1-625) for these 241 plant taxa is provided in **Annex 3**.

Subsequently, some reconsiderations were taken on the shortlist on which taxa could better be lumped for further analysis (e.g. a subspecies with its species, e.g. *Agapanthus praecox orientalis* with *A. praecox*; closely related species of species complexes, e.g. *Casuarina cunninghamiana* together with *C. equisetifolia*; functionally similar species of the same genus, e.g. *Cotoneaster* spp. of low-growing habit). After having done so, the shortlist was narrowed down to 181 functional taxa.

3.1.1 High-risk species: overall

Looking only at the overall score across the habitat groups (i.e. considering the maximum score of the three groups), twelve species were attributed the maximum score of 625 (Table 4).

Table 4. Top ranking species for overall ecological impact across all the habitat groups based on the maximum of scores across habitat groups.

#	TaxonName	max(score)
1	*Ailanthus altissima*	625
2	*Baccharis halimifolia*	625
3	*Berberis aquifolium*	625
4	*Campylopus introflexus*	625
5	*Carpobrotus edulis*	625
6	*Crassula helmsii*	625
7	*Heracleum mantegazzianum*	625
8	*Paspalum vaginatum*	625
9	*Prunus serotina*	625
10	*Rosa rugosa*	625
11	*Rubus armeniacus*	625
12	*Solidago alt./can./gig.*	625

Under the rationale of horizon scanning, it is of a general interest to consider the high risk species that currently only occur to a limited extent in the Atlantic coastal region. To look at this, we positioned the 181 taxa according to their scores and the number of occupied grid cells and considered the median of the scores and the occupancy. This groups the species of interest (high potential ecological impact, relatively rare in the Atlantic coastal area) in the upper left corner (Figure 6). In order to isolate this subset of species, we use the median of the occupancy to separate the more widespread species from the more rare species, and subsequently use the median of the scores within the latter group to separate the more risky species from the less risky species. The median of the scores is calculated only for the rarer half of species (not all the species), since the widespread species tend to pull the median of scores upwards. This is because the likelihood of introduction is part of the risk score, and this likelihood is, by definition, high for such widespread species.

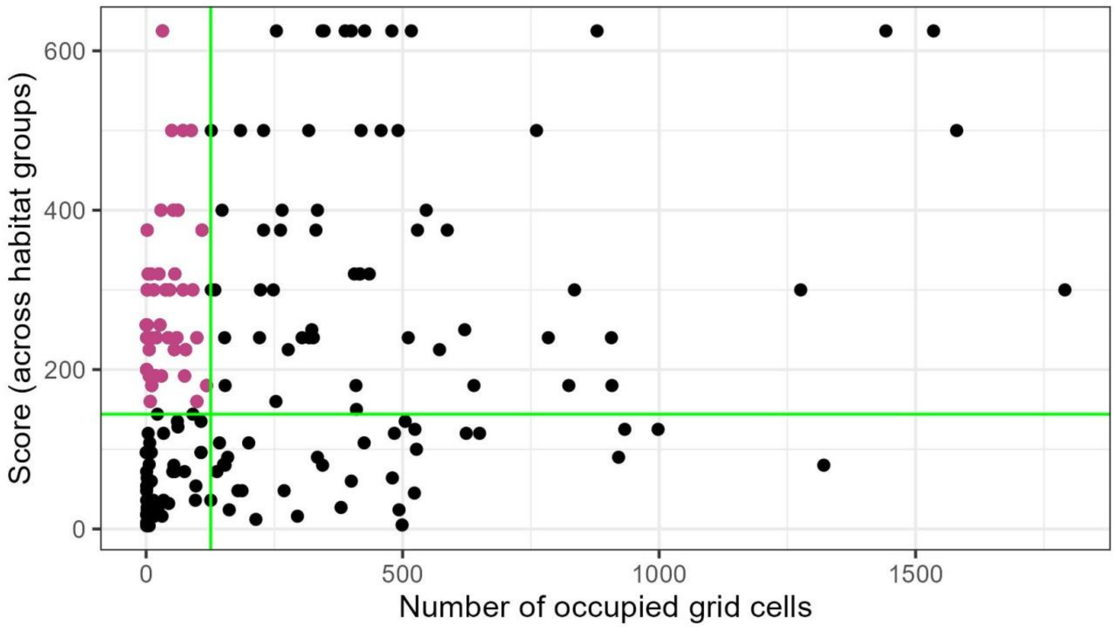


Figure 6. The score (across habitat groups) and the number of occupied grid cells. The vertical green line is the median of the occupancies. The horizontal green line is the median of the scores, for those species that fall below the occupancy median.

This results in a set of 44 species, given in Table 5. These correspond to the purple points in Figure 6.

Table 5. Top ranking species for overall ecological impact across all the habitat groups for the contingent of species that are not too widespread in the Atlantac coastal area (the horizon scan species).

#	TaxonName	#	TaxonName
1	*Acaena anserinifolia/ovalifolia*	23	*Ligustrum japonicum*
2	*Acaena caesiiglauca*	24	*Ligustrum lucidum*
3	*Acaena novae-zelandiae*	25	*Lindernia dubia*
4	*Aloe arborescens*	26	*Lonicera maackii*
5	*Alternanthera philoxeroides*	27	*Ludwigia peploides*
6	*Alternanthera sessilis*	28	*Mesembryanthemum cordifolium*
7	*Amelanchier spicata*	29	*Myriophyllum heterophyllum*
8	*Araujia sericifera*	30	*Opuntia ficus-indica*
9	*Aronia melanocarpa/prunifolia*	31	*Opuntia stricta*
10	*Arundo donax*	32	*Oxalis pes-caprae*
11	*Asclepias syriaca*	33	*Paspalum vaginatum*
12	*Atriplex micrantha*	34	*Populus balsamifera trichocarpa*
13	*Berberis julianae*	35	*Populus jackii*
14	*Conyza bilbaoana*	36	*Reynoutria bohemica*
15	*Delairea odorata*	37	*Schinus molle*
16	*Disphyma crassifolium*	38	*Schinus terebinthifolia*
17	*Equisetum hyemale affine*	39	*Solanum spp. (5 spp.)*
18	*Gaillardia pulchella*	40	*Spartina patens*
19	*Gaillardia x grandiflora*	41	*Spiranthes cernua x odorata*
20	*Gaultheria mucronata/procumbens*	42	*Tetragonia tetragonioides*
21	*Hydrocotyle bonariensis*	43	*Vaccinium corymbosum*
22	*Ipomoea indica*	44	*Vaccinium macrocarpum*

When looking at the distribution of species across susceptible habitats, we see that the "sandy" and the "shrubby" habitats harbour most potentially invasive species (Figure 7). Intuitively, salty habitats are naturally more resistant to invasions. They represent a relatively specialized habitat (and mostly require species to exhibit a degree of salt tolerance or adaptation to a very dynamic system such as mudflats or driftlines) and therefore have a lower number of species.

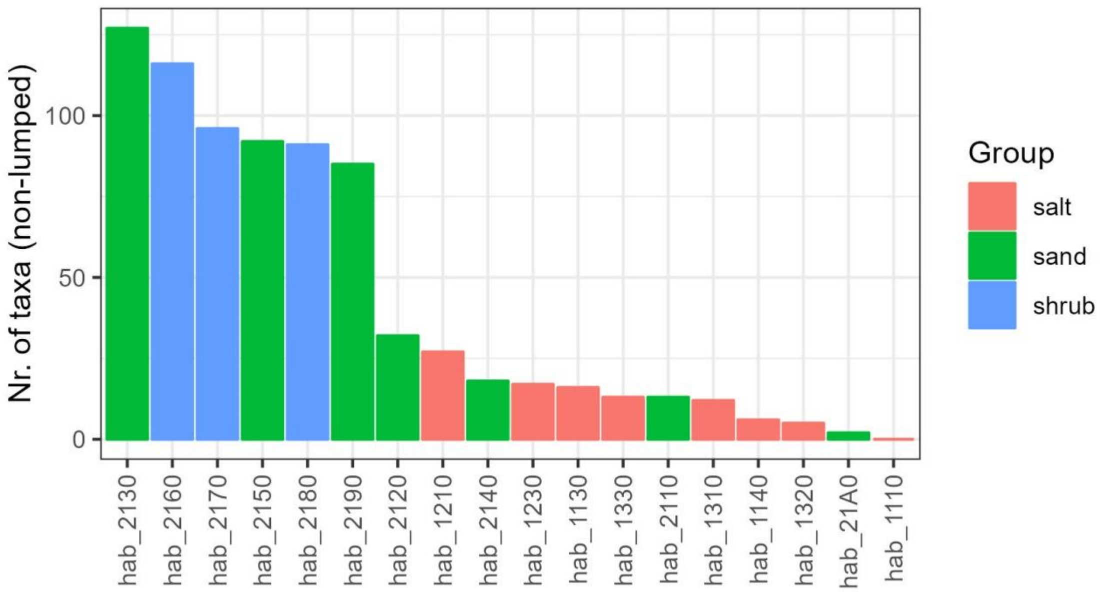


Figure 7. The number of species marked for each of the habitats.

Baccharis halimifolia, *Carpobrotus edulis*, *Mesembryanthemum cordifolium*, *Miscanthus sinensis* and *Rosa rugosa* were considered relevant and assessed in all three habitat groups.

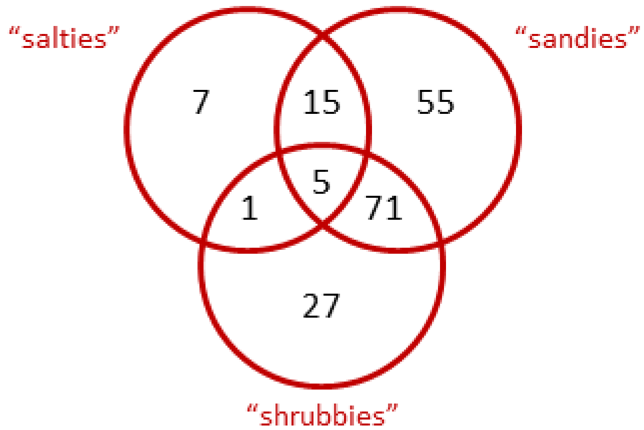


Figure 8. The distribution of the 181 scored taxa, according to the three habitat groups.

There was particular overlap in species among the "sandy" and "shrubby" habitat group (Figure 8). To a large extent these represented woody species that find habitat in closed vegetations, but may establish in open vegetation. Consistently, as this contributes to scrub encroachment, which is regarded as a threat to grassland-like habitats, the scores for these species tended to be slightly higher in the "sandy" group (Figure 9).

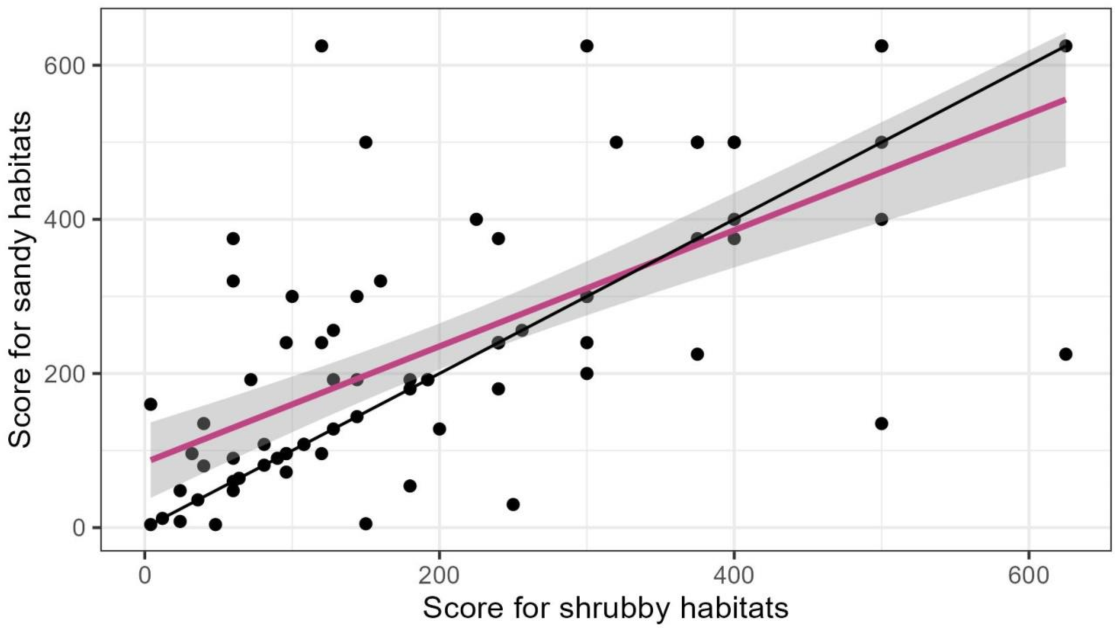


Figure 9. The scores of the 76 species shared among the “sandy” and “shrubby” habitat groups. The black line is the equality line (compare the density of points on, above and below this line). The purple line is a linear regression, with the grey zone showing the standard error.

3.1.2 High-risk species: salty habitats

Twenthy-eight species (out of the 181) were attributed scores pertaining to one or more of the "salty" habitats (codes 1110, 1130, 1140, 1210, 1230, 1310, 1320, 1330), their overall scores ranging from 6 to 625.

A re-iteration of the above analysis, to isolate the "rare but risky" species (upper left quarter in the occupancy-score graph), results in a set of nine priority species (Figure 10, Table 6).

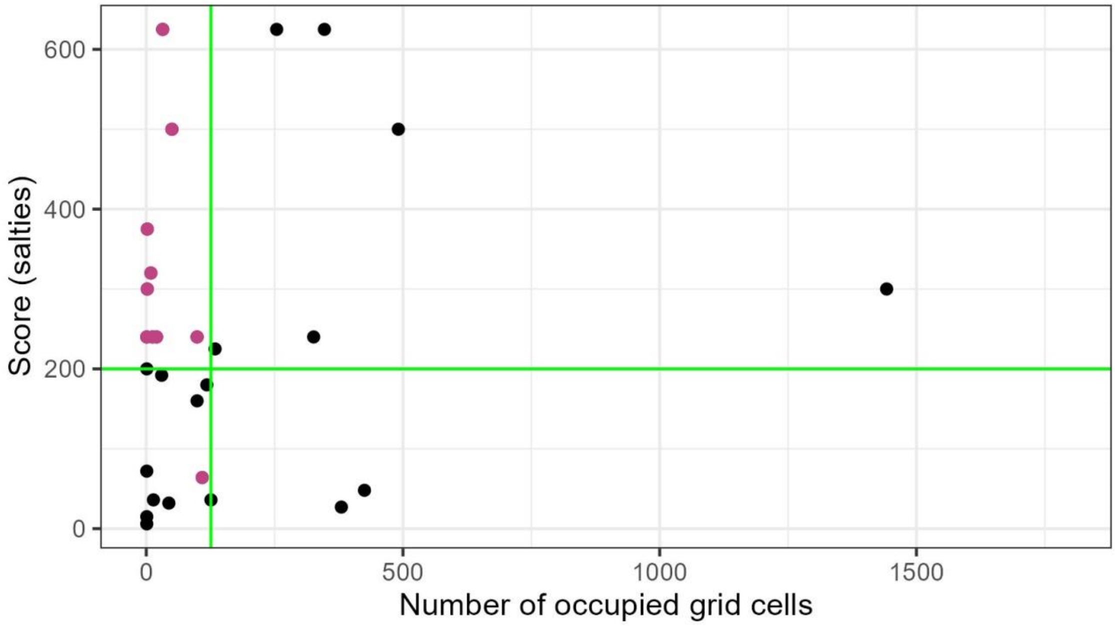


Figure 10. The score (for the "salty" group) and the number of occupied grid cells. The vertical green line is the median of the occupancies. The horizontal green line is the median of the scores, for those species that fall below the occupancy median.

Table 6. Top ranking alien species of **salty habitats** in terms of their potential ecological impacts with a less than median distribution area in the Atlantic coastal area.

#	**TaxonName**
1	*Aloe arborescens*
2	*Alternanthera philoxeroides*
3	*Alternanthera sessilis*
4	*Atriplex micrantha*
5	*Hydrocotyle bonariensis*
6	*Mesembryanthemum cordifolium*
7	*Opuntia ficus-indica*
8	*Opuntia stricta*
9	*Paspalum vaginatum*

3.1.3 High-risk species: sandy habitats

For the "sandy" habitats (2110, 2120, 2130, 2140, 21A0, 2150, 2190), 146 species (out of 181) were given risk scores. Their overall scores ranged from 4 to 625. Thirty-six species (Table 7) fall within the upper left quarter of the occupancy-score (Figure 11).

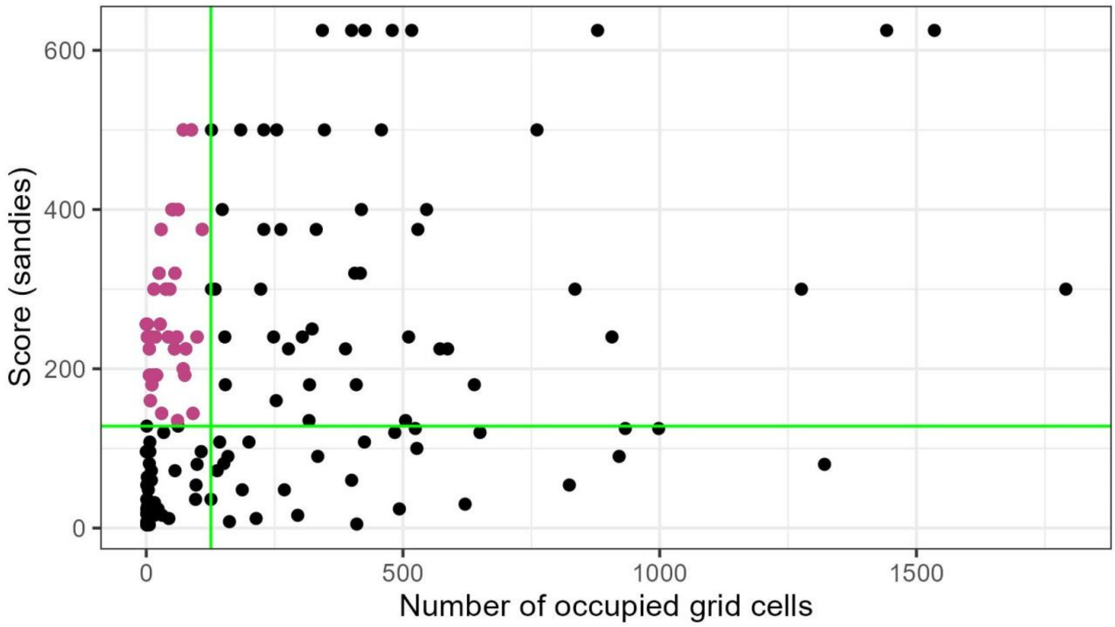


Figure 11. Score for the "sandy" group and occupancy. The vertical green line is the median of the occupancies, the horizontal line the median of the scores for species below the occupancy median.

Table 7. Top ranking alien species of **sandy habitats** in terms of their potential ecological impacts with a less than median distribution area in the Atlantic coastal area.

#	TaxonName	#	TaxonName
1	*Acacia melanoxylon*	19	*Ligustrum japonicum*
2	*Acaena anserinifolia/ovalifolia*	20	*Ligustrum lucidum*
3	*Acaena novae-zelandiae*	21	*Lindernia dubia*
4	*Aloe arborescens*	22	*Ludwigia peploides*
5	*Amelanchier spicata*	23	*Mesembryanthemum cordifolium*
6	*Araujia sericifera*	24	*Myriophyllum heterophyllum*
7	*Aronia melanocarpa/prunifolia*	25	*Opuntia ficus-indica*
8	*Asclepias syriaca*	26	*Opuntia stricta*
9	*Berberis julianae*	27	*Oxalis pes-caprae*
10	*Conyza bilbaoana*	28	*Populus balsamifera trichocarpa*
11	*Disphyma crassifolium*	29	*Populus jackii*
12	*Equisetum hyemale affine*	30	*Reynoutria bohemica*
13	*Gaillardia pulchella*	31	*Schinus molle*
14	*Gaillardia x grandiflora*	32	*Schinus terebinthifolia*
15	*Gaultheria mucronata/procumbens*	33	*Spiranthes cernua x odorata*
16	*Hydrocotyle bonariensis*	34	*Tetragonia tetragonioides*
17	*Ipomoea indica*	35	*Vaccinium corymbosum*
18	*Ipomoea purpurea*	36	*Vaccinium macrocarpum*

3.1.4 High-risk species: shrubby habitats

Lastly, for the “shrubby” habitats (codes 2160, 2170, 2180), 104 species were given scores (out of 181). Their scores ranged from 4 to 625.

Twenty-three high ranking species (Table 8) were relatively rare in terms of their occupancy in the Atlantic coastal region (Figure 12).

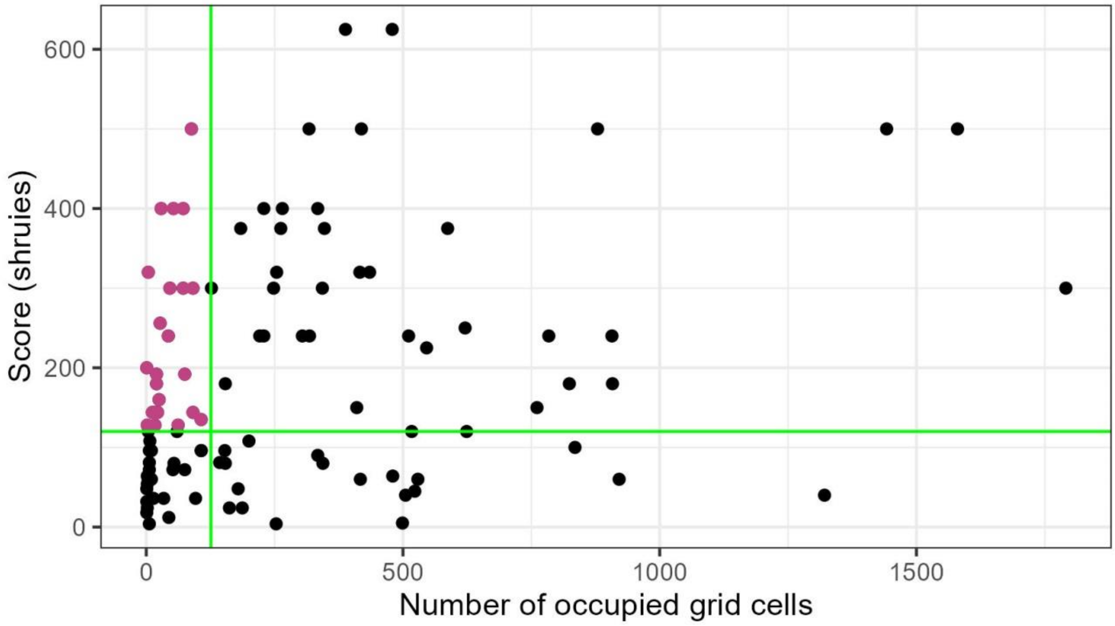


Figure 12. The score (for the “shrubby” group) and the number of occupied grid cells. The vertical green line is the median of the occupancies. The horizontal green line is the median of the scores, for those species that fall below the occupancy median.

Table 8. Top ranking alien species of **shrubby habitats** in terms of their potential ecological impacts with a less than median distribution area in the Atlantic coastal area.

#	TaxonName	#	TaxonName
1	*Acaena anserinifolia/ovalifolia*	13	*Lonicera maackii*
2	*Acaena caesiiglauca*	14	*Melia azedarach*
3	*Acaena novae-zelandiae*	15	*Mesembryanthemum cordifolium*
4	*Amelanchier spicata*	16	*Populus balsamifera trichocarpa*
5	*Aronia melanocarpa/prunifolia*	17	*Reynoutria bohemica*
6	*Asclepias syriaca*	18	*Ribes aureum*
7	*Berberis julianae*	19	*Schinus molle*
8	*Delairea odorata*	20	*Schinus terebinthifolia*
9	*Equisetum hyemale affine*	21	*Symphoricarpos orbiculatus*
10	*Gaultheria mucronata/procumbens*	22	*Vaccinium corymbosum*
11	*Ipomoea indica*	23	*Vaccinium macrocarpum*
12	*Ipomoea purpurea*		

3.1.5 Horizon scan species

Combining the distribution data and the potential ecological impact score from the risk screening workshop, we can identify the species that do not occur in the Atlantic coastal region of some of the individual countries but represent a more than median ecological risk (Table 9).

This list can have applications in multiple domains:

- They are candidates for hard **preventive action** through legislative action (e.g. bans on sale and planting) or soft preventative action (e.g. codes of conduct with the horticultural sector, awareness raising campaigns with garden owners);
- They can be included in **early warning systems**, such as the alien species portal www.waarnemingen.be/exoten directed towards citizen scientists and naturalists in Belgium, which currently highlights a thematic list of 111 plant invaders deemed relevant to the DUNIAS project. This way, naturalists are made more aware of these potential problem species, can get acquainted with their identification and impact, and are stimulated to rapidly report those species if they observe them;
- They could be the subject of **dedicated surveillance** plans;
- They represent **prime targets for rapid eradication** actions should they establish in protected coastal dune areas.

Picture 4. Piri-piri bur (*Acaena novae-zelandiae*), of concern in coastal sand dunes in the UK and Ireland and a true horizon scan species for the European mainland. It forms dense mats and is known to be spreading through the movement of people and animals along footpaths and from car parks (LIFE RAPID 2018).

Table 9. Alien species that do not occur with more than one 10km^2 in the Atlantic coastal region of the different countries but represent a more than median ecological risk, i.e. which have a maximum overall impact score (across the three habitat groups) > 192.

Country	Horizon scan species
Belgium	*Carpobrotus edulis, Mesembryanthemum cordifolium, Tetragonia tetragonioides, Alternanthera philoxeroides, Alternanthera sessilis, Schinus molle, Schinus terebinthifolia, Hydrocotyle bonariensis, Araujia sericifera, Yucca aloifolia, Yucca filamentosa, Aloe arborescens, Delairea odorata, Solidago altissima, Berberis darwinii, Opuntia ficus-indica, Opuntia stricta, Lonicera maackii, Tradescantia fluminensis, Ipomoea indica, Gaultheria shallon, Vaccinium macrocarpum, Acacia dealbata, Acacia longifolia, Acacia saligna, Lupinus arboreus, Gunnera tinctoria, Crocosmia crocosmiiflora, Ligustrum lucidum, Spiranthes cernua x odorata, Oxalis pes-caprae, Pinus contorta, Paspalum vaginatum, Spartina alterniflora, Spartina patens, Acaena anserinifolia, Acaena caesiiglauca, Acaena novae-zelandiae, Acaena ovalifolia, Aronia melanocarpa, Aronia prunifolia, Cotoneaster frigidus, Cotoneaster integrifolius, Cotoneaster microphyllus, Cotoneaster nitens, Cotoneaster pannosus, Cotoneaster watereri*
Ireland	*Lophocolea semiteres, Mesembryanthemum cordifolium, Tetragonia tetragonioides, Alternanthera philoxeroides, Alternanthera sessilis, Atriplex micrantha, Schinus molle, Schinus terebinthifolia, Hydrocotyle bonariensis, Araujia sericifera, Yucca aloifolia, Yucca filamentosa, Yucca flaccida, Yucca gloriosa, Aloe arborescens, Ambrosia artemisiifolia, Arctotheca calendula, Baccharis halimifolia, Cotula coronopifolia, Gaillardia pulchella, Gaillardia x grandiflora, Solidago altissima, Solidago gigantea, Berberis aquifolium, Berberis julianae, Berberis thunbergii, Opuntia ficus-indica, Opuntia stricta, Lonicera japonica, Lonicera maackii, Tradescantia fluminensis, Ipomoea indica, Elaeagnus angustifolia, Equisetum hyemale affine, Vaccinium macrocarpum, Acacia dealbata, Acacia longifolia, Acacia saligna, Lindernia dubia, Claytonia perfoliata, Ligustrum lucidum, Ludwigia peploides, Spiranthes cernua x odorata, Oxalis pes-caprae, Phytolacca americana, Paspalum vaginatum, Spartina alterniflora, Spartina patens, Spartina x townsendii, Reynoutria bohemica, Acaena anserinifolia, Acaena caesiiglauca, Amelanchier lamarckii, Aronia melanocarpa, Aronia prunifolia, Cotoneaster dielsianus, Cotoneaster divaricatus, Cotoneaster frigidus, Cotoneaster hjelmqvistii, Cotoneaster microphyllus, Cotoneaster nitens, Cotoneaster pannosus, Cotoneaster suecicus, Cotoneaster watereri, Prunus serotina, Rosa multiflora, Rubus armeniacus, Populus balsamifera, Populus balsamifera trichocarpa, Populus jackii, Acer negundo, Ailanthus altissima*
France	*Lophocolea semiteres, Alternanthera philoxeroides, Alternanthera sessilis, Schinus molle, Schinus terebinthifolia, Hydrocotyle bonariensis, Yucca flaccida, Solidago altissima, Berberis darwinii, Berberis julianae, Berberis thunbergii, Opuntia stricta, Lonicera maackii, Equisetum hyemale affine, Vaccinium macrocarpum, Acacia longifolia, Acacia saligna, Spiranthes cernua x odorata, Pinus contorta, Spartina patens, Acaena anserinifolia, Acaena caesiiglauca, Acaena novae-zelandiae, Acaena ovalifolia, Amelanchier lamarckii, Aronia melanocarpa, Aronia prunifolia, Cotoneaster bullatus, Cotoneaster dielsianus, Cotoneaster divaricatus, Cotoneaster frigidus, Cotoneaster hjelmqvistii, Cotoneaster integrifolius, Cotoneaster microphyllus, Cotoneaster nitens, Cotoneaster pannosus, Cotoneaster suecicus, Cotoneaster watereri, Rubus armeniacus, Populus balsamifera trichocarpa, Populus jackii*

Netherlands	*Mesembryanthemum cordifolium, Alternanthera philoxeroides, Alternanthera sessilis, Atriplex micrantha, Schinus molle, Schinus terebinthifolia, Hydrocotyle bonariensis, Araujia sericifera, Yucca aloifolia, Yucca filamentosa, Aloe arborescens, Arctotheca calendula, Gaillardia x grandiflora, Solidago altissima, Berberis darwinii, Opuntia ficus-indica, Opuntia stricta, Ipomoea indica, Acacia dealbata, Acacia longifolia, Acacia saligna, Lupinus arboreus, Ligustrum lucidum, Spiranthes cernua x odorata, Paspalum vaginatum, Spartina alterniflora, Spartina patens, Acaena anserinifolia, Acaena caesiiglauca, Acaena novae-zelandiae, Acaena ovalifolia, Cotoneaster frigidus, Cotoneaster integrifolius, Cotoneaster microphyllus, Cotoneaster nitens, Cotoneaster pannosus, Cotoneaster suecicus, Cotoneaster watereri, Populus jackii*
Spain	*Lophocolea semiteres, Alternanthera philoxeroides, Alternanthera sessilis, Atriplex micrantha, Schinus terebinthifolia, Heracleum mantegazzianum, Yucca filamentosa, Yucca flaccida, Gaillardia x grandiflora, Solidago altissima, Impatiens glandulifera, Berberis darwinii, Berberis julianae, Berberis thunbergii, Opuntia stricta, Lonicera maackii, Lonicera nitida, Crassula helmsii, Equisetum hyemale affine, Gaultheria shallon, Vaccinium macrocarpum, Lupinus arboreus, Gunnera tinctoria, Elodea nuttallii, Claytonia perfoliata, Ludwigia grandiflora, Ludwigia peploides, Spiranthes cernua x odorata, Pinus contorta, Spartina alterniflora, Spartina anglica, Spartina patens, Spartina x townsendii, Fallopia sachalinensis, Koenigia polystachya, Reynoutria bohemica, Acaena anserinifolia, Acaena caesiiglauca, Acaena novae-zelandiae, Acaena ovalifolia, Amelanchier lamarckii, Aronia melanocarpa, Aronia prunifolia, Cotoneaster bullatus, Cotoneaster dielsianus, Cotoneaster divaricatus, Cotoneaster frigidus, Cotoneaster hjelmqvistii, Cotoneaster integrifolius, Cotoneaster microphyllus, Cotoneaster nitens, Cotoneaster simonsii, Cotoneaster suecicus, Cotoneaster watereri, Rosa multiflora, Rosa rugosa, Rubus armeniacus, Populus balsamifera, Populus balsamifera trichocarpa, Populus jackii*
United Kingdom	*Alternanthera philoxeroides, Alternanthera sessilis, Atriplex micrantha, Schinus molle, Schinus terebinthifolia, Hydrocotyle bonariensis, Araujia sericifera, Yucca aloifolia, Yucca filamentosa, Yucca flaccida, Aloe arborescens, Solidago altissima, Opuntia ficus-indica, Opuntia stricta, Lonicera maackii, Ipomoea indica, Equisetum hyemale affine, Acacia longifolia, Acacia saligna, Lindernia dubia, Ludwigia peploides, Spiranthes cernua x odorata, Paspalum vaginatum, Spartina patens, Spartina x townsendii, Acaena caesiiglauca, Aronia prunifolia, Populus balsamifera trichocarpa*

Denmark	*Lophocolea semiteres, Carpobrotus edulis, Mesembryanthemum cordifolium, Tetragonia tetragonioides, Alternanthera philoxeroides, Alternanthera sessilis, Atriplex micrantha, Schinus molle, Schinus terebinthifolia, Hydrocotyle bonariensis, Araujia sericifera, Yucca aloifolia, Yucca filamentosa, Yucca flaccida, Yucca gloriosa, Aloe arborescens, Arctotheca calendula, Baccharis halimifolia, Delairea odorata, Gaillardia pulchella, Gaillardia x grandiflora, Solidago altissima, Berberis darwinii, Berberis julianae, Opuntia ficus-indica, Opuntia stricta, Lonicera japonica, Lonicera maackii, Lonicera nitida, Tradescantia fluminensis, Ipomoea indica, Crassula helmsii, Elaeagnus angustifolia, Equisetum hyemale affine, Gaultheria shallon, Vaccinium macrocarpum, Acacia dealbata, Acacia longifolia, Acacia saligna, Lupinus arboreus, Gunnera tinctoria, Myriophyllum aquaticum, Crocosmia crocosmiiflora, Lindernia dubia, Ligustrum lucidum, Ligustrum ovalifolium, Ludwigia grandiflora, Ludwigia peploides, Spiranthes cernua x odorata, Oxalis pes-caprae, Phytolacca americana, Paspalum vaginatum, Spartina patens, Fallopia sachalinensis, Koenigia polystachya, Acaena anserinifolia, Acaena caesiiglauca, Acaena novae-zelandiae, Acaena ovalifolia, Aronia prunifolia, Cotoneaster dielsianus, Cotoneaster franchetii, Cotoneaster frigidus, Cotoneaster integrifolius, Cotoneaster microphyllus, Cotoneaster nitens, Cotoneaster pannosus, Cotoneaster simonsii, Cotoneaster watereri, Populus balsamifera trichocarpa, Ailanthus altissima*
Germany	*Lophocolea semiteres, Carpobrotus edulis, Mesembryanthemum cordifolium, Tetragonia tetragonioides, Alternanthera philoxeroides, Alternanthera sessilis, Atriplex micrantha, Schinus molle, Schinus terebinthifolia, Hydrocotyle bonariensis, Araujia sericifera, Yucca aloifolia, Yucca filamentosa, Yucca flaccida, Yucca gloriosa, Aloe arborescens, Arctotheca calendula, Baccharis halimifolia, Delairea odorata, Gaillardia x grandiflora, Solidago altissima, Berberis darwinii, Opuntia ficus-indica, Opuntia stricta, Lonicera maackii, Lonicera nitida, Tradescantia fluminensis, Ipomoea indica, Equisetum hyemale affine, Gaultheria shallon, Vaccinium macrocarpum, Acacia dealbata, Acacia longifolia, Acacia saligna, Lupinus arboreus, Gunnera tinctoria, Myriophyllum aquaticum, Crocosmia crocosmiiflora, Lindernia dubia, Ligustrum lucidum, Ludwigia grandiflora, Ludwigia peploides, Spiranthes cernua x odorata, Oxalis pes-caprae, Pinus contorta, Paspalum vaginatum, Spartina alterniflora, Spartina patens, Spartina x townsendii, Fallopia sachalinensis, Koenigia polystachya, Acaena anserinifolia, Acaena caesiiglauca, Acaena novae-zelandiae, Acaena ovalifolia, Aronia melanocarpa, Aronia prunifolia, Cotoneaster dielsianus, Cotoneaster divaricatus, Cotoneaster frigidus, Cotoneaster hjelmqvistii, Cotoneaster integrifolius, Cotoneaster microphyllus, Cotoneaster nitens, Cotoneaster pannosus, Cotoneaster simonsii, Cotoneaster suecicus, Cotoneaster watereri, Populus balsamifera trichocarpa, Populus jackii*

Portugal	*Campylopus introflexus, Lophocolea semiteres, Mesembryanthemum cordifolium, Tetragonia tetragonioides, Alternanthera philoxeroides, Alternanthera sessilis, Atriplex micrantha, Schinus terebinthifolia, Heracleum mantegazzianum, Yucca aloifolia, Yucca filamentosa, Yucca flaccida, Baccharis halimifolia, Gaillardia pulchella, Gaillardia x grandiflora, Solidago altissima, Solidago canadensis, Solidago gigantea, Impatiens glandulifera, Berberis aquifolium, Berberis darwinii, Berberis julianae, Berberis thunbergii, Opuntia stricta, Lonicera maackii, Lonicera nitida, Cornus sericea, Crassula helmsii, Elaeagnus angustifolia, Equisetum hyemale affine, Gaultheria shallon, Vaccinium macrocarpum, Acacia saligna, Lupinus arboreus, Ribes sanguineum, Gunnera tinctoria, Elodea nuttallii, Lindernia dubia, Claytonia perfoliata, Ligustrum lucidum, Ligustrum ovalifolium, Ludwigia grandiflora, Ludwigia peploides, Spiranthes cernua x odorata, Picea sitchensis, Pinus contorta, Paspalum vaginatum, Spartina alterniflora, Spartina anglica, Spartina patens, Spartina x townsendii, Fallopia sachalinensis, Koenigia polystachya, Reynoutria bohemica, Acaena anserinifolia, Acaena caesiiglauca, Acaena novae-zelandiae, Acaena ovalifolia, Amelanchier lamarckii, Aronia melanocarpa, Aronia prunifolia, Cotoneaster bullatus, Cotoneaster dielsianus, Cotoneaster divaricatus, Cotoneaster franchetii, Cotoneaster frigidus, Cotoneaster hjelmqvistii, Cotoneaster horizontalis, Cotoneaster integrifolius, Cotoneaster microphyllus, Cotoneaster nitens, Cotoneaster pannosus, Cotoneaster simonsii, Cotoneaster suecicus, Cotoneaster watereri, Prunus serotina, Rosa multiflora, Rosa rugosa, Rubus armeniacus, Populus balsamifera, Populus balsamifera trichocarpa, Populus jackii, Lycium barbarum*

3.2 MANAGEMENT FEASIBILITY

For a number of established IAS (e.g. *Ailanthus altissima*, *Baccharis halimifolia*, *Berberis thunbergii, Cotoneaster spp.*), participants appeared surprisingly positive about the prospects of eradication from protected areas within the Atlantic coastal region. Species such as tree of heaven (*A. altissima*), although very common along infrastructure, roadside and other habitats, are deemed feasible to eradicate from protected areas. This might indicate that eradication from certain areas where it has high impact, is feasible despite the general impression that the species is everywhere on a territory and therefore totally unmanageable.

On the other end of the spectrum are species such as Australian swamp stonecrop (*Crassula helmsii*), where most participants deem (complete) eradication too costly and not feasible anymore (too late) (Figure 13, Annex 4). Indeed, the costs of effective eradication can be considerable although succesful removal has been achieved (van der Loop 2022). Similar patterns are observed for *Carpobrotus* eradication, yet for this species the overall feasibility was scored much higher by at least ten respondents. Clearly, the potential for instant recolonisation was seen as a hindrance to effective eradication.

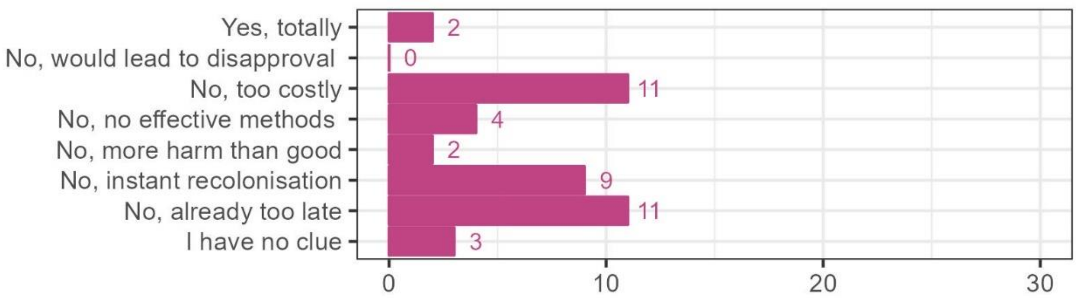


Figure 13. Feasibility assessment for eradication (criteria on Y axis, number of respondents on X axis) of *Crassula helmsii*.

For a number of species, clearly, there are outstanding questions from experts as to the feasibility of eradication from the Atlantic coastal area. Piri-piri burr (*Acaena novae-zelandiae*), Japanese barberry (*B. thunbergii*), heath star moss (*Campylopus introflexus*), montbretia (*Crocosmia crocosmiiflora*, Figure 15), the horsetail *Equisetum hyemale affine*, water primrose (*Ludwigia grandiflora*), tree lupin (*Lupinus arboreus*) and giant/tall goldenrod (*Solidago gigantea*/*altissima*) had at least ten respondents indicating that they didn't have any clue whether they could effectively be eradicated from protected areas in the Atlantic area (Annex 4). For some species this is most probably reminiscent to the lack of knowledge and experience on management. For other species is it surprising. For instance, *L. grandiflora* is a well known aquatic invasive plant of the Union list which is under management since very long, therefore management methods should be quite well known. Despite this, perhaps there are still questions on how to effectively eradicate it. Long established invaders like heath star moss, which can impact moss dunes, probably have not been under systematic management yet.

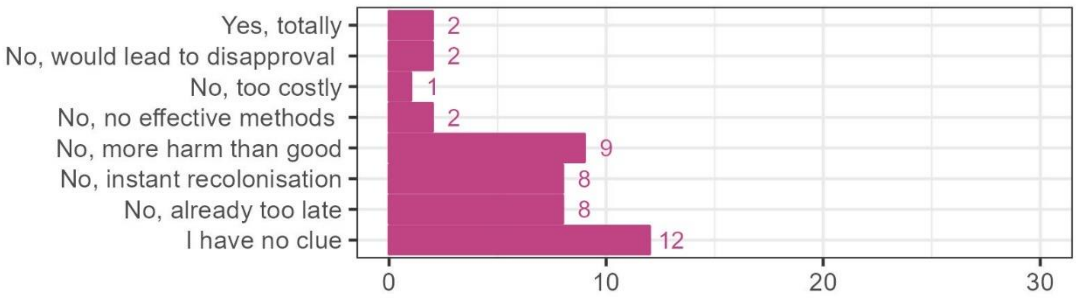


Figure 14. Feasibility assessment for eradication (criteria on Y axis, number of respondents on X axis) of *Spartina anglica*, and xample of a species with clear knowledge gaps.

For *Spartina anglica* (Figure 14) and heath star moss (*C. introflexus*), clearly respondents were aware of non-target effects of management (Annex 4). Indeed, *Spartina anglica* is an ecosystem engineer in tidal mudflats with root systems binding mud and stems, thereby increasing silt deposition. *Campylopus introflexus* forms extensive, dense mats on moss dunes and therefore removal could have non-target impact on typical native mosses or invertebrates.

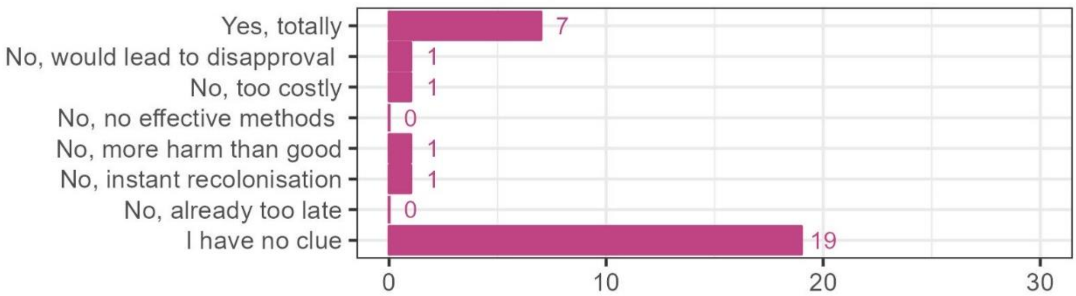


Figure 15. Feasibility assessment for eradication (criteria on Y axis, number of respondents on X axis) of *Crocosmia crocosmiiflora*, and xample of a species with clear knowledge gaps.

For *A. novae-zelandiae* the consensus was that every effort should be made to prevent it from reaching the European mainland. The species is subject to debate in the UK as to the feasibility of its eradication. Eradication of eastern baccharis (*B. halimifolia*) was deemed quite feasible by workshop participants but this could be the result of overrepresented northern European experts as the species is very widespread in certain areas of southern France and Spain. For *Cotoneaster* species, which are effectively widespread, the suggestion from the group was an eradication approach tailored to specific areas where removal could be achieved with low prospect of recolonisation from gardens. Participants indicated this argument was valid for many other species. Newbies like the *Yucca* species, although sometimes surprisingly hard to remove, were deemed very feasible to eradicate. One important element brought in the discussion was that the coastal area offers unique opportunities to justifying management. The removal of narrow-leaved ragwort (*Senecio inaequidens*), typically a larbour-intensive manual intervention in moss dunes, can for instance be justified considering the species has been shown to enhance the growth of marram grass (*Calamagrostis arenaria*) after it dies off, nutrients homogenize and enrich the sand. This process stabilizes dunes and lowers sediment transport which accelerates natural succession. This could eventually hamper dune growth and further reduce dune height, which compromises coastal protection (Van De Walle et al. 2022).

A general comment was that invasive species removal in itself should be viewed within the context of ecosystem restoration of the entire coastal dune system.

4 IAS IN CONSERVATION STATUS ASSESSMENTS

The Habitats Directive aims to maintain and restore habitats (Annex 1) and species of community interest (Annexes II, IV and V) in a favourable conservation status. As Member States are required to report every six years on the progress made, monitoring and reporting focuses on capturing the status and trends of these habitat types and species (Article 17). For habitats, status and trend information is required on the range, area, and habitat quality. The occurrence and/or abundance of invasive alien species is one of the pressures that this habitat quality monitoring is focusing on. In this chapter, we explore the criteria with respect to IAS and the results of that monitoring. We confront this with the actual situation in the field and provide recommendations for an optimized monitoring strategy with respect to IAS based on the risk screening at the workshop.

4.1 CURRENT DEALING WITH IAS IN THE MONITORING FOR ART 17 REPORTING

In Flanders (Belgium) the information needs for reporting on conservation status are met using two monitoring strategies: (1) habitat mapping to assess the range and area of habitats, and (2) a regional monitoring network to assess the quality of habitats (Westra et al. 2014, Westra et al. 2023). The actual monitoring network consists of around 150 randomly selected sampling points per habitat. These are revisited once every six years. For Belgian coastal habitats this results in around 1000 sampling points per cycle. The monitoring consists of performing a classic vegetation relevé (9m²) and estimating a number of habitat specific quality indicators such as structural composition, disturbances, tree encroachment and/or the occurence of (invasive) alien species on a larger scale (1000m²). Rare or very dynamic habitat types in Flanders (e.g. 2150-Atlantic decalcified fixed dunes or 2110-Embryonic shifting dunes) are monitored over their entire surface area.

Evaluation in terms of good or bad conservation status is based on matrices with a set of indicators and accompanying threshold values for each habitat (Oosterlynck et al. 2020). Indicators can be grouped into four categories:

- typical species composition (positive indicator species),
- disturbances (negative indicator species),
- habitat structures,
- spatial configuration (habitat size and fragmentation).

Occurrence and abundance of IAS is included as a disturbances indicator in the large majority of evalution matrices (Table 10.). The presence of IAS is considered relevant for all except two habitats of the “sandy” ecoseries (2130, 2150, 2190 except 2110 and 2120), all habitats of the “shrubby” ecoseries (2160, 2170, 2180) and only one habitat of the “salty” ecoseries (1310). The initial selection of IAS is based on the **Invasive Species Ecological Impact Assessments** available through the Harmonia database of the Belgian Forum on Invasive Species (https://ias.biodiversity.be/). All category A species, defined as having a high impact and a non-isolated distribution in Belgium, were listed (Branquart 2007, Vanderhoeven et al. 2015).

At the time of publication these criteria applied to 30 vascular plants (Table 10.). The evaluation matrices stress that these **lists of IAS should be treated as non-exhaustive and should accordingly be complemented with new (local) introductions of IAS posing an actual or future**

threat. The standard thresholds for abundance of IAS for a habitat patch to be in good condition is that they area absent. In a number of cases, e.g. *Berberis aquifolium*, *Prunus serotina* and *Ailanthus altissima* in scrub dune habitats, a less strict threshold is applied for pragmatic reasons as the prospects of total eradication are low. This also goes for the heath star moss *Campylopus introflexus* in more open, decalcified coastal dune habitats.

In some cases, non-invasive alien species are also considered when evaluating the condition of dune habitats (Table 10). These species often thrive there and can cause significant structural damage to the habitat despite them not spreading considerably. It is clear that **for many habitats, many of the here identified relevant alien species (see 3.1) are not yet taken into account in the current criteria for conservation status assessment.** This even included species of Union concern of the EU IAS Regulation such as *Baccharis halimifolia*.

Table 10. Overview of the criteria for assessing the conservation status of NATURA2000 coastal dune habitats in Flanders relating to invasive alien species (IAS) and other (non considered invasive) alien species (OAS), version 3 (Oosterlynck et al. 2020).

Habitat	**IAS**	**OAS**	**Tresholds**
2110	none listed	none listed	
2120	none listed	*Corispermum leptopterum*, *Senecio inaequidens*, *Conyza canadensis*	<= 10% cover OAS
2130_hd	*Rosa rugosa*, …	*Conyza canadensis*, *Gaillardia x grandiflora*, *Iberis umbellata*, *Oenothera* spp.,	IAS: absent OAS: <= 10% cover
2130_had	*Rosa rugosa*, …	none listed	absent
2150	*Rosa rugosa*, *Campylopus introflexus*,…	none listed	*C. introflexus*: <= 10% cover *R. rugosa*: absent
2160, 2170	*Berberis aquifolium, Prunus serotina, Cotoneaster spp., Ailanthus altissima*, …	*Symphoricarpos albus, Ribes alpinum, Ribes odoratum, Ribes sanguineum, Ribes spicatum, Lycium barbarum, Tamarix* spp., *Fallopia auberti*, *Eleaegnus* spp., …	IAS: At most occasional OAS: <= 10% cover

2180	*Alnus incana, Populus trichocarpa, Populus balsamifera, Ailanthus altissima, Prunus serotina, Berberis aquifolium*, …	None listed	absent
2190	*Crassula helmsii*, …	None listed	absent

4.2 CONSERVATION STATUS OF BELGIAN DUNE HABITATS BASED ON CURRENT ARTICLE 17 MONITORING

Here, we explore and discuss some results of the conservation status monitoring in dune habitat specifically with regards to the IAS-indicators, from the most recent Art 17 reporting cycle (Paelinckx et al. 2019).

The field data roughly spans a period from 2012 to 2018 and comprises 70 measurements in Habitat 2120, 503 measurements in 2130 Habitat, 96 measurements in 2160 Habitat, 73 measurements in 2170 Habitat, 27 in 2180 Habitat and 204 in 2190 Habitat (Table 11).

Table 11. Number of vegetation relevés PINK (Permanent Inventory Nature Reserves along the Coast, Provoost et al. 2010, 2014) and NATURA 2000 monitoring.

Type	**Name**	**PINK Relevés**	**NATURA2000 Relevés**	**Remarks**
2110	Embryonic shifting dunes	0	0	Entire surface surveyed
2120	Shifting Dunes	0	69	
2130	Grey dunes	420	83	
2150	Calluno-Ulicetum	0	0	Entire surface survey
2160	Dunes with Hippophae rhamnoides	42	54	
2170	Dunes with Salix repens	42	31	
2180	Wooded dunes	0	27	
2190	Humid dune slacks	154	50	
Total		658	314	

Results from the monitoring are expressed as an estimate of the proportion of habitat area in a good condition for a certain indicator (Figure 16). The estimates are calculated from a random set of vegetation relevés and therefore allow for calculation of confidence intervals. The dashed line represents the 75% threshold that is suggested in the Habitat Directive as a plausible cut-off point between an overall unfavourable or favourable conservation status.

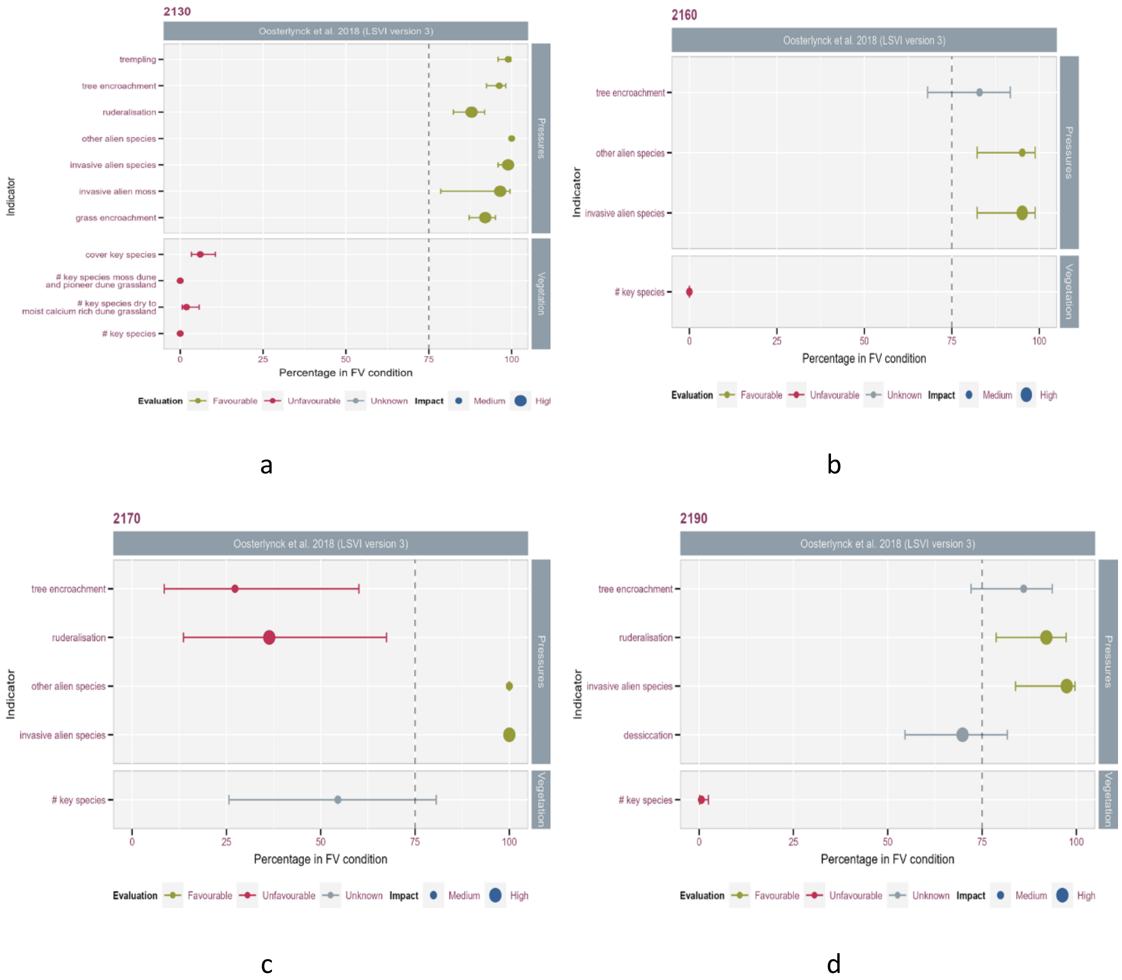


Figure 16. Monitoring results for (a) 2130 Habitat (Fixed coastal dunes with herbs (grey dunes), n = 503), (b) 2160 Habitat (Dunes with Hippophae rhamnoides, n=96), (c) 2170 (Dunes with Salix repens ssp. argentea, n=73) and (d) 2190 (Humid dune slacks, n=204) for the relevant indicators form evaluation matrices version 3 (Oosterlynck et al. 2020) on the left, grouped in pressures and vegetation indicators on the right (Paelinckx et al. 2019). Estimates of the proportion of sampling points in favourable condition are shown as coloured dots (red, green, and grey) according to their relation to the 25% threshold (dashed vertical line). Left and right confidence intervals are shown by means of the flags. The size of the dots reflects their importance (medium or high) in the overall calculation of conservation status, which is an integration of these different indicators into one final verdict (favourable or unfavourable).

Strikingly, results from the Art. 17 vegetation monitoring indicate that IAS are currently not posing a significant threat to Atlantic dune habitats. However, it is generally accepted that mitigating negative impact from invasive alien plant species is one of the major challenges for nature conservation today, especially in dynamic systems such as coastal dunes. This discrepancy calls for some critical reflections on the ability of the current monitoring programs and associated indicators to accurately capture the real world pressure associated with IAS in dune habitats. Some recommendations for future consideration are listed in the next chapter.

4.3 RECOMMENDATIONS FOR CONSIDERATION OF IAS IN CONSERVATION STATUS ASSESSMENTS

As outlined above, detailed monitoring for keystone species, disturbance indicators and habitat structure seems to be missing large-scale changes in habitat quality due to IAS. The apparent discrepancy between the real-world IAS problem in dune habitats and the results from the Art. 17 monitoring is mainly the consequence of the predefined threshold level for *overall* favourable conservation status, i.e. with as little as 0-24% of the total habitat surface in unfavourable condition the overall status is favourable. At the habitat patch level the treshold for good ecological status is absence of high impact IAS, yet, when aggregating information for Art. 17 reporting, the treshold allows up to 24% of the patches to be infested to some extent with IAS. Although for all dune habitats IAS presence is estimated well below this share, mostly around a few percent, confidence intervals often range up to 20-25%. Since IAS, by definition, rapidly invade and dominate natural stands, **re-evaluation of applied thresholds** is needed to confirm if these are truly compatible with a favourable and thus sustainable (=future) habitat condition.

The discrepancy between the actual IAS-problem in dune habitats and the results from the Art 17 monitoring can also in part be assigned to mapping rules and habitat definitions. **Invasive alien species dominated vegetation is excluded from the habitat definition**, and therefore their presence is currently underrepresented in the sampling population.

Furthermore, it can be argued that strict presence/absence and coverage data of IAS in a random sampling design is probably not an appropriate monitoring methodology to capture future invasion dynamics of (I)AS. Alien species introductions, in many cases, are isolated and rare events yet given the right conditions, they can rapidly evolve into a more widespread future problems. **Monitoring the surface area or coverage of alien species is not representative of future potential habitat impact through plant invasions**, as the current sampling design does not capture such rare events. Nonetheless, the monitoring should be able to detect invasion processes once the trend becomes more explicit.

Based on these observations, we propose a number of recommendations for Article 17 reporting:

- To pursue a more qualitative assessment of the presence of (I)AS. This could be achieved by screening a larger proportion of the sample, in this case dune habitats, for a specific set of (I)AS of interest for a specific habitat type.
- It could prove valuable to incorporate existing additional data on the distribution of focal IAS species (cf. the PINK/BEK surveys in Belgium) on top of the systematic surveys performed for determining local conservation status.
- The presence of an IAS should weigh more on the overall status assessment. For example, to ensure coherence of the legislative regime in IAS and the Habitat's Directive, it could be relevant to include a target on the absolute absence of Union List species of the IAS Regulation in any protected coastal dune habitat (i.e. their presence would lead to unfavourable conservation status), especially for Union List species that were identified impacting coastal habitats in our risk screening (e.g. *Baccharis halimifolia*, *Heracleum mantegazzianum*, *Ailanthus altissima*, invasive macrophytes) (Annex 3),

- High impact species identified through the risk screening (Table 12) could be added to the current evaluation matrices that are used for conservation status assessments in the framework of Article 17 monitoring (Table 10). Using this list of (potentially) high impact alien species (Table 12) throughout the Atlantic coastal region would also harmonize the monitoring approach across Member States. Of course, when selecting species, the **context of the specific country should be taken into account** and further, more refined selections of alien species could be needed e.g. adding taxa, re-evaluation of (potentially) affected habitats when new research becomes available, species that were missing from the longlist, adapting the scores to the specific context, removing irrelevant species etc.

Picture 5. Invasive plant species can profoundly impact the species composition, structure and functioning of coastal dune ecosystems. Spanish Dagger (*Yucca gloriosa*) from eastern North America, western balsam-poplar (*Populus trichocarpa*) from the western United States, and Russian-vine (*Fallopia baldschuanica*) from central Asia accompany native buckthorn (*Hippophae rhamnoides*) shrub in nature reserve Ter Yde (Oostduinkerke, Belgium, 2012).

Table 12. High risk species for the different Annex I habitats (criterion for selection: overall score > median score of the respective habitat group; i.e. > 232,5 for "salties", > 180 for "sandies", > 144 for "shrubbies"). Species of the same genus with equal impact scores were lumped for convenience (see 3.1).

Habitat	***Species***
hab_1110	*No species identified that matches the criterium*
hab_1130	*Alternanthera philoxeroides, Alternanthera sessilis, Baccharis halimifolia, Cotula coronopifolia, Hydrocotyle bonariensis, Paspalum vaginatum, Spartina ang./alt./x t.*
hab_1140	*Paspalum vaginatum, Spartina ang./alt./x t.*
hab_1210	*Atriplex micrantha, Carpobrotus edulis, Hydrocotyle bonariensis*
hab_1230	*Acaena novae-zelandiae, Aloe arborescens, Baccharis halimifolia, Carpobrotus edulis, Cotula coronopifolia, Hydrocotyle bonariensis, Mesembryanthemum cordifolium, Opuntia ficus-indica, Opuntia stricta, Yucca spp. (4 spp.)*
hab_1310	*Baccharis halimifolia, Cotula coronopifolia, Paspalum vaginatum, Spartina ang./alt./x t.*
hab_1320	*Paspalum vaginatum, Spartina ang./alt./x t.*
hab_1330	*Atriplex micrantha, Baccharis halimifolia, Cotula coronopifolia, Paspalum vaginatum, Rosa rugosa, Spartina ang./alt./x t.*
hab_2110	*Aloe arborescens, Araujia sericifera, Arctotheca calendula, Baccharis halimifolia, Carpobrotus edulis, Rosa rugosa, Tetragonia tetragonioides*
hab_2120	*Acaena novae-zelandiae, Aloe arborescens, Ambrosia artemisiifolia, Araujia sericifera, Arctotheca calendula, Baccharis halimifolia, Berberis aquifolium, Carpobrotus edulis, Elaeagnus angustifolia, Gaillardia pulchella, Gaillardia x grandiflora, Hydrocotyle bonariensis, Lycium barbarum, Oxalis pes-caprae, Populus balsamifera, Populus balsamifera trichocarpa, Populus jackii, Rosa rugosa, Senecio inaequidens, Tetragonia tetragonioides, Yucca spp. (4 spp.)*
hab_2130	*Acaena anserinifolia/ovalifolia, Acaena novae-zelandiae, Acer negundo, Ailanthus altissima, Aloe arborescens, Ambrosia artemisiifolia, Amelanchier lamarckii, Amelanchier spicata, Araujia sericifera, Arctotheca calendula, Asclepias syriaca, Baccharis halimifolia, Berberis aquifolium, Berberis darwinii, Berberis julianae, Campylopus introflexus, Carpobrotus edulis, Cotoneaster horizontalis (creeping habit), Cotoneaster spp., low-growing habit (7 spp.), Cotoneaster spp., tall-growing habit (9 spp.), Crocosmia crocosmiiflora, Elaeagnus angustifolia, Fallopia sachalinensis, Gaillardia pulchella, Gaillardia x grandiflora, Gaultheria mucronata/procumbens, Gaultheria shallon, Gunnera tinctoria, Heracleum mantegazzianum, Ipomoea indica, Ligustrum japonicum, Ligustrum lucidum, Ligustrum ovalifolium, Lophocolea semiteres, Lupinus arboreus, Lycium barbarum, Opuntia ficus-indica, Opuntia stricta, Oxalis pes-caprae, Phytolacca americana, Picea sitchensis, Pinus contorta, Populus balsamifera, Populus balsamifera trichocarpa, Populus jackii, Prunus serotina, Reynoutria bohemica, Reynoutria japonica, Rosa rugosa, Rubus armeniacus, Senecio inaequidens, Solidago alt./can./gig., Tetragonia tetragonioides, Yucca spp. (4 spp.)*

hab_2140	*Acaena anserinifolia/ovalifolia, Aronia melanocarpa/prunifolia, Baccharis halimifolia, Fallopia sachalinensis, Gaultheria mucronata/procumbens, Heracleum mantegazzianum, Lophocolea semiteres, Picea sitchensis, Rosa rugosa, Vaccinium corymbosum*
hab_21A0	*Gunnera tinctoria, Rosa rugosa*
hab_2150	*Acaena anserinifolia/ovalifolia, Acaena novae-zelandiae, Amelanchier lamarckii, Amelanchier spicata, Arctotheca calendula, Aronia melanocarpa/prunifolia, Baccharis halimifolia, Berberis aquifolium, Berberis darwinii, Campylopus introflexus, Carpobrotus edulis, Cotoneaster horizontalis (creeping habit), Cotoneaster spp., low-growing habit (7 spp.), Cotoneaster spp., tall-growing habit (9 spp.), Crocosmia crocosmiiflora, Fallopia sachalinensis, Gaultheria mucronata/procumbens, Gaultheria shallon, Ipomoea indica, Ligustrum japonicum, Ligustrum lucidum, Ligustrum ovalifolium, Lophocolea semiteres, Lupinus arboreus, Lycium barbarum, Opuntia ficus-indica, Opuntia stricta, Oxalis pes-caprae, Phytolacca americana, Picea sitchensis, Pinus contorta, Prunus serotina, Reynoutria japonica, Rosa rugosa, Solidago alt./can./gig., Tetragonia tetragonioides, Vaccinium corymbosum*
hab_2190	*Acaena novae-zelandiae, Acer negundo, Aloe arborescens, Araujia sericifera, Arctotheca calendula, Aronia melanocarpa/prunifolia, Baccharis halimifolia, Berberis darwinii, Carpobrotus edulis, Cotoneaster horizontalis (creeping habit), Crassula helmsii, Crocosmia crocosmiiflora, Elodea nuttallii, Equisetum hyemale affine, Gaultheria mucronata/procumbens, Gaultheria shallon, Gunnera tinctoria, Heracleum mantegazzianum, Hydrocotyle bonariensis, Impatiens glandulifera, Ipomoea indica, Lindernia dubia, Ludwigia grandiflora, Ludwigia peploides, Lupinus arboreus, Mesembryanthemum cordifolium, Myriophyllum aquaticum, Populus balsamifera, Populus balsamifera trichocarpa, Prunus serotina, Reynoutria bohemica, Reynoutria japonica, Schinus molle, Schinus terebinthifolia, Solidago alt./can./gig., Spiranthes cernua x odorata, Tetragonia tetragonioides, Tradescantia fluminensis, Vaccinium corymbosum, Vaccinium macrocarpum*
hab_2160	*Acacia dea./lon./sal., Acaena anserinifolia/ovalifolia, Acaena caesiiglauca, Acaena novae-zelandiae, Ailanthus altissima, Amelanchier lamarckii, Amelanchier spicata, Asclepias syriaca, Baccharis halimifolia, Berberis aquifolium, Berberis darwinii, Berberis julianae, Berberis thunbergii, Carpobrotus edulis, Claytonia perfoliata, Cotoneaster horizontalis (creeping habit), Cotoneaster spp., low-growing habit (7 spp.), Cotoneaster spp., tall-growing habit (9 spp.), Crocosmia crocosmiiflora, Elaeagnus angustifolia, Equisetum hyemale affine, Fallopia baldschuanica, Fuchsia magellanica, Heracleum mantegazzianum, Ipomoea indica, Koenigia polystachya, Lonicera japonica, Lupinus arboreus, Mesembryanthemum cordifolium, Picea sitchensis, Pinus contorta, Prunus serotina, Reynoutria bohemica, Reynoutria japonica, Ribes sanguineum, Robinia pseudoacacia, Rosa rugosa, Schinus molle, Vaccinium macrocarpum, Yucca spp. (4 spp.)*
hab_2170	*Acacia dea./lon./sal., Acaena anserinifolia/ovalifolia, Acaena caesiiglauca, Acaena novae-zelandiae, Ailanthus altissima, Amelanchier lamarckii, Amelanchier spicata, Aronia melanocarpa/prunifolia, Baccharis halimifolia, Berberis aquifolium, Berberis darwinii, Carpobrotus edulis, Claytonia perfoliata, Cotoneaster horizontalis (creeping habit), Cotoneaster spp., low-growing habit (7 spp.), Cotoneaster spp., tall-growing habit (9 spp.), Crocosmia crocosmiiflora, Delairea odorata, Elaeagnus angustifolia, Fallopia baldschuanica, Fuchsia magellanica, Ipomoea indica, Koenigia polystachya, Lophocolea semiteres, Mesembryanthemum cordifolium, Picea sitchensis, Prunus serotina, Ribes sanguineum, Robinia pseudoacacia, Rosa rugosa, Schinus molle, Spiraea douglasii*

hab_2180	*Acacia dea./lon./sal., Acaena anserinifolia/ovalifolia, Acaena caesiiglauca, Acer negundo, Ailanthus altissima, Amelanchier lamarckii, Amelanchier spicata, Aronia melanocarpa/prunifolia, Berberis aquifolium, Berberis darwinii, Carpobrotus edulis, Claytonia perfoliata, Cornus sericea, Cotoneaster horizontalis (creeping habit), Cotoneaster spp., low-growing habit (7 spp.), Cotoneaster spp., tall-growing habit (9 spp.), Delairea odorata, Fuchsia magellanica, Heracleum mantegazzianum, Ipomoea indica, Koenigia polystachya, Lonicera maackii, Lonicera nitida, Lophocolea semiteres, Mesembryanthemum cordifolium, Picea sitchensis, Prunus laurocerasus, Prunus serotina, Robinia pseudoacacia, Rosa multiflora, Rosa rugosa, Schinus molle*

5 MANAGEMENT ACCOUNTS OF SELECTED SPECIES

The following chapter presents management accounts for a selection of species considered for management action in the LIFE DUNIAS project. This selection is specific to the project and has no direct link with the horizon scanning exerise. It presents especially a number of new invasive species where a comprehensive overview of potential control methods was largely lacking (e.g. *Cotoneaster* spp., *Lycium barbarum*, *Parthenocissus* spp.), therefore species which are managed for some time already (e.g. *Prunus serotina*) are lacking from this overview. *Prunus serotina* is one of the most widespread invasive alien plants along the Belgian coast and certainly a priority for management (see 3.1). Management of the species is however performed for quite some time already and best practice information is therefore already available (e.g. Buysse 2012, Invexo 2012). For many of the high impact dune invaders identified through the horizon scan (e.g. *Vincetoxium nigrum*, *Aronia x prunifolia*, *Gaultheria shallon*, *Prunus serotina*, *Syringa vulgaris*), we are happy to recommend van Valkenburg et al. (2022) for basic information on management (see especially summary tables 1 and 2 in this publication).

5.1 STRUCTURE OF THE MANAGEMENT ACCOUNTS

5.1.1 Species profiles

The species profile presents a tabulated overview of factual data (F) as well as data coming from the assessments performed at the horizon scanning workshop (HS). The exact meaning of the different fields is described for a dummy species example in Table 13.

Table 13. Description of fields used for species profiling in the management accounts. F = information is factual, HS = information is based on assessments from the horizon scanning workshop.

Union List (F)	Indicates whether the species is present on the list of invasive species of Union concern sensu Regulation 1143/2014 (including the update of August 2022, Implementing Regulation 2022/1203).
Environment (F)	Indicates the environments (marine, brackish, freshwater, terrestrial) the species can grow in.
Natura 2000 susceptibility (HS)	Tick boxes indicating which Annex I habitats of the EU Habitats Directive considered during the horizon scan workshop (see 0) are susceptible for invasion by the species i.e. where the species could sustain populations in the European Atlantic coastal area. Note that this is only a selection of coastal dune habitats considered during the exercise which had the specific geographic scope of the Atlantic coastal area in a number of European countries (Figure 2).
Occurrence in Atlantic coastal zone (F, HS)	Indication of the degree of invasion within the Atlantic coastal zone of each of the countries considered. Note that the Atlantic coastal zone is interpreted as a gridded version of the European Atlantic coastal region (10 × 10 km^2 cells). Per country, the number of grid cells occupied by the species is represented as calculated from GBIF data. We also present the occurrence relative (%) to the total number of 10 × 10 km^2 cells in the Atlantic coastal region of every country (Belgium 19, Denmark 108, France 448, Germany 146, Ireland 402, Netherlands 204, Portugal 19, Spain 192, United Kingdom 1412). Note that GBIF is certainly subject to gaps in data publication which could profoundly impact the quality of alien species distributions (cf. Groom

	et al. 2015), this is especially the case for data from citizen science (e.g. Price-Jones et al. 2022).
Impact scoring (max score across habitats) (HS)	Tick boxes of impact (1-5) and confidence (low, medium, high) scores resulting from the horizon scanning workshop, separated for each step in the invasion process (introduction, establishment, spread and environmental impact).
Overall impact score per habitat (HS)	Overall ecological impact score (product of scores across all invasion stages) coming out of the horizon scanning workshop. The maximum of this score is 625. The score is presented per habitat group ("salty" habitats, 1110-1330; "sandy" habitats, 2110-'50 + '90; "shrubby" habitats, 2160-'80). – indicates the species was not assessed in that ecoseries which means it was deemed ecologically less relevant in the preselection stage ór it could not be considered during the workshop.
Impact mechanisms (F, HS)	Tick boxes outlining potential or documented ecological impacts using a selection of impact mechanisms relevant for alien plants. These are adapted from the impact mechanisms defined in the Environmental Impact Classification for Alien Taxa (EICAT) classification of invasion impact mechanisms of the IUCN (IUCN 2020, largely based on Blackburn et al. 2014 and Hawkins et al. 2015) and the impact descriptions used in the guidelines for Environmental Impact Assessment of alien taxa (ISEIA) (Branquart 2007) and the Belgian risk assessment protocol Harmonia+ (D'hondt et al. 2015): 1. **Competition**: the alien species competes with native species for resources (e.g., food, water, space), including pollinators, potentially leading to negative impacts on native species. Note that we consider allelopathy as a forms of competition. 2. **Hybridization**: the alien taxon hybridises with native taxa, leading to deleterious impact on native taxa, or genetic pollution through introgression, threatening genetic integrity. 3. **Toxicity / poisoning**: the alien species is toxic to other biota (including humans), causes physical discomfort (rhinitis, conjunctivitis, skinburns) or is allergenic by ingestion, inhalation or contact. Contrary to the IUCN definition we consider allelopathic impact on other plants under competition. 4. **Interactions with other IAS**: the alien taxon interacts with other native or alien taxa (e.g. through any mechanism, including pollination, seed dispersal, apparent competition, mesopredator release), facilitating indirect deleterious impact on native taxa. 5. **Nutrient cycling**: the alien species potentially causes a significant chemical modification of the habitat (e.g. nutrient concentrations, soil minerals, nitrogen fixation) 6. **Physical modification of habitat**: the alien species causes changes to the physical characteristics of the native environment (e.g. disturbance regimes, light regimes, increased erosion), potentially leading to negative impacts on native species. 7. **Disruption of natural succession**: the alien species causes changes in the composition and/or rate of succession of vegetation communities that share the same habitat 8. **Disruption of food webs**: the alien species modifies the structure of the food web (e.g. plant-herbivore interactions at various trophic levels) potentially leading to ecosystem imbalance
Distribution maps (F)	Three distribution maps are presented: (1) the distribution within (red dots) and outside (blue dots) the European Atlantic coastal zone (depicted in

	grey) using GBIF data [GBIF Occurrence Download https://doi.org/10.15468/dl.32ed7r], (2) the distribution in Flanders (north Belgium) using GBIF data [GBIF Occurrence Download https://doi.org/10.15468/dl.32ed7r] since 1950, showing NATURA2000 areas (EU Bird and EU Habitat Directive areas together) in green, and (3) a recent (2007-2022) account of the distribution of in the Flemish coastal area based on the most reliable and complete plant surveys available i.e. PINK (Provoost et al. 2010, 2014) and BEK (Provoost et al. 2020) and validated data from the citizen science platform www.waarnemingen.be (Swinnen et al. 2018, Vanreusel et al. 2022) [GBIF Occurrence Download https://doi.org/10.15468/dl.b4waf7]. These maps depict the beach (in yellow), protected coastal dune areas (in green) and major road networks for orientation. When downloading data from GBIF, we used only validated presence data with coördinates. Together, these maps provide a crude idea of (1) the relative importance of Belgian coastal dune populations in the European distribution, (2) the relative importance of coastal dune populations in the regional, Flemish distribution, and (3) a detailed account of the known distribution in protected coastal dunes along the Belgian coast.

5.1.2 Invasion history and distribution

This chapter provides a brief account of invasion history of the species in Belgium (and Flanders in particular), with emphasis on what is known with respect to the invasion of the coastal ecosystem. Data on introduction date, pathways of introduction and spread are reported, as well as any referenced data on trends in distribution or impacts. These sections also provide brief accounts of the species native range, degree of establishment and known impacts.

Furthermore, a pecies trend is presented for the Flemish region, based on data from Florabank (Van Landuyt et al. 2012). The trendline (based on a generalized additive model with binomial distribution and logit link) presents a timeseries of the percentage of well surveyed 1x1 km squares with the species. Florabank represents a systematic plant survey where recorders write down all plant species they find in a square. A well prospected square is defined as a square where at least 100 plant species were recorded.

5.1.3 Management profile

This section provides a brief account of morphological, anatomical, functional or ecological characteristics that are relevant for management, so as to give the manager a first impression of what (s)he is dealing with. Typical examples include: whether the species is tuberous or rhizomatous and can therefore regenerate from these structures, can resprout from root or stem fragments or other, information on the formation of a seed bank and the longevity of it, information on sexual reproduction such as the amount of seeds produced, their mode of dispersal (wind, water, zoochory) and whether these require a cold period to break dormancy. Often, also some specific information on the reasons for invasion success is mentioned here.

5.1.4 Options for management

Because a full best practice adapted to regional conditions and taking into account management objectives (sensu the guidelines for drafting best management practices formulated by Adriaens et al. 2015, 2018) was impossible within the timeframe of this work, this section qualitatively describes potential options for management of the species in the coastal dune context based on scholarly literature, referenced sources and enquiries by email with (inter)national colleagues. The information is structured according to the nature of the methods described: mechanical/manual, chemical or biological. A synopsis focussing on feasible manual/mechanical methods is available in Table 14.

Species	Management methods
Cotoneasters (*Cotoneaster spp*.)	Uprooting using a spade or mechanical pulling of both the stumps and superficial roots. Ideally this is done before the formation of berries as these should be removed as well. Follow-up to deal with resprouting shoots.
Snowberry (*Symphoricarpos albus*)	Manual digging with a spade to remove plants and underground rhizomes, winching and pulling entire plants mechanically. Aftercare is needed to treat resprouting stems frrom underground rhizomes.
Japanese rose (*Rosa rugosa*)	Mechanical excavation of rhizomes and roots until a depth of one metre and taking into account a one metre lateral buffer around visible plants. Plant material is best sieved out of the substrate with a (drum) sieve with two cm mesh. Follow-up management is very important to remove resprouting roots, this can mostly be done manually or with a shovel.
Oregon grape (*Berberis aquifolium*)	Mechanical excavation of rhizomes and roots until a depth of 60 cm and taking into account a lateral buffer around visible plants. Plant material is best sieved out of the substrate (e.g. drum sieve, shaking). Follow-up management is very important to remove resprouting roots, this can mostly be done manually or with a shovel.
Tree of heaven (*Ailanthus altissima*)	Manual removal of young seedlings by pulling. Mechanical removal of bigger trees with a crane, removing as much of the root system as possible. Ideally performed before seed set. Aftercare to remove regenerating sprouts (on trunks).
Oleaster (*Elaeagnus angustifolia*)	Pulling, digging or mechanical removal of trees. Alternatively, cutting with stump treatment (1 ml 41% glyphosate). Follow-up treatment of any resprouts and seedlings.

Eastern baccharis (*Baccharis halimifolia*)	Hand pulling or mechanical removal of entire plants with their root systems. Plants should be removed before fruiting and seed set (i.e. before end of September), ideally before flowering. Aftercare to deal with root runners and seedlings.
Virginia creepers (*Parthenocissus spp.*)	Manual pulling or digging, removing the root system as much as possible. Mechanical removal in winter followed by chemical treatment (1% glyphosate solution) the following season should yield good results. First cut the liana loose from the tree if needed. Care should be taken to treat removed plant material properly.

Table 14. Synopsis of pontentially suitable management methods for the different species in the context of removals for the LIFE DUNIAS project.

With regards to chemical methods and any trademarks of products or active compounds mentioned, it is important to note that we did not explore which of those products are currently allowed for use against the species in Belgium and Flanders and under which conditions. Because this information is extensive, subject to change, and exemptions are possible, we refer to the competent authorities for further inquiries (Federal Public Service Health, Food chain safety and Environment; Flanders Environment Agency). In any case, legal restrictions should be considered before application is performed. In general, caution is recommended when using chemicals near open water, choosing compounds or products that have less harmful effects on aquatic life. Also, choose methods that allow spot application, bringing chemical agents as directly as possible onto the target species to reduce the effect on other vegetation (e.g. stump treatment, stem injection, spraying of foliage). Dry (but not too hot) weather conditons during application are important to consider to avoid washing away of the chemical agent (de Groot and Oldenburger 2011). Proper disposal of treated plant material is important as plants can resprout, rerout or form seeds after treatment from removed fragments. The options for this (composting, removal from site and the ways to do this) need to be considered before undertaking management. Unless specific attention is needed for any of the species described, we here refer to the reference guide on IAS plant disposal of IUCN France (UICN Comité français, Suez Recyclage, Valorisation France 2022).

Also, when applying chemicals, it should be noted that performing small scale trials is always a useful strategy before applying such products more broadly and across larger surface areas in protected areas. Such trials, depending on the needs and levels of knowledge, could consider modes of application (leaf treatment, stump treatment or other combinations), effectiveness of different chemical formulations, non-target effects, health and safety, public opposition etc.

With regards to biological control, we provide information on biocontrol initiatives and tried to find information on operational biocontrol programmes against the species and what stage these are at (screening of potential agents, host specificity testing, release). Biological control in Flanders is legally possible with an specific exemption on the Species Decree (and after preliminary risk assessment) and can be a full part of an integrated control strategy. Should such programmes be implemented, release should be accompanied by thorough scientific follow-up and contingency measures. However, to date, no initiatives have been taken in this direction in Flanders.

In google scholar, management information was sought using a varying set of keywords including the species name (or its congeners, synonyms or common names in various languages), and any of the terms [Invasive], [Non-native], [Exotic], [Removal], [Eradication], [Management], [Control], [herbicide], [biological control]. If information on management was found, it is presented here, including an indication of management success and with emphasis on data relevant for potential practical application of the method within the framework of the LIFE DUNIAS project.

5.2 TREE OF HEAVEN (*AILANTHUS ALTISSIMA*)

5.2.1 Species profile

Union List	☒ Yes		☐ No	
Environment	☐ marine ☐ brackish		☐ freshwater ☒ terrestrial	
Natura 2000 susceptibility	☐ 1110 - Sandbanks ☐ 1130 - Estuaries ☐ 1140 - Mudflats and sandflats ☐ 1210 - Annual vegetation of drift lines * ☐ 1230 - Vegetated sea cliffs of coasts * ☐ 1310 - Annuals colonising mud and sand ☐ 1320 - *Spartina* swards ☐ 1330 - Atlantic salt meadows ☐ 2110 - Embryonic shifting dunes ☐ 2120 - Shifting dunes along shoreline (white dunes) ☒ 2130 - Fixed coastal dunes with herbs (grey dunes) ☐ 2140 - Decalcified dunes with *Empetrum* * ☐ 21A0 - Machairs * ☐ 2150 - Atlantic decalcified fixed dunes ☐ 2190 - Humid dune slacks ☒ 2160 - Dunes with *Hippophae rhamnoides* ☒ 2170 - Dunes with *Salix repens* ssp. *argentea* ☒ 2180 - Wooded dunes of the Atlantic region			
Occurrence in Atlantic coastal zone (Number of occupied 10km²-grid cells)	Belgium	13 (68%)	United Kingdom	62 (4%)
	France	170 (38%)	Denmark	0
	Ireland	1 (0.2%)	Germany	5 (3%)
	Netherlands	53 (26%)	Portugal	7 (37%)
	Spain	32 (17%)		
Impact scoring (max score across habitats)	**Score** 1 2 3 4 5		**Confidence** Low Medium High	
Introduction	☐ ☐ ☐ ☐ ☒		☐ ☐ ☒	
Establishment	☐ ☐ ☐ ☐ ☒		☐ ☐ ☒	
Spread	☐ ☐ ☐ ☐ ☒		☐ ☐ ☒	
Environmental impact	☐ ☐ ☐ ☐ ☒		☐ ☐ ☒	
Overall impact score per habitat	(Salty) habitats 1110-1330		--	
	(Sandy) habitats 2110-50/-90		625	
	(Shrubby) habitats 2160-80		300	
Impact mechanisms	☒ Competition ☐ Hybridization ☐ Toxicity / poisoning ☐ Interactions with other IAS		☒ Nutrient cycling ☒ Physical modification of habitat ☒ Disruption of natural succession ☐ Disruption of food webs	
Distribution				

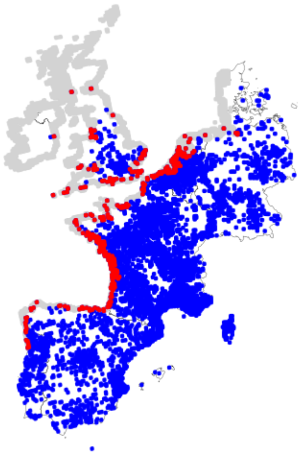


Figure 17. Distribution of *Ailanthus altissima* within (red dots) and outside (blue dots) the European Atlantic coastal zone (in grey).

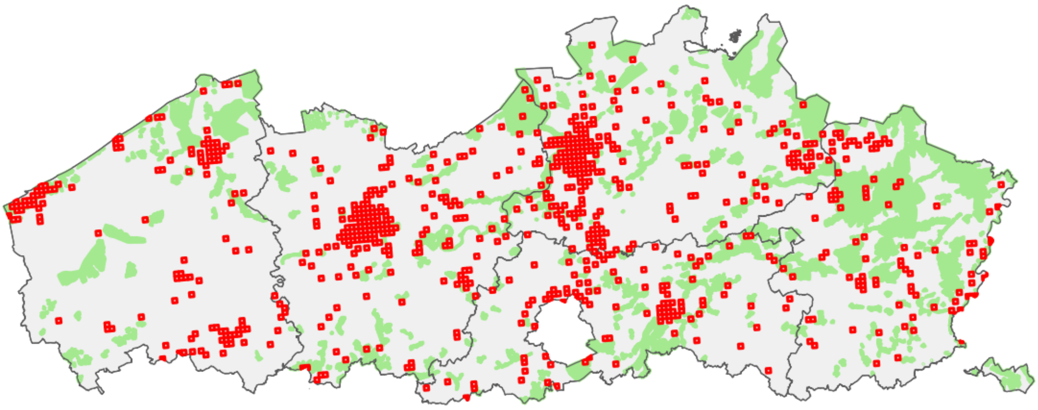


Figure 18. Distribution of *Ailanthus altissima* in Flanders since 1950. NATURA2000 areas (EU Bird and Habitat Directive) in green.

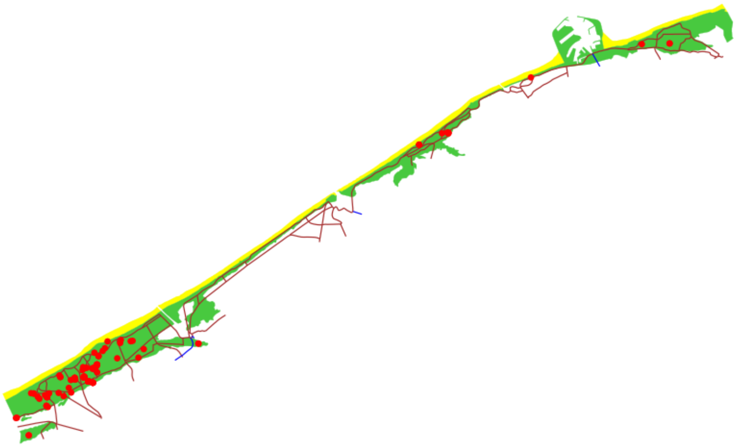


Figure 19. Distribution of *Ailanthus altissima* in the Flemish coastal area (2007-2022) based on detailed plant surveys (Provoost et al. 2010, 2014, 2020) and the citizen science platform www.waarnemingen.be (Vanreusel et al. 2022). Beaches (yellow), coastal dunes (green) and major roads (brown) are shown for orientation.

5.2.2 Invasion history and distribution

Tree of heaven is very widespread in the Mediterranean region (Figure 17). It has been used as an ornamental tree in public parks and private gardens and estates for well over a century. It was reported naturalised in Belgium since the 1950's and has been on the increase, especially in urban areas since 1980 (Van Landuyt 2006, DEMNA 2020, Verloove 2020). Although the occupancy trend in protected areas in Belgium is unclear in general, both the number of observations and the occupancy of the species in Belgium are still increasing. In Flanders the species is spreading relatively recently with most records dating post-1990 (Figure 20), and further rapid expansion is very likely in suitable, uninvaded areas (especially in thermophilous river valleys and coastal dunes) (Van Landuyt 2006, Verloove 2020). It is still increasingly reported in urban areas, where it is more adapted to cope with the urban heat effect, and is expected to use these urban refuges to invade more natural areas (Géron et al. 2022).

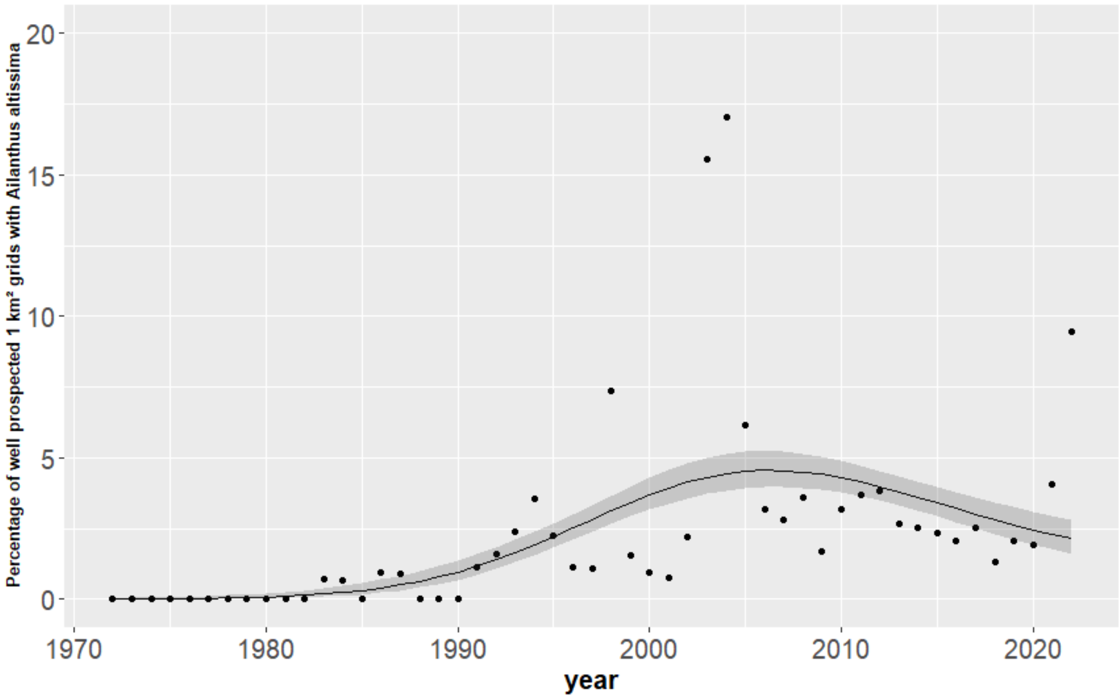


Figure 20. Trend in the percentage of well prospected 1x1km squares in Flanders where *Ailanthus altissima* was recorded based on the floristic surveys in Florabank (Van Landuyt et al. 2012).

Ailanthus altissima is locally very common, especially in man-made habitats such as wastelands, disused railways, on old walls, brownsites, along motorways and on canal banks. It impacts on native vegetation through allelopathy, especially at the level of the roots (Heisey 1990). In Flanders, outside ruderal and urban settings, the species has colonized dunes and invaded almost 10% of protected dune reserves over a surface area of about 2000 m^2 (INBO-data). A bigger *Ailanthus* coastal woodland forest in the Calmeynbos (De Panne), which originated as an escape from a nearby residential area, has meanwhile been removed (J. Lamaire, pers. comm.).

5.2.3 Management profile

Ailanthus altissima is a deciduous tree which can grow up to 25 m. It is a light-demanding, thermophilic species occuring on well-drained soils. The plants are physiologically adapted to withstand periods of drought by reducing evapotranspiration via the leaves in combination with reduced root hydraulic conductance (Trifilò et al. 2004, van Valkenburg et al. 2022). The flowering period is June-July, after which the species produces abundant winged seeds (Picture 6), up to one million per tree (Weber 2003, de Groot and Oldenburger 2011). These easily spread by wind and water and can disperse over several hundred meters (Landenberger et al. 2007), covering larger distances if dispersed by water (Kowarik & Säumel 2008). However, seeds do not remain dormant for more than one year (Hunter, 2000).

The species is a persistent stump and root sprouter (Miller, 2003). After death or injury of the main stem, the wide-spreading shallow root system can give rise to many sprouts. Thus, the species can easily propagate from root cuttings or after coppicing. Tree-of-heaven sprouts have been found to have 3-4 m of first year height growth, while seedlings can grow 1-2 m in the first year. This vigorous growth can continue for 4 or more years.

Picture 6. *Ailanthus altissima*, young tree (left) and fruits (right).

5.2.4 Options for management

5.2.4.1 Mechanical and manual

Ailanthus altissima is probably best controlled by manual removal (pulling) of young seedlings that do not have a tap root yet (Meloche and Murphy 2006, Q-bank 2019, CABI 2019). This should (as with *Baccharis halimifolia*) preferably be performed after rain when the soil is loose - although this could be less relevant for coastal dunes - and when the seedlings are large enough to grab. Care should be taken to remove the entire root system to prevent resprouting (SEPPC, 2012) and plants should be pulled young and before seed set. In the context of sandy dunes, bigger plants and trees can be mechanically pulled out with a crane, trying to remove as much of the root system as possible, after which the remaining regenerating sprouts should be removed manually. In terms of the organisation of a pulling campaign, in Australia, the Bradley Method is advocated for nature reserves with budgetary constraints and with sensitive plant populations (Bradley 1971) (see 5.1.4). This makes sense with a pioneering, allelopathic species like *Ailanthus* that will profit from non-vegetated areas. The removal of rootstocks by hand digging is a slow but sure way of removal. This technique is suitable for small infestations and around trees and shrubs where other methods are unpractical. Of course, in case budgets (and machinery) are available, larger source populations could move up the priority list.

Another possibility is manual cutting (potentially using tools such as brush cutters, power saws, axes, machetes, loppers and clippers). This method however only removes above-ground portions of the plant and mostly causes the plants to regenerate and produce even more shoots. Cutting trees usually causes the formation of root shoots and without additional treatment of the stumps this can lead to a significant increase in stem numbers and strong compaction of the stand (Meloche and Murphy 2006). If possible, the entire root system should be removed, for example by pulling them out with a crane. Bigger trees can be girdled if standing dead wood in an area is not a problem, with the effect being greatest in spring when the trees are actively growing. Girdling usually causes fewer root shoots to be formed than with cutting (Agentschap voor Natuur en Bos 2014). Mechanical treatments of bigger trees alone (e.g. cutting the trunk at the root collar or girdling the tree do not kill the tree but rather stimulate vigorous resprouting from the remaining trunk and roots (Burch, 2003; CABI, 2019). Even a "double-cut stump treatment" performed each year for 5 consecutive years failed to significantly reduce the ability to resprout (Constán-Nava, 2010).

Follow-up after management is always necessary regardless of the applied method, as the tree can regenerate from root remnants. Treated sites should be visited one or more times a year, and new suckers or seedlings handled during at least 3 years. There is however little risk of a viable durable seed bank building up. In case this is possible, establishing a cover of (preferably native) trees or grass can help shade out and discourage re-establishment of *Ailanthus* seedlings.

5.2.4.2 Chemical

Past experiments have proven that only the application of herbicides (e.g. glyphosate, triclopyr combined with physical treatment has effectively controlled regrowth of adult trees after cutting and significantly reduced the presence of *A. altissima* in invaded areas (Burch 2003, Meloche 2006, DiTomaso & Kyser 2007).

Stem injection (with cover of the drilled holes) is advocated as the safest technique to be used, especially on trees in natural habitats. Undiluted glyphosate (e.g. Myrtos® 360 SL, NUFARM Italia srl, Milan - 360 g lt-1) is injected into holes in the stem with a plastic syringe. One ml of the herbicide is used when DBH (diameter at breast height) of trees is lower than 8 cm, while 2 mL are used when DBH is larger than 8 cm. In terrestrial ecosystems glyphosate has low mobility, as it is rapidly adsorbed by soil colloids and eventually inactivated by microbial degradation (Badalamenti & La Mantia 2013), yet glyphosate and any other product that rely on biodegradation to become inactive can become persistent on sterile soils such as sand and peat, which can have implications for the recolonization of the site and any subsequent use of the soil (T. Renals, pers. comm.). DiTomasio (2007) showed undiluted imazapyr to be equally effective, while Miller (2003) proved Garlon 3A, Pathway*, Pathfinder II, or Arsenal AC* in dilutions to be effective. For felled trees, these herbicides can also be applied to stem and stump tops immediately after cutting. After injection each hole should be sealed with a wound-sealing compound. The herbicide must penetrate to the cambial tissue and be water-soluble to be effective (wiki.bugwood.org). One hole is drilled into each tree, with a diameter ranging from 8 to 10 mm. Trunk holes are located 1 m above the soil surface, about 5 cm deep into the stem or trunk, holes are pointed downward (at 45°) (Badalamenti & La Mantia 2013). Stem injection needs to be performed late in the vegetative growth of the species when an injected herbicide is readily translocated to the roots, mid-summer being the best time.

Basal bark application, which involves applying high (10-20%) concentrations of herbicides in oil or other penetrating carriers (necessary for the mixture to penetrate bark and enter the vascular system) to the basal portion of stems, does not require any cutting. This method should provide good root kill especially in fall when vascular fluids are moving toward the roots (wiki.bugwood.org). Imazapyr is another herbicide which is effective for basal bark application (Boer, 2013). Follow-up foliar herbicide application to basal sprouts and root suckers may be necessary (Swearingen & Panhill, 2009).

Cut-stump treatment implies cutting the tree down and directly (within 20 minutes) applying herbicides to the cut surface. This is best done during the growing season, preferably in late spring and is effective in killing root systems. Imazapyr, triclopyr, dicamba, Garlon 4, Tordon K herbicides and a combination of 2,4 D and picloran have been described (DiTomaso & Kyser 2007; Burch, 2003; Boer, 2013). Glyphospate has proven not very effective (Swearingen & Panhill, 2009).

For saplings and seedlings a foliar spray method can be applied using glyphosate (non-selective) or triclopyr (selective for dicots; so excluding grasses and conifers, among others). For large thickets of seedlings these active compounds have proven to be effective and could be used for spot treatments (SE-EPPC, 2002, Miller 2003). Granular herbicide pellets, scattered at the bases of unwanted plants and leached down to the roots with rainfall, are not discussed here for their presumed higher potential of non-target effects.

5.2.4.3 Biological

There appears to be currently no operational biocontrol programme for this tree species. Ding et al. (2006) reported 46 phytophagous arthropods, 16 fungi, and one potyvirus attacking *A. altissima* in its native range in China, some apparently causing significant damage. Two weevils, *Eucryptorrhynchus brandti* and *E. chinensis*, are major pests of the plant in China and are specific to *A. altissima*, showing promise as potential biological control agents. Two rust fungi, *Aecidium ailanthi* J. Y. Zhuan sp. nov. and *Coleosporium* sp. have been reported on tree of heaven in China and are also promising potential candidates for biological control of the plant. In its introduced range (North America, Europe), nine insect herbivores and 68 fungi were found associated with the species. Based on this screening, the authors identified Ailanthus webworm (*Atteva punctella*), and the soilborne fungus *Fusarium osysporum* f. sp. *perniciosum* (causative agent of mimosa wilt) as potentially useful biocontrol agents that should be the subject of host specificity testing and proper risk assessment.

Since 2020, CABI has been working with partners to coordinate options for biological control of tree of heaven in Canada (https://www.cabi.org/projects/biological-control-of-tree-of-heaven/). This research focuses on the potential of the eriophyid mite, *Aculus taihangensis* (formerly *A. mosoniensis*) as a biocontrol agent. The mite, which is established in parts of Europe (e.g. Italy), can cause severe damage to seedlings and can inhibit new growth in early spring (Marini et al. 2021). Host specificity testing is ongoing.

5.3 EASTERN BACCHARIS (*BACCHARIS HALIMIFOLIA*)

5.3.1 Species profile

Union List	☒ Yes		☐ No	
Environment	☐ marine ☒ brackish		☐ freshwater ☒ terrestrial	
Natura 2000 susceptibility	☐ 1110 - Sandbanks ☒ 1130 - Estuaries ☐ 1140 - Mudflats and sandflats ☐ 1210 - Annual vegetation of drift lines * ☒ 1230 - Vegetated sea cliffs of coasts * ☒ 1310 - Annuals colonising mud and sand ☐ 1320 - *Spartina* swards ☒ 1330 - Atlantic salt meadows ☒ 2110 - Embryonic shifting dunes ☒ 2120 - Shifting dunes along shoreline (white dunes) ☒ 2130 - Fixed coastal dunes with herbs (grey dunes) ☒ 2140 - Decalcified dunes with *Empetrum* * ☒ 21A0 - Machairs * ☒ 2150 - Atlantic decalcified fixed dunes ☒ 2190 - Humid dune slacks ☒ 2160 - Dunes with *Hippophae rhamnoides* ☒ 2170 - Dunes with *Salix repens* ssp. *argentea* ☒ 2180 - Wooded dunes of the Atlantic region			
Occurrence in Atlantic coastal zone (Number of occupied 10km²-grid cells	Belgium	10 (53%)	United Kingdom	2 (0.1%)
	France	208 (46%)	Denmark	0
	Ireland	0	Germany	0
	Netherlands	6 (3%)	Portugal	0
	Spain	28 (15%)		

Impact scoring (max score across habitats)	**Score** 1	2	3	4	5	**Confidence** Low	Medium	High
Introduction	☐	☐	☐	☐	☒	☐	☐	☒
Establishment	☐	☐	☐	☐	☒	☐	☐	☒
Spread	☐	☐	☐	☐	☒	☐	☐	☒
Environmental impact	☐	☐	☐	☐	☒	☐	☐	☒

Overall impact score per habitat	(Salty) habitats 1110-1330	625
	(Sandy) habitats 2110-50/-90	500
	(Shrubby) habitats 2160-80	320

Impact mechanisms	☒ Competition	☒ Nutrient cycling
	☐ Hybridization	☒ Physical modification of habitat
	☐ Toxicity / poisoning	☒ Disruption of natural succession
	☐ Interactions with other IAS	☐ Disruption of food webs

Distribution

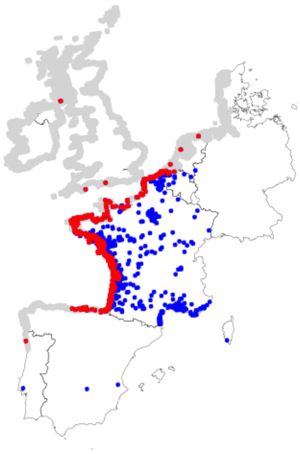


Figure 21. Distribution of *Baccharis halimifolia* within (red dots) and outside (blue dots) the European Atlantic coastal zone (in grey).

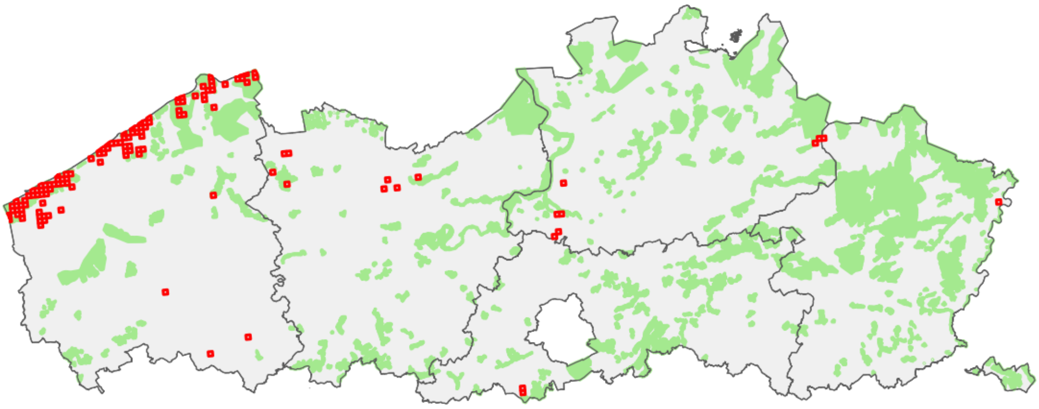


Figure 22. Distribution of *Baccharis halimifolia* in Flanders since 1950. NATURA2000 areas (EU Bird and Habitat Directive) in green.

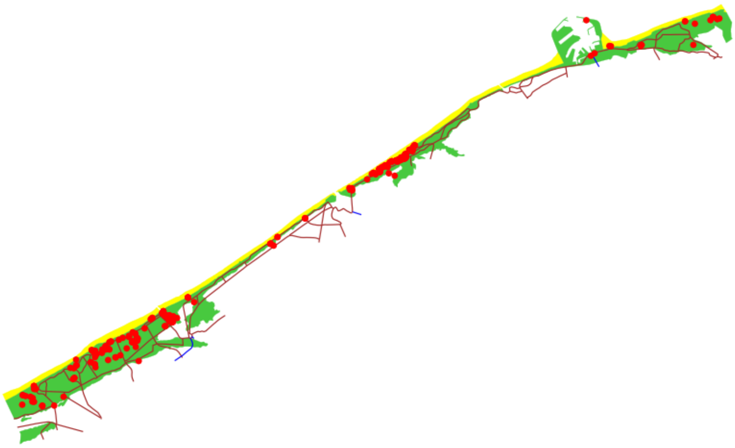


Figure 23. Distribution of *Baccharis halimifolia* in the Flemish coastal area (2007-2022) based on detailed plant surveys (Provoost et al. 2010, 2014, 2020) and the citizen science platform www.waarnemingen.be (Vanreusel et al. 2022). Beaches (yellow), coastal dunes (green) and major roads (brown) are shown for orientation.

5.3.2 Invasion history and distribution

In Belgium, *Baccharis halimifolia* benefited from urban sprawl along the Belgian coast and the demand for plants adapted to the coastal climate for plantations in public greenery, along roads and tramways (e.g. in De Panne), on roundabouts and in private gardens. Eastern baccharis has spread throughout the entire coastline since 1997 (Rappé 2006, Rappé et al. 2004, Figure 23). It is mostly found in (sub)urban environments and fringes of natural areas, where it grows in grassland or open scrub. The species is on the increase since 2000 (Figure 24). Based on field surveys within 46 nature reserves (Provoost et al. 2012, 2015), it occurs in 11 % of Belgian dune areas and the infected area amounts to about 800 m^2 (unpublished data). Most of the plants in gardens and public greenery however, are not included in this inventory.

B. halimifolia shows a particular preference for salty environments such as the banks and upper salt marsh of the Yzer estuary in Nieuwpoort or the green beach in the 'Bay of Heist' on the east coast (mostly publicly managed reserves but also many smaller stands on private property) (Provoost & Adriaens, 2011). Potential habitat is present as Atlantic salt meadows (Zwin, Uitkerkse polder, Scheldt estuary), an Annex I habitat. The species starts growing as individual shrubs but can form an extended dense scrub. Outside coastal areas, there are some isolated *Baccharis* bushes that mostly represent planted shrubs, garden escapes and roadside planting (the plants withstand salt spray). It is only rarely found in agricultural areas. For some of those locations it is unclear whether the plants produce seedlings. *B. halimifolia* is currently already under management in some nature reserves e.g. it is considered eradicated from the Bay of Heist and Uitkerke. The plant is unmistakable by the form of its leaves. Along the coast, the species is included in the floristic monitoring schemes, so the distribution is believed to be representative. In the Netherlands individual plants are found only in a few locations (Zeeland province), but the species has no established populations. In the past it disappeared spontaneously in some places (van Valkenburg et al. 2014) and some plants have been actively removed by NVWA (NVWA 2016). In France, it is widely distributed along the entire Atlantic and Provence coast (Fried et al. 2016) (Figure 21). Along the Atlantic coast, it reaches the Belgian border and occurs in nature reserves in Nord-Pas-De-Calais such as in Wimereux and Ambleteuse.

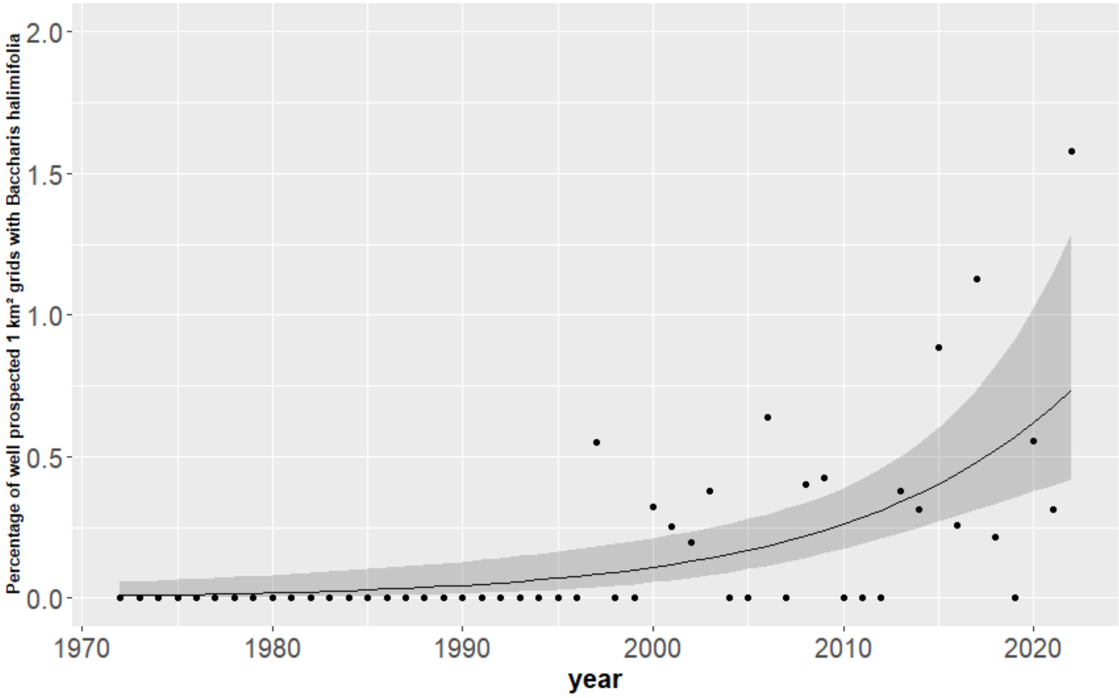


Figure 24. Trend in the percentage of well prospected 1x1km squares in Flanders where *Baccharis halimifolia* was recorded based on the floristic surveys in Florabank (Van Landuyt et al. 2012).

An expert panel deemed eradication to be the recommended goal for management in Belgium (Adriaens et al. 2019). To achieve this, a survey should be conducted to determine the full extent of the *B. halimifolia* distribution, using the existing species monitoring (PINK, BEK) of natural areas and NATURA2000 areas along the coast (Provoost et al. 2012) but adding dedicated surveillance at likely places of introduction of *B. halimifolia*, especially along roadsides, on brownfields with bare soil and along canals. Increased attention for the species is required in the Polder area, especially in areas with halophytic grasslands. The most appropriate time for surveillance is during the flowering period (mostly June-August). *B. halimifolia* has a very high seed production and is dispersed by wind and water, which ensures a good colonization capacity (Fried et al. 2016). Outside this coastal area *B. halimifolia* occurs in plantings but is much more rare in the wild (Figure 22). Yet, suitable habitat (moist soils with high organic content, poorly drained saline soils) is present further east (e.g. along the river Scheldt and in natural areas around the port of Antwerp) and is well within range of its wind-dispersed fruits. The ban on selling, growing and planting the species should be strictly enforced. Public authorities should be informed on ecological risks and be stimulated to remove current *Baccharis* stands.

5.3.3 Management profile

B. halimifolia produces masses of small fruits which are easily dispersed by wind and water over long distances. It has a long lived seed bank expected to persist for a minimum of 2 years.

Picture 7. *Baccharis halimifolia* – habitus (left) and leaves (right).

5.3.4 Options for management

5.3.4.1 <u>Mechanical and manual</u>

Young plants (maximum of 1 to 1.5 m in height) are year-round manually removed by hand pulling of the entire plant, including the root system to prevent resprouting. This is best done when the soil is moist, which facilitates total removal of the plant. Bigger shrubs, for which manual removal is impossible, can be removed mechanically using an excavator to pull out entire plants from the soil.

On larger *Baccharis* bushes (>3 m), girdling is an option and has been applied in a Corsican saltmarsh in combination with removal of fruiting branches. A sufficient number of branches should be girldled, with a band of at least 4-5 cm of bark removed. However, some resprouting was noticed, mostly under the girdled zones (Singh et al. 2022). Other plants were succesfully removed using a stump grinder and manual removal of sprouts from the mother plant.

As the species is dioecious, ideally, all management interventions should be performed before flowering to prevent the spread of pollen and the subsequent formation of seeds. If management is undertaken later in season, to prevent seeds from spreading, plants should be removed before fruiting. In Belgium, the species mostly flowers from August-October. As the species is still casual in the wild in the Netherlands eradication is preferably performed north to south along the Belgian coast. In combating this species, it is extremely important to control the contamination of adjacent areas given the simple distribution of the species via water and wind. In addition, it is crucial to thoroughly clean machines and materials to prevent further spread, though some contamination of machinery is always possible should seeds get caught in lubricating grease for instance (pers. comm. M. van de Loo).

If possible, the management waste is best treated by controlled burning to prevent regrowth. If this is not possible, dead plants can be stacked on a heap, taking into account that root material does not touch the bottom and inflorescences are placed at the bottom of the heap. In Corsica, the removed plant material was places in plastic bags before being incinerated to prevent further dispersal of seeds during and after management (Singh et al. 2022).

Continued aftercare is necessary in light of the strong regrowth via root runners and seedlings (Miller & Skaradek, 2002). Mowing or cutting *Baccharis* stands before bloom targets only aboveground plant material and does not ensure permanent removal. The same is true for management consisting of cutting inflorescences. These can however be suitable methods to buy time should one be unable to implement more drastic measures.

5.3.4.2 Chemical

B. halimifolia plants can also be cut with scissors after which glyphosate is applied on the stumps (glyphosate 36% diluted in oil in a proportion of 1:1) (Ihobe 2014). Treatments of glyphosate, 2,4-D acid or 2,4-D amine achieved over 90% control in a variety of tests (Auld 1970; Armstrong and Wells 1979). Weber (2003) reported that chemical control provided satisfactory results with 2,4-D, dicamba plus MCPA, glyphosate, picloram plus 2,4-D, and tryclopyr. DiTomaso & Kyser (2007) identified that triclopyr was far more efficient than imazamox, aminopyralid and glyphosate. Combinations of herbicides (e.g. picloram combined with aminopyralid and triclopyr or 2,4-D combined with dichloprop-p) have provided efficient results (still visible after 6 months) in France (Commission syndicale de grande Brière Mottière 2007). Foliar spraying has been tested in estuarine environments.

Herbicides may also be applied on cut stumps (for plants of more than 1.5 m in height), just after cutting, and this is particularly efficient when the tree is cut at the soil level (Charpentier, Riou and Thibault 2006). The application of glyphosate and ammonium sulfamate (the latter active substance is less toxic than glyphosate) has controlled 90% of the trees treated with the method in an experiment in France (Commission syndicale de grande Brière Mottière 2007). It is recommended to apply such a measure in autumn when sap is going down. Applied in the north of Spain, this methodology showed high effectiveness (97%) in small or medium-sized invasions, and less effectiveness in large and widespread invasions (70–75%). Application on stumps greatly reduces the quantities of active substances used, however the concentration of the product has to be much higher than in the case of foliar spraying. Efficient application of glyphosate on stumps requires concentrations 25-fold higher (c. 50% of commercial dilution) than foliar application requires (c. 2% of commercial dilution, Ihobe 2014).

5.3.4.3 Biological

Grazing can be a useful method to treat resprouting after physical removal was applied. In France, sheep have been used to control resprouting after application of physical methods on large areas in saltmarshes, but with continuous grazing pressure (GT IBMA 2016).

Due to the high cost of mechanical removal and the unintended effects of herbicide application on other species, alternative management methods such as controlled inundations and classical biological control could also be considered (Fried et al. 2016). Australia has released a bush rust and 12 species of insect to control the species however this did not yield the desired results (Fried et al. 2016 and references therein).

5.4 OREGON GRAPE/MAHONIA (*BERBERIS AQUIFOLIUM*)

5.4.1 Species profile

Union List	☐ Yes		☒ No	
Environment	☐ marine		☐ freshwater	
	☐ brackish		☒ terrestrial	
Natura 2000 susceptibility	☐ 1110 - Sandbanks			
	☐ 1130 - Estuaries			
	☐ 1140 - Mudflats and sandflats			
	☐ 1210 - Annual vegetation of drift lines *			
	☐ 1230 - Vegetated sea cliffs of coasts *			
	☐ 1310 - Annuals colonising mud and sand			
	☐ 1320 - *Spartina* swards			
	☐ 1330 - Atlantic salt meadows			
	☐ 2110 - Embryonic shifting dunes			
	☐ 2120 - Shifting dunes along shoreline (white dunes)			
	☒ 2130 - Fixed coastal dunes with herbs (grey dunes)			
	☐ 2140 - Decalcified dunes with *Empetrum* *			
	☐ 21A0 - Machairs *			
	☒ 2150 - Atlantic decalcified fixed dunes			
	☐ 2190 - Humid dune slacks			
	☒ 2160 - Dunes with *Hippophae rhamnoides*			
	☒ 2170 - Dunes with *Salix repens* ssp. *argentea*			
	☒ 2180 - Wooded dunes of the Atlantic region			
Occurrence in Atlantic coastal zone (Number of occupied 10km²-grid cells)	Belgium	17 (89%)	United Kingdom	129 (9%)
	France	144 (32%)	Denmark	5 (5%)
	Ireland	0	Germany	37 (25%)
	Netherlands	127 (62%)	Portugal	0
	Spain	20 (10%)		

Impact scoring (max score across habitats)	**Score** 1 2 3 4 5	**Confidence** Low	Medium	High
Introduction	☐ ☐ ☐ ☐ ☒	☐	☐	☒
Establishment	☐ ☐ ☐ ☐ ☒	☐	☐	☒
Spread	☐ ☐ ☐ ☐ ☒	☐	☐	☒
Environmental impact	☐ ☐ ☐ ☐ ☒	☐	☐	☒

Overall impact score per habitat	Tidal salt marshes	--
	(Sandy) habitats 2110-50/-90	625
	(Shrubby) habitats 2160-80	500
Impact mechanisms	☒ Competition	☒ Nutrient cycling
	☐ Hybridization	☒ Physical modification of habitat
	☐ Toxicity / poisoning	☒ Disruption of natural succession
	☐ Interactions with other IAS	☐ Disruption of food webs

Distribution

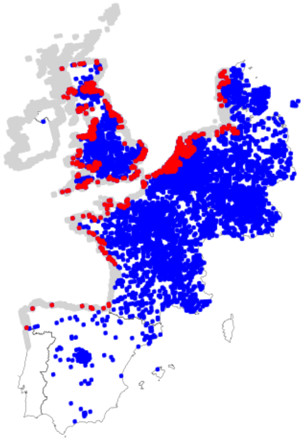


Figure 25. Distribution of *Berberis aquifolium* within (red dots) and outside (blue dots) the European Atlantic coastal zone (in grey).

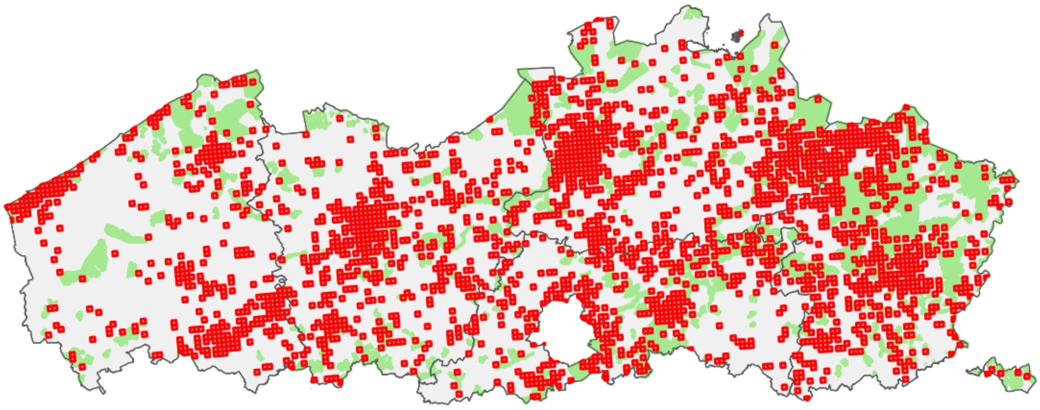


Figure 26. Distribution of *Berberis aquifolium* in Flanders since 1950. NATURA2000 areas (EU Bird and Habitat Directive) in green.

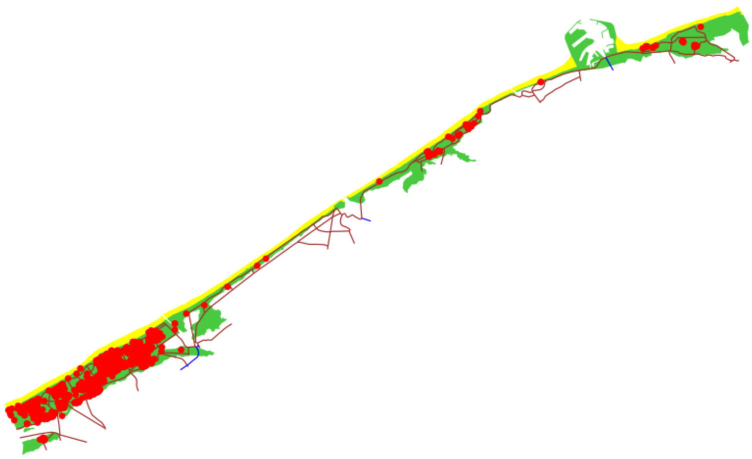


Figure 27. Distribution of *Berberis aquifolium* in the Flemish coastal area (2007-2022) based on detailed plant surveys (Provoost et al. 2010, 2014, 2020) and the citizen science platform www.waarnemingen.be (Vanreusel et al. 2022). Beaches (yellow), coastal dunes (green) and major roads (brown) are shown for orientation.

5.4.2 Invasion history and distribution

The alien invasive *Berberis* species forming a vast population in Belgian coastal dunes is referred to as Oregon-grape - *Berberis aquifolium* Pursh. (Berberidaceae), formerly known as *Mahonia aquifolium* Nutt. The exact origin and taxonomy of most individuals in the wild is uncertain. Many of the invasive *Berberis* populations in central Europe may have arisen from hybridized cultivars of *B. aquifolium* with *B. repens* Lindl. or *B. pinnata* Lag., which belong to the compound-leaved *Berberis* spp. and originate from the western states of North America (Adhikari et al. 2015, Ross & Auge 2008). These taxa have been subject to selection for ornamental purposes, e.g. for faster growth rate, reproductive versatility, stress tolerance, pathogen resistance and greater biomass production (Ross & Auge 2008; Ross et al. 2008). Indeed, Ross et al. (2008) showed that the majority of cultivars and invasive populations in Germany formed a gene pool different from the native species. Cultivated forms of *B. aquifolium* are now naturalized in various natural and semi-natural environments in Europe. It is one of the most successful alien shrubs in central and eastern Germany where it invades semi-natural habitats (Auge & Brandl 1997). The species is common in western and central Europe, from the Pyrenees to southern Scandinavia.

In Belgium, *B. aquifolium* was first recorded in the wild in 1906 and naturalized in the period 1920–1950 (Verloove 2002). Its distribution only increased rapidly since the 1990's; the reasons for this increase are unknown. The highest densities are found in the northern part of the country, notably in urban environments and in the coastal dunes (Verloove 2002, Figure 26). In urban areas it occupies a wide range of habitats such as waste land, disused industrial and railway yards, railway tracks and old walls. In the south of Belgium, it also occurs on rocky, wooded slopes (Verloove 2006c).

Figure 28. Occurrence of *Berberis aquifolium* in dune reserves along the Belgian west coast (Data: Provoost et al. 2015).

The first observation along the coast dates back to 1972. However, the large expansion only occurred during the past decades (Figure 29). Verloove (2006) describes the expansion in the coastal dunes as a “recent phenomenon” and “characteristic for the Belgian dunes”. Although the trend is unknown, it is however not uncommon in the European Atlantic coastal dune area (Figure 25).

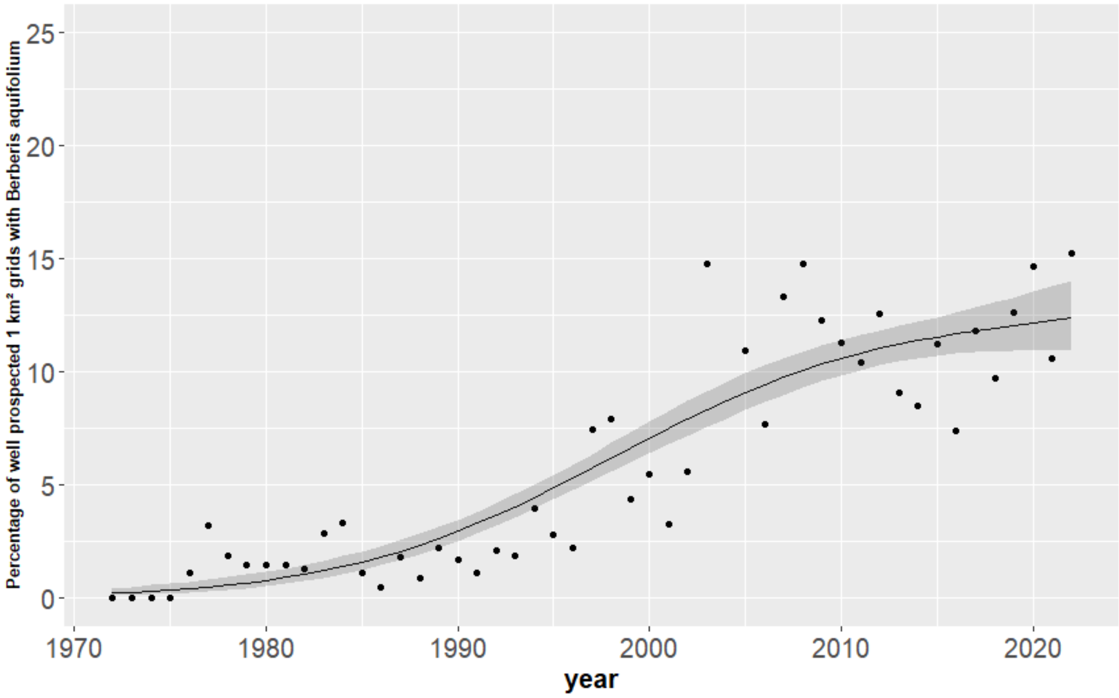


Figure 29. Trend in the percentage of well prospected 1x1km squares in Flanders where *Berberis aquifolium* was recorded based on the floristic surveys in Florabank (Van Landuyt et al. 2012).

According to the INBO data on invasive alien species in the coastal dunes, *Berberis aquifolium* is currently the most frequently encountered non-native shrub species in terms of numbers of point- or patch occurrences (5000 so far). Total infested area is about 10 ha, a figure preceded only by *Rosa rugosa* (see 5.7.2), at least before the large scale eradication projects of *Rosa rugosa* carried out in 2020 and 2021. Especially the smaller dune areas along the western part of the dunes are heavily infested by Oregon grape (Figure 27). It is scattered and relatively rare along the rest of the coast. The concentration of plants along the edges of the dune sites indicates that gardens and public plantings bordering natural areas represent a major source of introduction. The distribution shows strong concentrations, usually close to garden-rich villa districts. The expansion seems localised despite its capacity for ornithochorous spread. The vast majority of the plants occur in a few large clusters (several ha in size) that provide the lion's share of seeds for further dispersal (Figure 28). It is very likely that the seed production in the natural areas by now is already much higher than in the original garden sources. Consequently, the dune reserves themselves currently act as the main dispersal source since the very large populations already present (Provoost et al. 2015).

5.4.3 Management profile

Berberis aquifolium is an evergreen perennial shrub. Plants can grow up to two meters, are many-stemmed and stoloniferous. The species shows rapid clonal growth, mostly by stem layering and below-ground stolons (Auge and Brandl 1997). Through its highly branched root system, it attaches itself firmly in the sand. As a result of its strong vegetative growth with root suckers, the species locally appears in monospecific stands, overgrowing and displacing native species and thoroughly impacting dune succession (Verloove 2002, 2006; Provoost et al. 2015).

The species' numerous blue berries are easily dispersed over long distances by thrushes and other songbirds as was shown for other *Berberis* species (Silander and Klepeis 1999). Therefore, the plant can appear everywhere within the dune sites, including places which are hardly accessible to managers, such as dense scrub.

The cultivated origin of the naturalised *Berberis aquifolium* populations means the plants differ from their natural ancestors in morphology and other characteristics. Common garden experiments showed that plants from invasive populations in central Europe grew larger in terms of stem length, number of leaves and above-ground biomass than either of the two native species (Ross 2009). This author therefore concludes that hybridization and subsequent selection by breeders have led to an evolutionary increase of plant vigour in the introduced range. The Belgian coastal populations are extensively suckering and have leaves with numerous leaflets which according to some authors suggests introgression from *B. repens* (Verloove 2018). However, Ross et al. (2008) could not find evidence of hybridization of *B. aquifolium* and *B. repens*. shrubs with pinnate leaves, yellow flowers and fleshy fruits.

Picture 8. Left: *Berberis aquifolium* vegetation cover. Right: *B. aquifolium* individual shrub.

5.4.4 Options for management

Oregon grape and its hybrids should be removed with the roots as regrowth from the root system is possible. Ripe berries should also be removed (van Valkenburg et al. 2022).

5.4.4.1 Mechanical and manual

As for all ligneous invasive species, seedlings and young plants can be pulled out manually. However, through its highly branched root system, even young plants of *B. aquifolium* attach firmly in the sand, making manual pulling difficult and labor-intensive. In a field experiment on isolated individual *Berberis* plants, Adriaens et al. (2019) found 65% of the plants resprouting after careful manual uprooting. This means even small remnants of roots or stolons can resprout.

Patches of *B. aquifolium* can successfully be tackled by mechanically digging out at a depth of +/- 0.5m (Adriaens and Provoost 2015) and sieving the dug out material. A 20 mm sieve is found as an ideal balance between retaining the plant material and letting the sand pass through. A bufferzone of at least 1 m around the aboveground stand is required in order to include all the belowground pant parts.

No information was found on mowing of *B. aquifolium* stands. Although this measure can certainly reduce the species' impact and prevent it from producing seed, it is unlikely that mowing will be an appropriate eradication technique since very low but vigorous stands are known from a number of grazed open dune sites.

5.4.4.2 Chemical

Based on experiments in Belgian coastal dunes, Adriaens et al. (2019) concluded that leaf treatment (by hand spraying) with a 5% Roundup Max (450g/l glyphosate) solution was the most effective eradication measure, compared to cutting and stem treatment with a similar herbicide concentration, and certainly compared to manual uprooting. A kill rate of 88% was attained with the leaf treatment.

Surprisingly, an experiment in 2020 with different types of herbicide was not able to reproduce these high kill rates. Here, a Roundup-treatment on similar *Berberis* plants resulted in a reduction of vitality of about 30% of the plants but no effective killing was observed. The most effective herbicide was TRIBEL XXL with 30% of the plants killed and a reduction of vitality in another 55% of the treated individuals. Tribel XXL contains 93 g/l 1,4-D and 103,6 g/l Triclopyr and was applied in a 1,25% dilution.

Also Stahl & Schwab (2014) measured no effect of chemical treatment in invasive *B. aquifolium* populations of orchid-rich forest in central Germany. In this study, the herbicide used was Clinic (Nufarm) in a 33% glyphosate concentration which was applied in early July on the leaves with a paintbrush. This higher concentration may have hindered effective uptake of the product by the leathery leaves or differences in environmental circumstances (e.g. shade, soil conditions) might explain the contrasting results.

Large efforts have been done to eradicate the European *B. vulgaris* (common barberry) in North America because it was found to be responsible for dramatic reductions in wheat crop yields. Common barberry is an alternate host for cereal stem rust *Puccinia graminis* (Gucker 2009). Although the species' populations were often reduced or eliminated by eradication efforts, some post-eradication surveys indicate substantial spread from untreated or surviving plants. The best eradication results were obtained with repeated use of herbicides.

Although chemical treatment is probably the most appropriate eradication method for isolated *Berberis* plants, a lot of practical experience still needs to be gained regarding active substances in herbicides, dilution, optimal period of application and meteorological and phenological conditions.

5.4.4.3 Biological

B. aquifolium currently occurs in grazed dunes. Although grazers can defoliate older plants, it is unlikely that non-targeted grazing will reduce the spread. It is recommended to investigate the effects of targeted sheep grazing.

No information was found on operational biological control programmes for *B. aquifolium*.

5.5 COTONEASTERS (*COTONEASTER* SPP.)

5.5.1 Species profile

Union List	☐ Yes	☒ No
Environment	☐ marine	☐ freshwater
	☐ brackish	☒ terrestrial
Natura 2000 susceptibility	☐ 1110 - Sandbanks	
	☐ 1130 - Estuaries	
	☐ 1140 - Mudflats and sandflats	
	☐ 1210 - Annual vegetation of drift lines *	
	☐ 1230 - Vegetated sea cliffs of coasts *	
	☐ 1310 - Annuals colonising mud and sand	
	☐ 1320 - *Spartina* swards	
	☐ 1330 - Atlantic salt meadows	
	☐ 2110 - Embryonic shifting dunes	
	☐ 2120 - Shifting dunes along shoreline (white dunes)	
	☒ 2130 - Fixed coastal dunes with herbs (grey dunes)	
	☐ 2140 - Decalcified dunes with *Empetrum* *	
	☐ 21A0 - Machairs *	
	☒ 2150 - Atlantic decalcified fixed dunes	
	☐ 2190 - Humid dune slacks	
	☒ 2160 - Dunes with *Hippophae rhamnoides*	
	☒ 2170 - Dunes with *Salix repens* ssp. *argentea*	
	☒ 2180 - Wooded dunes of the Atlantic region	

Occurrence in Atlantic coastal zone (Number of occupied 10km²-grid cells) – based on *C. horizontalis*			
Belgium	14 (74%)	United Kingdom	500 (35%)
France	112 (25%)	Denmark	8 (7%)
Ireland	23 (6%)	Germany	24 (16%)
Netherlands	73 (36%)	Portugal	0
Spain	7 (4%)		

Impact scoring (max score across habitats)	**Score** 1 2 3 4 5	**Confidence** Low Medium High
Introduction	☐ ☐ ☐ ☐ ☒	☐ ☐ ☒
Establishment	☐ ☐ ☐ ☐ ☒	☐ ☐ ☒
Spread	☐ ☐ ☐ ☐ ☒	☐ ☐ ☒
Environmental impact	☐ ☐ ☐ ☐ ☒	☐ ☐ ☒

Overall impact score per habitat – *Tall, large-leaved*	(Salty) habitats 1110-1330	--
	(Sandy) habitats 2110-50/-90	256
	(Shrubby) habitats 2160-80	250
Overall impact score per habitat – *Low, small-leaved*	(Salty) habitats 1110-1330	--
	(Sandy) habitats 2110-50/-90	256
	(Shrubby) habitats 2160-80	500
Overall impact score per habitat – *horizontalis group*	(Salty) habitats 1110-1330	--
	(Sandy) habitats 2110-50/-90	625
	(Shrubby) habitats 2160-80	250

Impact mechanisms	☒ Competition	☒ Nutrient cycling
	☐ Hybridization	☒ Physical modification of habitat
	☐ Toxicity / poisoning	☒ Disruption of natural succession
	☐ Interactions with other IAS	☐ Disruption of food webs

Distribution

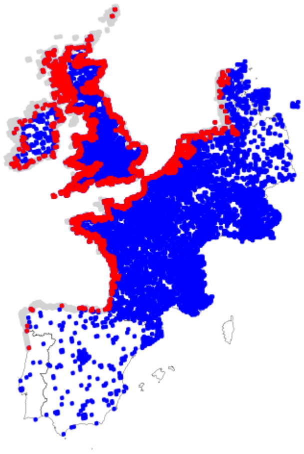


Figure 30. Distribution of *Cotoneaster spp.* within (red dots) and outside (blue dots) the European Atlantic coastal zone (in grey).

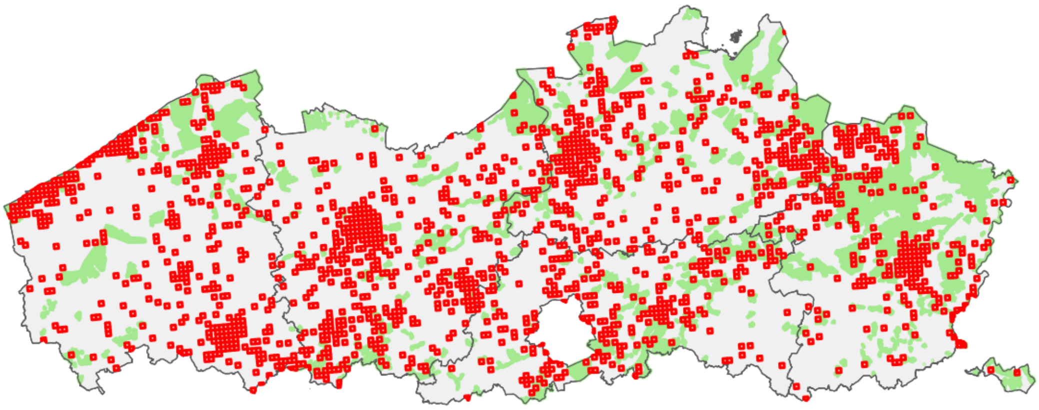


Figure 31. Distribution of *Cotoneaster spp.* in Flanders since 1950. NATURA2000 areas (EU Bird and Habitat Directive) in green.

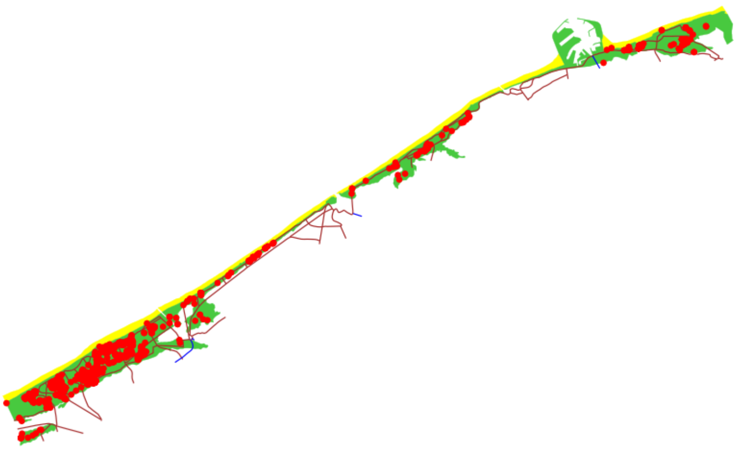


Figure 32. Distribution of *Cotoneaster spp.* in the Flemish coastal area (2007-2022) based on detailed plant surveys (Provoost et al. 2010, 2014, 2020) and the citizen science platform www.waarnemingen.be (Vanreusel et al. 2022). Beaches (yellow), coastal dunes (green) and major roads (brown) are shown for orientation.

Note that for the distribution maps, the following species of *Cotoneaster* were jointly considered– species marked in bold occur in the Flemish coastal dunes: ***C. divaricatus, C. salicifolius, C. rehderi, C. franchetii***, *C. pannosus, C. intermedius*, ***C. horizontalis***, *C. microphyllus, C. acutifolius, C. multiflorus*, ***C. ×watereri***, *C. nitens*, ***C. ×suecicus, C. hjelmqvistii, C. integrifolius***, *C. frigidus, C. tomentosus, C. ascendens, C. bullatus*, ***C. dielsianus, C. simonsii, C. sternianus, C. zabelii***

Picture 9. *Cotoneaster rehderi* (syn. *C. bullatus* var. *macrophyllus*), one of the most commonly encountered species of the genus in the Flemish coastal dunes.

5.5.2 Invasion history and distribution

The genus *Cotoneaster* (Rosaceae) occurs in large parts of temperate Eurasia with a clear centre of diversity in the mountains of China and the Himalayas. This region is likewise the origin of most cultivated and naturalising *Cotoneaster* spp. in Western Europe (Dickoré & Kasparek 2010). The genus’ taxonomy is complicated by interspecific hybridization and apomixis (asexual reproduction without fertilization with offspring generally identical to the parent plant). Fryer & Hylmö (2009) recognise about 400 taxa in their monograph, although in horticulture cultivated taxa are easily considered as ‘species’. In practice, although pany species are apomictic and vary little (Fryer 1998), there is little agreement on delineation of species. A revision by Lingdi & Brach (2003) recognised only 90 species worldwide, amongst which 59 occur in China. However, it is not obvious to use the species concepts of Lingdi & Brach (2003) for naturalised cotoneasters in Western Europe since these mostly originate from cultivated plants. As a consequence, there is also a lot of disagreement amongst European botanists. While Stace (2010) recognises 86 taxa for the British Isles, Dickoré & Kasparek (2010) only accept 20 species for Central Europe, amongst which seven are indigenous to Europe. This shows that a reliable regional taxonomic framework is essential to get started with naturalised *Cotoneaster* spp.

The extensive review of Verloove (2013) offers such a framework for Belgium. According to this author, 30 non-native *Cotoneaster* taxa have been recorded in the wild in Belgium. Only 12 species occur in considerable numbers however, amongst which the indigenous *C. integerrimus*. This species grows on calcareous rocky soils and is restricted to Wallonia. In the Netherlands, 18 species and hybrids were found up to 2015 (Boer 2015). The invasion in coastal dunes is still limited in extent. Within Europe, several naturalised cotoneasters seem widespread in central Europe, up to southern Scandinavia. According to the GBIF database, *Cotoneaster horizontalis* is the most widespread, or it is best surveyed. *Cotoneaster horizontalis* is however not the most common species along the coast as it prefers rocky habitats.

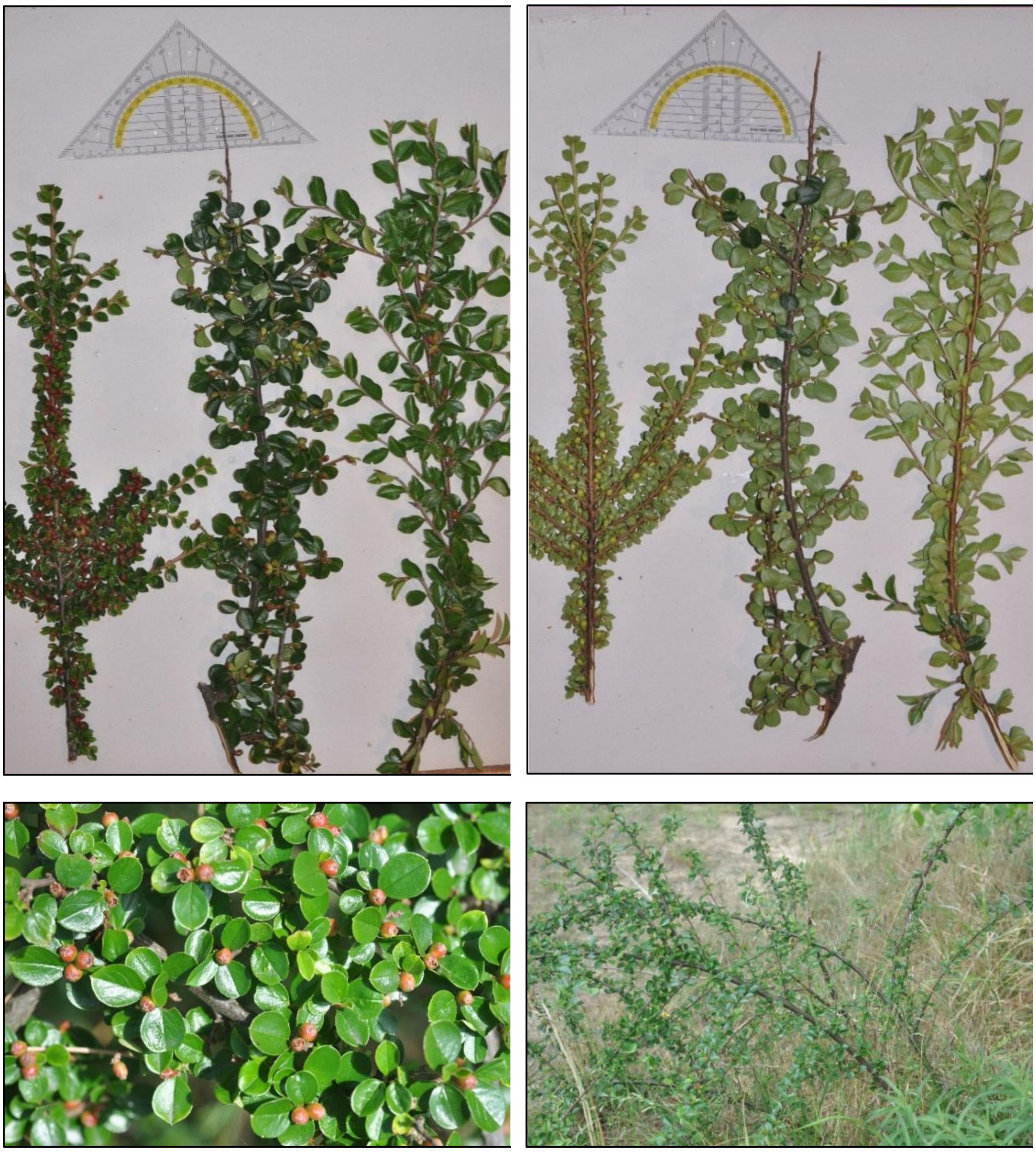
Although there is a wide variety of growth forms (see management profile), all the other species found in nature share an origin as garden escape (private gardens or public parks and greenery). Tens of species are grown in garden centres. The plants are appreciated because they can be evergreen, they can be used as hedge plant or as ground cover and they have colourful berries.

Despite this ornamental interest, *Cotoneaster* species in Belgium show a relatively late expansion in the wild. The first records date from the 1950's (*C. simonsii* and others). The atlas of the Flemish flora (Van Landuyt et al. 2006) describes *C. dielsianus*, *C. horizontalis*, *C. rhederi*, *C. salicifolius* and *C. sternianus*. *Cotoneaster horizontalis* is the only one with a substantial number of records. Since then, many more species (>30) are present on the territory (cf. Florabank, waarnemingen.be), but many are rare with <20 records. This partly illustrates the relatively late expansion, although this image is certainly blurred because of the lack of interest amongst botanists. During the past decade however, both an expansion of the species and an increased attention amongst naturalists occurred, no doubt stimulated by the success of the citizen science platform www.waarnemingen.be (Vanreusel et al. 2022).

In the coastal area, 17 *Cotoneaster* species have been recorded according to waarnemingen.be, which includes INBO data. However, probably only 7 species occur in considerable numbers in the coastal dunes: *Cotoneaster rehderi, C. divaricatus, C. franchetii, C. simonsii, C. hjelmqvistii, C. horizontalis* and *C. dielsianus*. Cotoneasters are already well distributed over the entire costal dune area. The INBO database includes 770 point locations where one or more naturalised *Cotoneaster* individuals were found. The total infested area is estimated at 0,5 ha. Most observations however, concern '*Cotoneaster'* at genus level. Clear hotspots in abundance and species numbers prevail west of the Yser estuary: eastern part of the Westhoek, Houtsaegerduinen, Noordduinen-Hoge Blekker, Schipgat-St André, western part of the Doornpanne, Witte Burg-Plaatsduinen and western part of Ter Yde.

Figure 33. The distribution of *Cotoneaster* in the west coast dunes (De Panne – Koksijde). The distribution is clearly concentrated along the dune margins and linked to the gardens from which they escaped.

Picture 10. Upper panel (left): upperside of *Cotoneaster horizontalis*, *C. hjelmqvistii* and *C. divaricatus*. Upper panel (right): underside of *Cotoneaster horizontalis*, *C. hjelmqvistii* and *C. divaricatus*. Lower panel: *Cotoneaster hjelmqvistii* (left), *Cotoneaster divaricatus* (right).



Picture 11. Upper side (top row) and under side (bottom row) of the leaves of some *Cotoneaster* spp. found in the Flemish coastal dunes: *Cotoneaster salicifolius* (left), *C. rehderi* (syn. *C. bullatus* var. *macrophyllus*) (middle) and *C. franchetii* (right).

5.5.3 Management profile

Cotoneaster species generally grow on dry, calcareous soils. Within their native range, soils are often rocky. This corresponds with the soil conditions in the habitat of the indigenous *Cotoneaster integerrimus*, e.g. within the calcareous areas of southern Belgium. Apart from urban areas, also calcareous dunes are a preferred landscape type where naturalised *Cotoneaster* species thrive. They are mostly found on sunny locations but some species tolerate moderate shading, as in open dune woodland. The ecological characteristics of the different *Cotoneaster* species are linked to the general morphology. All species are woody perennials but we can roughly distinguish three "habitus groups" that potentially differ in impact, habitat and management profile:

1) Tall, large-leaved shrubs (*C. rehderi, C. dielsianus, C. franchetii*). *Cotoneaster rehderi* is probably one of the most shade tolerant species and can compete with other tall shrubs (*Hippophae rhamnoides, Ligustrum vulgare*). It is found in open dunes as well as scrub or even open woodland.

2) Low, small-leaved shrubs (*C. hjelmqvistii, C. simonsii, C. divaricatus*). Because of their limited abilities to compete with other shrubs, these species are found in open dune vegetation.

3) Procumbent to low, small-leaved (dwarf-)shrubs (*C. horizontalis*). Deciduous or semi-evergreen. Limited to short vegetation in open dunes.

Most *Cotoneaster* species are apomictic, meaning they are able to produce viable seed without pollination and subsequent fertilisation. However, also pollination can lead to seed production. Cotoneasters are pollinated by insects. The plants produce abundant fleshy fruits which are dispersed by birds. Seeds of *C. horizontalis* can remain viable for 5 years (Pilkington 2011).

Vegetative propagation varies between species. *C. horizontalis* for example is self-layering; where tips of the aerial branches contact the ground they can root and form daughter plants (Piqueray et al. 2008)

5.5.4 Options for management

Information on management of *Cotoneaster* is scarce, except for *C. horizontalis*. As they are woody perennials, management techniques for *Cotoneaster* species will roughly be similar to other ligneous plant species. However, plants are generally relatively small and might have specific characteristics relevant for management. The variety in growth forms certainly urges for a diversified management approach. Gaining practical experience is urgent.

5.5.4.1 Mechanical and manual

Digging up or (mechanically) pulling *Cotoneaster* is an effective control method (Agentschap voor Natuur en Bos 2014). In the dunes, mechanical removal is a good option as the soil has a relatively loose structure, and the natural dynamics often benefit from some soil disturbance. Checking regrowth is always necessary

Young or small plants can relatively easily be uprooted by hand, spade or reek, especially in the loose sandy dune soils. Since the scattered distribution of *Cotoneaster* species, often within a high ecological value dune landscape, this is currently probably the most efficient eradication technique with a minimal collateral damage. However, several species can resprout from stumps and roots (Di Tomaso et al. 2013), necessitating follow-up control. Considering the diversity of *Cotoneaster* species, there is hardly any experience with uprooting in dunes. Mahy & Halford (2009) found pulling plants from the soil manually was extremely difficult and ineffective. However, the rocky soils of the calcareous grasslands where the experiments were conducted cannot be compared to the sandy dune soils.

During uprooting and transport, care should be taken that no fruits fall on the ground since they will readily germinate and form new growing locations. Large stands of *Cotoneaster* species are rare and if so, these are often mixed with other ligneous alien invasives such as *Berberis aquifolia* (Plaatsduinen e.g.). In these cases, mechanical digging out of the entire rooting system is recommended.

5.5.4.2 Chemical

Mahy and Halford (2009) concluded that the best control method available for *C. horizontalis* on calcareous grassland in the Walloon region was to cut and paint the stump with glyphosate (RoundUp). No details on concentrations are provided. Also Pilkington (2011) suggests application of herbicides glyphosate or triclopyr as a wiper or by handheld sprayer when plants are actively growing between spring and autumn.

5.5.4.3 Biological

No information was found on effective biological eradication measures. As *Cotoneaster* species are slightly poisonous, grazing is not an interesting control technique.

5.6 CHINESE WOLFBERRY (*LYCIUM BARBARUM*)

5.6.1 Species profile

Union List	☐ Yes	☒ No
Environment	☐ marine	☐ freshwater
	☐ brackish	☒ terrestrial

Natura 2000 susceptibility

☐ 1110 - Sandbanks
☐ 1130 - Estuaries
☐ 1140 - Mudflats and sandflats
☐ 1210 - Annual vegetation of drift lines *
☐ 1230 - Vegetated sea cliffs of coasts *
☐ 1310 - Annuals colonising mud and sand
☐ 1320 - *Spartina* swards
☐ 1330 - Atlantic salt meadows
☐ 2110 - Embryonic shifting dunes
☒ 2120 - Shifting dunes along shoreline (white dunes)
☒ 2130 - Fixed coastal dunes with herbs (grey dunes)
☐ 2140 - Decalcified dunes with *Empetrum* *
☐ 21A0 - Machairs *
☒ 2150 - Atlantic decalcified fixed dunes
☐ 2190 - Humid dune slacks
☒ 2160 - Dunes with *Hippophae rhamnoides*
☒ 2170 - Dunes with *Salix repens* ssp. *argentea*
☐ 2180 - Wooded dunes of the Atlantic region

Occurrence in Atlantic coastal zone (Number of occupied 10km²-grid cells)

Belgium	12 (63%)	United Kingdom	282 (20%)
France	129 (29%)	Denmark	23 (21%)
Ireland	2 (0.5%)	Germany	19 (13%)
Netherlands	60 (29%)	Portugal	0
Spain	2 (1%)		

Impact scoring (max score across habitats)

	1	2	3	4	5	Confidence: Low	Medium	High
Introduction	☐	☐	☐	☐	☒	☐	☐	☒
Establishment	☐	☐	☐	☐	☒	☐	☐	☒
Spread	☐	☐	☐	☐	☒	☐	☐	☒
Environmental impact	☐	☐	☐	☒	☐	☐	☒	☐

Overall impact score per habitat

(Salty) habitats 1110-1330	--
(Sandy) habitats 2110-50/-90	375
(Shrubby) habitats 2160-80	60

Impact mechanisms

☒ Competition	☐ Nutrient cycling
☐ Hybridization	☒ Physical modification of habitat
☐ Toxicity / poisoning	☒ Disruption of natural succession
☐ Interactions with other IAS	☐ Disruption of food webs

Distribution

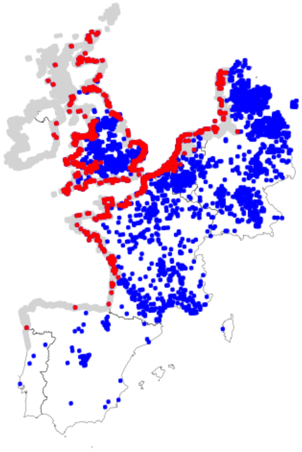


Figure 34. Distribution of *Lycium barbarum* within (red dots) and outside (blue dots) the European Atlantic coastal zone (in grey).

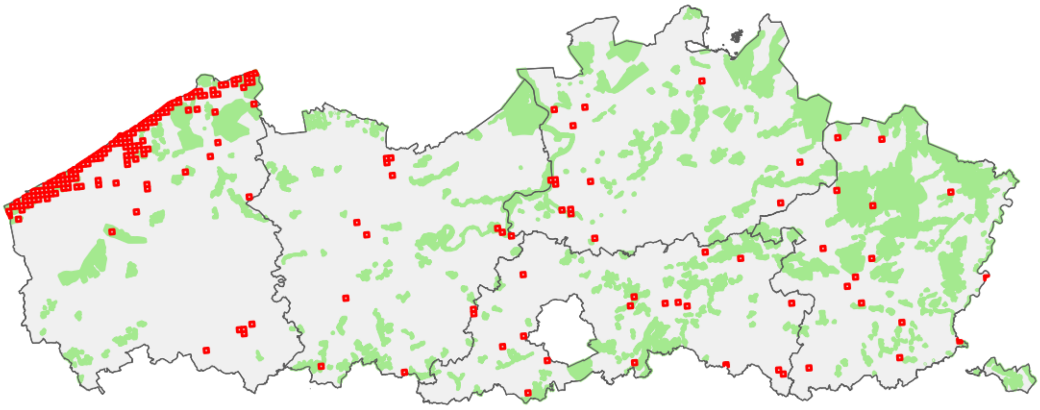


Figure 35. Distribution of *Lycium barbarum* in Flanders since 1950. NATURA2000 areas (EU Bird and Habitat Directive) in green.

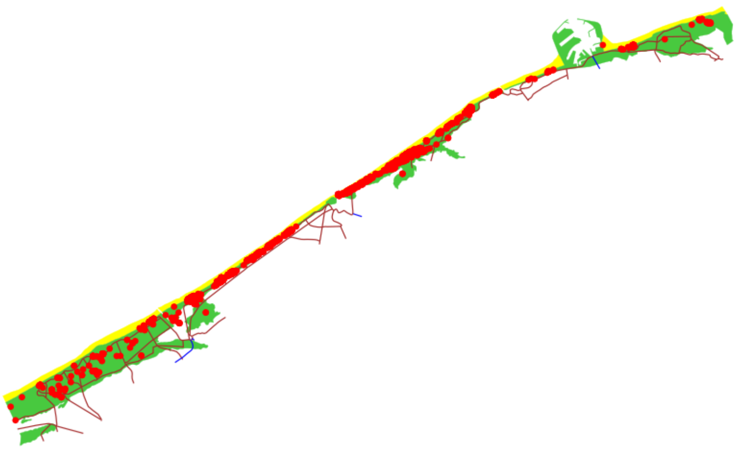


Figure 36. Distribution of *Lycium barbarum* in the Flemish coastal area (2007-2022) based on detailed plant surveys (Provoost et al. 2010, 2014, 2020) and the citizen science platform www.waarnemingen.be (Vanreusel et al. 2022). Beaches (yellow), coastal dunes (green) and major roads (brown) are shown for orientation.

5.6.2 Invasion history and distribution

The first record of *Lycium barbarum* in Belgium dates from 1857, as an escape from cultivation near Tienen (Verloove 2006a, 2022). Whereas the species has only sporadically been observed at inland locations ever since, it has gained a particularly firm foothold in the coastal dune region (Van Landuyt 2006, Figure 35). Here, *L. barbarum* was deliberately planted, as it was internationally regarded to be “an excellent shrub for fixing blowing sands” (Webster 1918). The use of *L. barbarum* for these purposes in Europe already dates back to the second half of the 18th century (Van Steijn 1933). Accordingly, the species is mentioned in early floristic accounts for the coastal dunes of Flanders, with a clear reference of it being planted (e.g. Wéry 1906, Hocquette 1927). These old reports often use the synonym *L. halimifolium* Mill. Given the LIFE DUNIAS project’s aim to limit the commercial use of the species, it is worth noting that the species is still often sold under that name.

Lycium barbarum has subsequently gained popularity as a garden plant, appreciated for its flowers and, particularly, fruits. The red berries are fleshy and edible, commercially known as ‘goji berries’ and considered superfoods. Since the beginning of this century, goji berries and derived products (e.g. juices) are praised in western countries as supposed remedies for well-being and anti-aging, the popularity of which is largely due to efficient marketing (Potterat 2010). It is also on the radar as a high risk non-native in forest gardening (food forests) (Hoppenreijs et al. 2019).

Currently, *L. barbarum* is well-represented within the coastal dune region. It occurs in about half of the (1 km^2) grid squares (Van Landuyt 2006), including in nature reserves (Provoost et al. 2015, Figure 36). During INBO inventories it was found on 575 locations, covering an estimated area of 5,6 ha. This makes *L. barbarum* the 4th most abundant alien scrub species within the coastal dunes. At regional level however it is still quite rare (<5% of prospected squares) and shows no marked distribution trend (Figure 37).

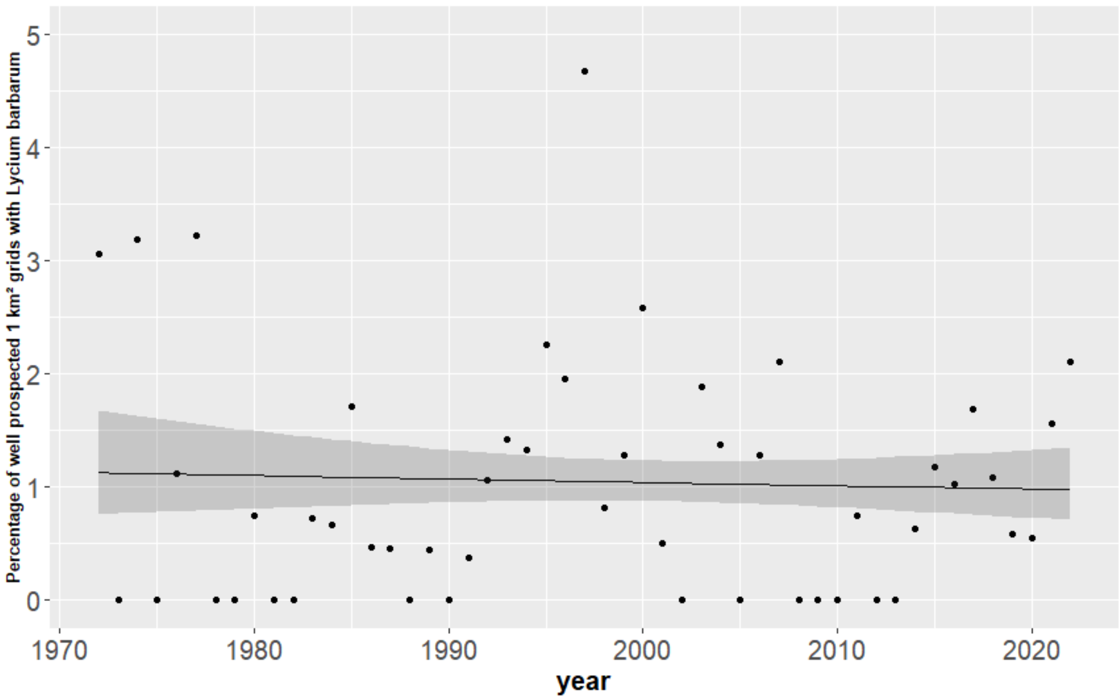


Figure 37. Trend in the percentage of well prospected 1x1km squares in Flanders where *Lycium barbarum* was recorded based on the floristic surveys in Florabank (Van Landuyt et al. 2012).

L. barbarum closely resembles *L. chinense*, also from Asia (the fruits of which also classify as 'goji' berries). The extent to which *L. chinense* is currently present in the coastal dunes of Belgium is unclear but presumably it is still very rare such as in the Netherlands (van Valkenburg et al. 2022). Several shrubby *Lycium* species are native to Europe, the most widespread of which is *L. europaeum*.

5.6.3 Management profile

The architecture and clonal demography of *L. barbarum* have been studied in detail by Pyšek (1991). The species spreads clonally, with clumps of sprouts growing from horizontal roots that generally lie relatively close to the soil surface (≤ 10 cm; Figure 38). Post-disturbance, such sprouts initially grow rapidly in height (up to ± 5 cm per day), until, after about 30 days, these stems become woody and tend to bow under their weight. New branches then grow upwards from these stems, giving the plant an overall arching appearance. The plants can grow up to 3 metres.

Meanwhile, intense competition for light limits the emergence of new sprouts at ground level. In a fully covered, re-vegetated stand, the resulting stem density was found to range from 188 to 336 sprouts per square meter (mean: 252; three months after fire disturbance; Pyšek, 1991). The number of stem clumps ranged from 40 to 56 clumps per square meter (mean: 46).

The combination of clonal growth with the capability of clumped sprouts to rapidly grow into woody stems, explains the species success in rapidly gaining ground in disturbed sites ("phalanx" growth form; Ye et al. 2006).

Figure 38. Detail of a clump of stems of *Lycium barbarum* near ground level (dashed line). Taken from Pyšek (1991).

5.6.4 Options for management

Written accounts on the management of *L. barbarum* are very scarce, but Noble et al. (2021) recently reviewed control options for the closely related *L. ferocissimum*. It is worth mentioning this South African species was recently found along the Mediterranean coast in France (Fried in Noble et al., 2021), with the Atlantic coastal region being vulnerable for establishment of this species too.

5.6.4.1 Mechanical and manual

At locations where disturbance is a concern (with regards to native vegetation, or terrain usage), winching and pulling are considered the best options to remove above- and belowground biomass. For winching, a chain or cable is put around the base of large plants, and a consistent force is exerted to remove them (Picture 12). Pulling (or plucking) can be performed with an excavator. Alternatively, hydraulic arms mounted on a front-end loader may be used to lift plants from their basis (a model of which was developed for use in *L. ferocissimum* (Picture 12). In less sensitive locations, large excavators or bulldozers can be used to control dense thickets. Ecavated material can then be sieved (e.g. drum sieve cf. *R. rugosa*).

When handling branches manually, care must be taken as the stems can be thorny.

Picture 12. Left: winching out a single *Lycium* plant (*L. ferocissimum*). Right: a *Lycium* puller. Photo credits: J. Fallaw (left) and R. Higgins (right), taken from Noble et al. (2021).

In all cases, the success of physical management depends on follow-up actions. The highest success rates are obtained with chemical aftercare of regrowth or newly emerged plants (cut-stump technique and/or foliar spraying).

5.6.4.2 Chemical

Chemical control options of *Lycium* plants are generally in line with those for other scrub species, and include foliar spraying, cut-stump application or stem injection.

Foliar spraying may involve picloram, triclopyr, picloram-triclopyr mixes, aminopyralid, glyphosate, and glyphosate-based mixes. Adjuvants improve herbicide uptake. However, mature *Lycium* plants demonstrate strong resilience to foliar spraying, with new foliage readily appearing. It is therefore best to apply foliar spraying after some disturbance down to ground level (e.g. cutting, mowing or burning), since new sprouts then become numerous, non-woody and overall leafy (Pyšek 1991). The plants are thus at their most vulnerable to systemic herbicide during that stage (which lasts for about one month).

The cut-stump technique may involve picloram, triclopyr (mixed with diesel), triclopyr-picloram mixes (in diesel), glyphosate (mixed 1:1 with water) has been used successfully in *L. ferocissimum*.

Picloram-based herbicides can be used for stem-injection application, while glyphosate-based herbicides can be used for stem-scrape techniques.

5.6.4.3 Biological

No candidates for biological control were identified that may easily be used against *L. barbarum* in European coastal dune landscapes. The rust fungus *Puccinia rapipes* is considered as a potential control agent for *L. ferocissimum* in Australia, and is also known to negatively affect *L. barbarum* (Noble et al. 2021).

Given the enormous importance of Solanaceae as crops, any introduction of possible control agents would need very careful research. Moreover, it should be remembered that *L. barbarum* has commodity value in itself (goji berries), and that Europe is home to several native species of *Lycium*.

5.7 JAPANESE ROSE (*ROSA RUGOSA*)

5.7.1 Species profile

Union List	☐ Yes		☒ No	
Environment	☐ marine ☐ brackish		☐ freshwater ☒ terrestrial	
Natura 2000 susceptibility	☐ 1110 - Sandbanks ☐ 1130 - Estuaries ☐ 1140 - Mudflats and sandflats ☐ 1210 - Annual vegetation of drift lines * ☐ 1230 - Vegetated sea cliffs of coasts * ☐ 1310 - Annuals colonising mud and sand ☐ 1320 - *Spartina* swards ☒ 1330 - Atlantic salt meadows ☒ 2110 - Embryonic shifting dunes ☒ 2120 - Shifting dunes along shoreline (white dunes) ☒ 2130 - Fixed coastal dunes with herbs (grey dunes) ☒ 2140 - Decalcified dunes with *Empetrum* * ☐ 21A0 - Machairs * ☒ 2150 - Atlantic decalcified fixed dunes ☐ 2190 - Humid dune slacks ☒ 2160 - Dunes with *Hippophae rhamnoides* ☒ 2170 - Dunes with *Salix repens* ssp. *argentea* ☒ 2180 - Wooded dunes of the Atlantic region			
Occurrence in Atlantic coastal zone (Number of occupied 10km²-grid cells)	Belgium France Ireland Netherlands Spain	17 (89%) 234 (52%) 74 (18%) 172 (84%) 0	United Kingdom Denmark Germany Portugal	750 (53%) 104 (96%) 91 (62%) 0
Impact scoring (max score across habitats)	**Score** 1 2 3 4 5		**Confidence** Low Medium High	
Introduction	☐ ☐ ☐ ☐ ☒		☐ ☐ ☒	
Establishment	☐ ☐ ☐ ☐ ☒		☐ ☐ ☒	
Spread	☐ ☐ ☐ ☐ ☒		☐ ☐ ☒	
Environmental impact	☐ ☐ ☐ ☐ ☒		☐ ☐ ☒	
Overall impact score per habitat	(Salty) habitats 1110-1330 (Sandy) habitats 2110-50/-90 (Shrubby) habitats 2160-80		300 625 500	
Impact mechanisms	☒ Competition ☒ Hybridization ☐ Toxicity / poisoning ☐ Interactions with other IAS		☒ Nutrient cycling ☒ Physical modification of habitat ☒ Disruption of natural succession ☐ Disruption of food webs	
Distribution				

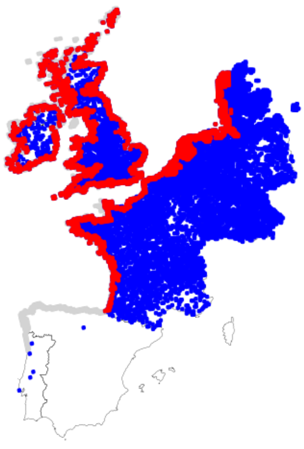


Figure 39. Distribution of *Rosa rugosa* within (red dots) and outside (blue dots) the European Atlantic coastal zone (in grey).

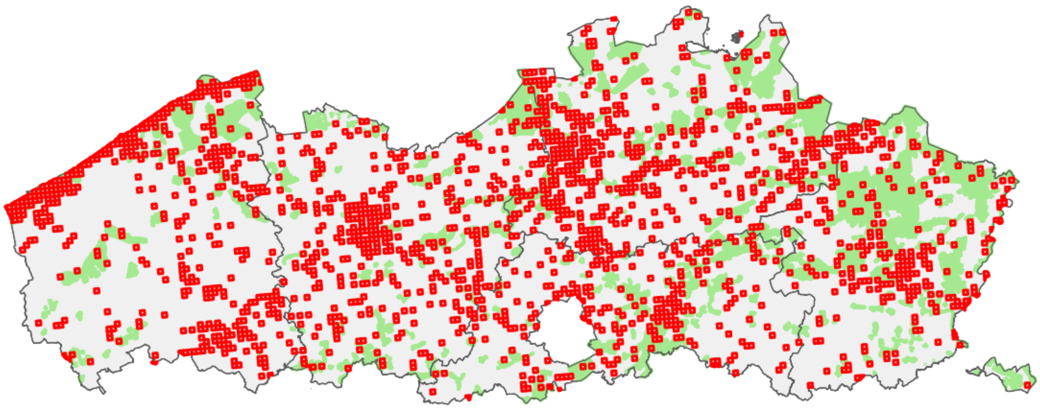


Figure 40. Distribution of *Rosa rugosa* in Flanders since 1950. NATURA2000 areas (EU Bird and Habitat Directive) in green.

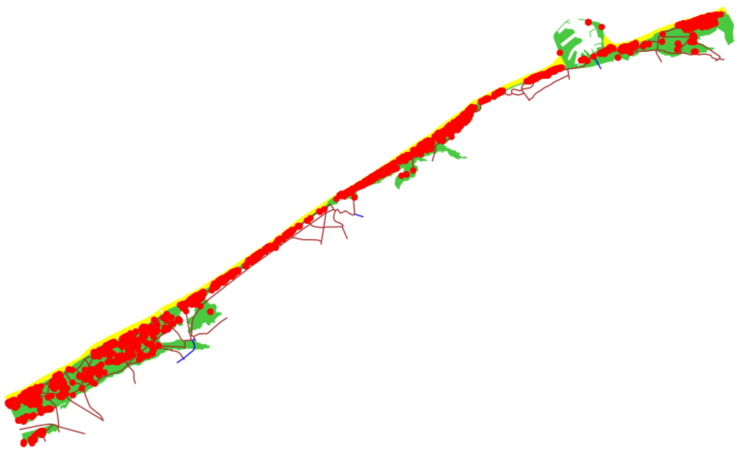


Figure 41. Distribution of *Rosa rugosa* in the Flemish coastal area (2007-2022) based on detailed plant surveys (Provoost et al. 2010, 2014, 2020) and the citizen science platform www.waarnemingen.be (Vanreusel et al. 2022). Beaches (yellow), coastal dunes (green) and major roads (brown) are shown for orientation.

5.7.2 Invasion history and distribution

Rosa rugosa is an East Asian rose species that has been widely introduced into Europe as a garden and landscape ornamental, with additional uses in erosion control, in herbal medicine, and as rootstock for grafting roses (Bruun 2005, Isermann 2008). The species has been repeatedly introduced, in various forms (including hybrids), and from different parts of its natural range, complicating our understanding of its history in Europe (Kelager et al. 2013). The year of first introduction may have been 1796, although the species did not become widely known until the mid-19th century (Boardman & Smith 2016). Being a salt-tolerant species adapted to living in sand dunes, the use of *R. rugosa* in coastal areas is recognized since long. For example, Webster (1918) stated that the species is "thoroughly recommended as a seaside shrub for covering sand-banks".

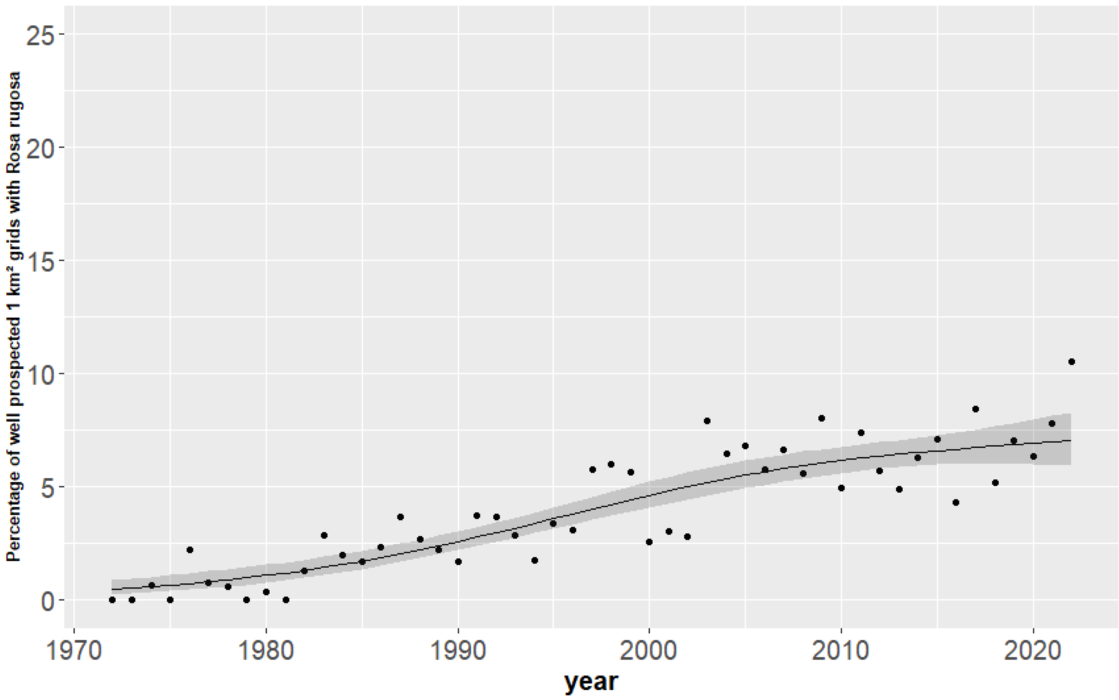


Figure 42. Trend in the percentage of well prospected 1x1km squares in Flanders where *Rosa rugosa* was recorded based on the floristic surveys in Florabank (Van Landuyt et al. 2012).

The species is accordingly mentioned in early botanical accounts for the coastal dunes of Flanders (e.g. Massart 1910, Magnel 1921). The first geo-referenced floristic record dates from 1938 in Westende (Van Landuyt et al. 2012). *Rosa rugosa* is currently well-represented within the coastal dune region, i.e. in about half of the 1-km² grid squares (Zwaenepoel 2006). At regional level (Flanders) it occurs in 10% of prospected km squares (Figure 42). The species was found to be the most abundant invasive species in coastal dune reserves in terms of infested surface area (Provoost et al. 2015). According to the INBO data it was abundantly present within an area up to 20 ha. However, due to intensive eradication efforts in 2020 and 2021, this surface area was reduced with nearly 9 ha (Figure 43). Worth noting, genetic samples taken from *R. rugosa* at Zeebrugge identified Japan as the country of origin (Kelager et al. 2013).

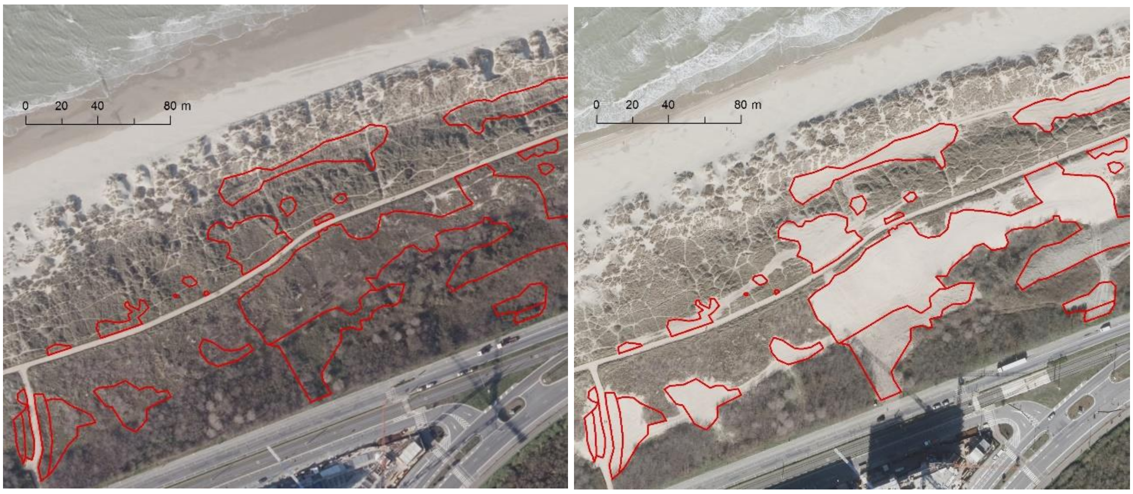


Figure 43. Results of large scale eradication of Japanese rose (*Rosa rugosa*) in Blankenberge by the Flemish Agency for Nature and Forest.

5.7.3 Management profile

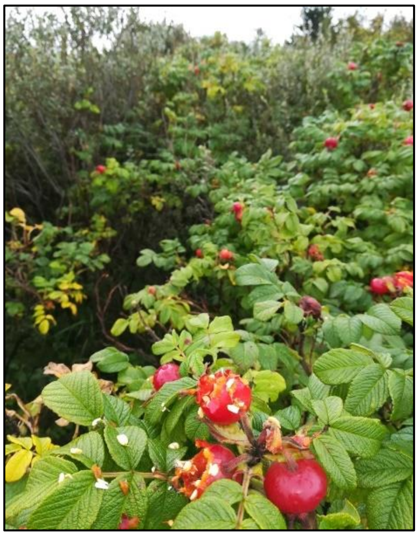
Rosa rugosa is a rhizomatous shrub that is strongly suckering, i.e. forming plenty of aboveground shoots directly from the rhizome. When mature, it thus forms very dense, near to impenetrable thickets that may cover several hectares (Bruun 2005, Picture 13).

Clones expand predominantly with a closed front (“phalanx” mode), although single suckers interspersed in herbaceaous vegetation may also appear (“guerrila” mode; Ye et al. 2006). Established patches in Danish and English dunes were found to grow in area by about 20% per year, suggesting a doubling in area every 4–5 years (Kollmann et al. 2009, Boardman & Smith 2016). Neither study found signs of die-back or replacement in the central parts of the patches. In a lateral sense, patches expanded with 0.2–0.7 m/year.

The normal rooting depth in dune sand is 0.5–1 m, but may extend up to 2 m (Schlätzer 1974, in Bruun 2005). Rosa rugosa tolerates a moderate annual sand covering, and even seems to benefit from it (Belcher 1977).

Depending on their size, the rose hips (false fruits) contain several tens of achenes to over one hundred (references in Bruun 2005). By definition, each achene contains a single seed. The average seed production in European stands of R. rugosa was estimated at 1.862 seeds m-2 (range: 46–7171; Zhang et al. 2018). The most relevant dispersers for mid- to long-distance dispersal are birds, which feed on either entire hips, hip flesh or achenes (thrushes, corvids, pigeons, and others; Bruun 2005). Field experiments in Danish dunes pointed out that seedlings easily establish in a variety of habitats once seeds have arrived, but that the number of seeds arriving in suitable (micro)sites is limited (Kollmann et al. 2007). The seed bank of the species is short-lived (Kollmann et al. 2009).

Picture 13. Left: dense thicket of *Rosa rugosa* at Middelkerke. Right: bird-picked hips of *R. rugosa*.



In addition, higher anthropogenic disturbance and slightly higher nutrient loads adjacent to houses, roads and the beach explain increased establishment and clonal growth of the species (Jørgensen & Kollmann 2009).

5.7.4 Options for management

Significant experiences with the control of *R. rugosa* in coastal dune areas have been gained in the past decade. Technical recommendations for the species' management stem from actions in, among others, Denmark (LÆSØ 2018, LIFE11 NAT/DK/000893; REDCOHA 2019, LIFE12 NAT/DK/001073), Sweden (SANDLIFE 2018, LIFE11 NAT/SE/000849), the Netherlands (Witteveldt 2013, LIFE09 NAT/NL/000417) and Flanders (K. Lesage, pers. comm.).

5.7.4.1 <u>Mechanical and manual</u>

The most efficient way of removing patches of *R. rugosa* is through excavation, but in such a way that rhizomes and roots are prevented from re-suckering (Ribotta et al. 2021). As a general rule, plants are dug up to a meter deep. A one metre lateral buffer is included, and any obstacle is taken along. It is essential that operators are well-briefed in advance of the project (REDCOHA 2019).

To prevent regeneration, a first option is to bury plants on site, but this comes with real risks of regeneration that need to be mitigated by careful execution and/or appropriate aftercare. Following up on actions that strived to bury plants at least one metre deep, Kollmann et al. (2011) found about 1 sprout per 2 m² to surface two months after the treatment. Most sprouts came from fragments buried at depths of less than 15 cm. The larger the fragment (recorded variation: 4–170 cm in length), the more sprouts grew from it. The authors conclude that a complete, "clean" burial in sandy soil is less obvious than might be anticipated. If this approach is chosen, a burial depth of 0.5 m should be sufficient, the success thus being measured by the amount of fragments that escape burial. For the burial method, a large excavator can be used (REDCOHA 2019). In LIFE Restoration of Danish Coastal Habitats (REDCOHA 2019) a 1.5-2 m deep hole was dug first, into which all vegetation and roots were laid and covered with clean sand.

Post-treatment consisted of pulling up any regrowth. Also, larger surfaces were treated at a cost of around 2,5 euros per square meter.

A second, more preferred option is to sieve out plant fragments (SANDLIFE 2018). Different principles of sieving (e.g. rotating, shaking), machine types (e.g. mounted on an excavator, standalone machinery), and machine sizes (e.g. pulled by tractor, autonomously driving) exist (Figure 44). A sieve mesh size of 20 mm is considered optimal (K. Lesage, pers. comm.).

In Belgium, 8,8 hectares of *R. rugosa* were removed in 2020 (7,7 ha) and 2021 (1,1 ha). The plants were dug out with a large excavator till a depth of 1m, after which all the material was sieved with a large drum sieve with a mesh size of two cm. All roots and other plant fragments stayed in the sieve, whereas the sand was deposited in the dunes again, after which the dune was reprofiled. Small amounts of regrowth were observed. Aftercare consisted of manual removal of the shoots (digging out with a shovel) (K. Lesage pers. comm).

Figure 44. Left: a rotary sieve bucket for an excavator (Y. Adams). Right: an autonomically driving drum sieve (K. Lesage).

The sieved material needs to be disposed of properly, taking into account that rocks, metal, plastics and other litter have become inter-mixed. The removal of patches in this way leads to bare patches of sand, that are prone to aeolian drift (Ribotta et al. 2021). If undesired, a strategy should be included to prevent this from happening, by planting native vegetation (marram grass *Ammophila arenaria*) or placing barriers (e.g. straw bales).

Manual pulling is feasible only for (very) small plants. It is generally not useful apart from early aftercare treatments. Given that the aboveground parts abound with spines, care must be taken to handle stems safely. Mowing or mulching of *R. rugosa* multiple times a year reduces plant vitality, but does not remove it (Eiger 1992, in Bruun 2005; LÆSØ 2018; Waldeck 2010). Other large-scale control techniques that have been documented, are (1) pulling (but not excavating) plants, (2) tilling to ± 40 cm depth using a biorotor, (3) harrowing, and (4) covering with geotextile or plastic (Kollmann et al. 2011, LÆSØ 2018, REDCOHA 2019). Generally, these measures suppress plant performance temporarily. With the latter treatment, plant vigour appeared muted to satisfactory levels when followed-up for two years. The measure may thus hold promise in particular conditions where the vegetation can be covered in a reliable fashion over long terms.

Whatever the choice of action and its initial success, there is a need for continued dedication in performing aftercare following initial treatments (Ribotta et al. 2021). Such aftercare might compose of further machinal work (at smaller scale), manual pulling or digging, or chemical interventions.

5.7.4.2 Chemical

Herbicides can be applied through the cut-stump technique (lubricating the herbicide to cut stems using a brush, sponge or weeper) or by foliar spraying (Didriksen 1999, in Bruun 2005; Ribotta et al. 2021). For the latter, the spraying preferably targets regrowth, following some disturbance down to ground level (e.g. cutting, mowing or burning). REDCOHA (2019) therefore recommends to crush bushes during winter, then applying herbicide in June and again in October. Based on preliminary experience from these actions, two to three seasons appear sufficient to kill off plants entirely.

As in any case of herbicide applications, the rules and recommendations of good practice need to be respected (with respect to legal restrictions, weather conditions, doses, safety measurements, training and skills, non-target effects...).

Most accounts refer to glyphosate-based herbicides, whereas triclopyr-based herbicides have been applied in Flanders and the Netherlands (Witteveldt 2013). Unfortunately, no long-term scientific surveys have been performed to properly assess the success of different herbicide applications in *R. rugosa* (but see Boesen 2012). Initial regrowth often seems substantial, thus pointing out an important gap in the best aftercare strategy for sensitive areas. In Danish dune systems, LIFE REDCOHA applied a 2% glyphosate 360 solution in June and October for two consecutive years at an expense of 2,5 euros per square meter (REDCOHA 2019). Here, the areas treated twice per season for over two years did not show any regrowth. In Wales, the Sands of LIFE project treated *R. rugosa* with glyphosate (90 liters dilute @ 300 ml round up/15 L = 1.2LRound up Vantage), adding a dye (acid blue 9) to the herbicide and equally performed two applications per year (end of May and end of July) during 2-3 years. *Rosa rugosa* was also mown, after which regrowth was sprayed (pers. comm. J. Burton). The national trust (UK) used the more selective herbicide triclopyr because this doesn’t affect grasses, and applies the herbicide in august in a warm and dry period (pers. comm. I. Spall).

5.7.4.3 Biological

Many herbivorous arthropods and pathogenic microorganisms are associated with *Rosa* species, *R. rugosa* being no exception (Bruun 2005). Yet, more insect species attack *R. rugosa* in its native range than in its introduced range, suggesting that the invasiveness of the species in Europe may be at least partly due to escape from its natural enemies.

Few organisms appear to be narrowly specialized to *R. rugosa*. Promising candidates for biocontrol seem to be particular species of aphids, a leaf hopper, tortricid moth, cynipid gall-wasp, and some rust fungi (Bruun 2006). Yet, more research would be needed in order to safely apply such species in the field.

Grazing of *R. rugosa* by livestock species (sheep, goats, cattle, horses) is not considered as a management measure here. However, grazing is to some extent successful in suppressing plant performance and restoring native vegetation, depending on the species, the situation of *R. rugosa*, and the surrounding vegetation (Artmann 2012, references above).

5.8 OLEASTER/RUSSIAN OLIVE (*ELAEAGNUS ANGUSTIFOLIA*)

5.8.1 Species profile

Union List	☐ Yes		☒ No	
Environment	☐ marine		☐ freshwater	
	☐ brackish		☒ terrestrial	
Natura 2000 susceptibility	☐ 1110 - Sandbanks			
	☒ 1130 - Estuaries			
	☐ 1140 - Mudflats and sandflats			
	☐ 1210 - Annual vegetation of drift lines *			
	☐ 1230 - Vegetated sea cliffs of coasts *			
	☐ 1310 - Annuals colonising mud and sand			
	☐ 1320 - *Spartina* swards			
	☐ 1330 - Atlantic salt meadows			
	☐ 2110 - Embryonic shifting dunes			
	☒ 2120 - Shifting dunes along shoreline (white dunes)			
	☒ 2130 - Fixed coastal dunes with herbs (grey dunes)			
	☐ 2140 - Decalcified dunes with *Empetrum* *			
	☐ 21A0 - Machairs *			
	☐ 2150 - Atlantic decalcified fixed dunes			
	☐ 2190 - Humid dune slacks			
	☒ 2160 - Dunes with *Hippophae rhamnoides*			
	☒ 2170 - Dunes with *Salix repens* ssp. *argentea*			
	☒ 2180 - Wooded dunes of the Atlantic region			
Occurrence in Atlantic coastal zone (Number of occupied 10km²-grid cells)	Belgium	14 (74%)	United Kingdom	5 (0.4%)
	France	146 (33%)	Denmark	0
	Ireland	0	Germany	2 (1%)
	Netherlands	47 (23%)	Portugal	0
	Spain	15 (8%)		

Impact scoring (max score across habitats)	**Score** 1 2 3 4 5	**Confidence** Low	Medium	High
Introduction	☐ ☐ ☐ ☐ ☒	☐	☐	☒
Establishment	☐ ☐ ☐ ☐ ☒	☐	☐	☒
Spread	☐ ☐ ☒ ☐ ☐	☐	☐	☒
Environmental impact	☐ ☐ ☐ ☐ ☒	☐	☒	☐

Overall impact score per habitat		
	(Salty) habitats 1110-1330	--
	(Sandy) habitats 2110-50/-90	375
	(Shrubby) habitats 2160-80	240

Impact mechanisms		
	☒ Competition	☐ Nutrient cycling
	☐ Hybridization	☒ Physical modification of habitat
	☐ Toxicity / poisoning	☒ Disruption of natural succession
	☐ Interactions with other IAS	☐ Disruption of food webs

Distribution

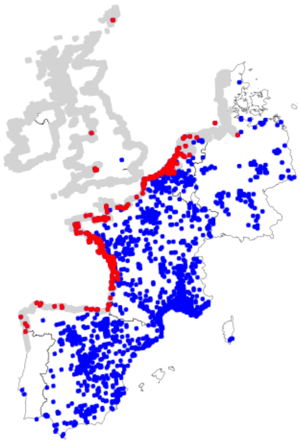


Figure 45. Distribution of *Elaeagnus angustifolia* within (red dots) and outside (blue dots) the European Atlantic coastal zone (in grey).

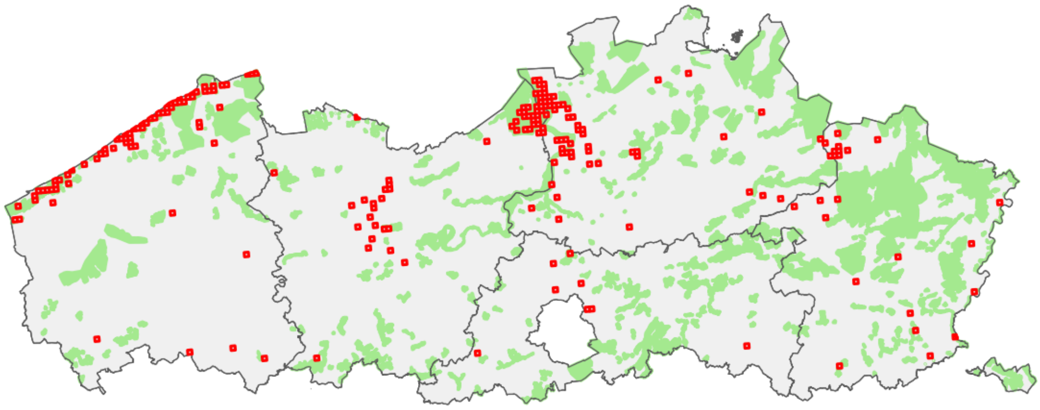


Figure 46. Distribution of *Elaeagnus angustifolia* in Flanders since 1950. NATURA2000 areas (EU Bird and Habitat Directive) in green.

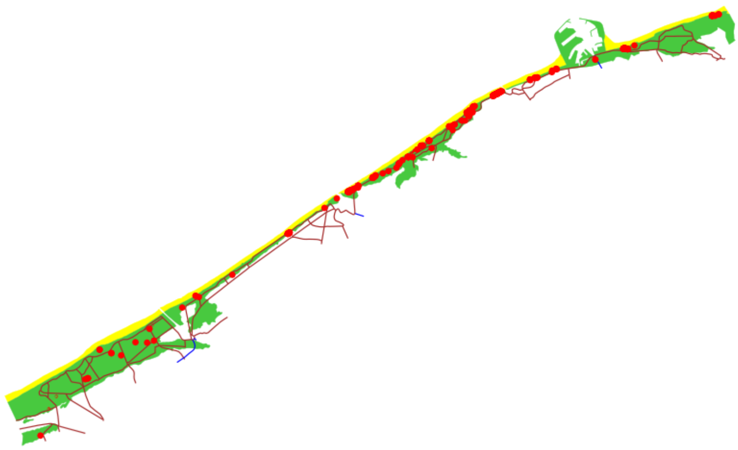


Figure 47. Distribution of *Elaeagnus angustifolia* in the Flemish coastal area (2007-2022) based on detailed plant surveys (Provoost et al. 2010, 2014, 2020) and the citizen science platform www.waarnemingen.be (Vanreusel et al. 2022). Beaches (yellow), coastal dunes (green) and major roads (brown) are shown for orientation.

5.8.2 Invasion history and distribution

Elaeagnus angustifolia is native to parts of Southern Europe, Central and South Eastern Asia. It was introduced in Flanders as an ornamental plant in public green areas (e.g. windbreak and erosion control), but also in dunes to fixate sand (Verloove 2022a). At regional level it is still quite rare in floristic surveys but seems to increase since the mid 1990ies (Figure 48). Currently, it occurs in Flanders at dry, sandy places, in disturbed areas and in open semi-natural habitats which are moderately to highly nutrient-rich (dunes, salt marshes, grasslands, etc.) (Verloove 2006b; Baus et al. 2009).

The first record from a herbarium collection dates back to 1939 (Wenduine, dunes) (Verloove 2006b). However, the origin of this record (escaped or not) was unclear (Verloove 2022a). Since 1980, the species has been increasingly reported in dunes but also in sandy areas such as Antwerp harbour (Verloove 2006b). Occasionally, the species is observed in abandoned railway and industrial estates (Verloove 2006b). It probably reached these locations by frugivorous birds, whereas in dunes and other locations, the species is most often a relic of cultivation. The degree of establishment is uncertain, however, very probable at locations where it is persistent such as the dunes and in the vicinity of Antwerp (Verloove 2022a).

Picture 14. *Elaeagnus angustifolia* (L. Verhelst)

Currently, *E. angustifolia* is concentrated in Flanders within the coastal dunes and the area of Antwerp harbour (Verloove. 2006b; Figure 46). Uncertainty remains on whether it settled spontaneously or was planted (Verloove 2006b). The species might be confused in Flanders with other species such as *E. multiflora* (Verloove 2006b). *Elaeagnus umbellata* and *E. × ebbingei* are also present but research has proven that *E. angustifolia* is the most common species of the genus in Flanders (Verloove 2006b; Verloove 2022a).

During INBO inventories E. angustofolius or similar species were found on 250 locations, covering an estimated area of 2,7 ha.

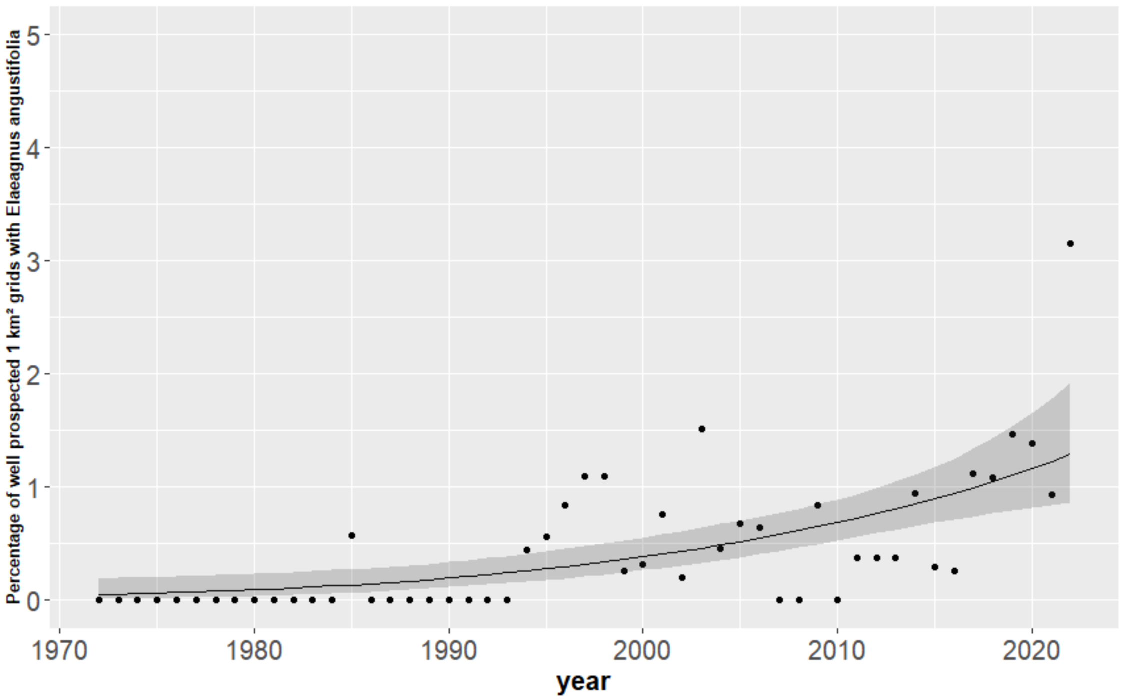


Figure 48. Trend in the percentage of well prospected 1x1km squares in Flanders where *Elaeagnus angustifolia* was recorded based on the floristic surveys in Florabank (Van Landuyt et al. 2012).

5.8.3 Management profile

Elaeagnus angustifolia occurs as a small tree or large multi-stemmed shrub that can grow up to 12 m in height with trunks from 10 to 50 cm thick and thorny branches (Zouhar 2005). The bark is greenish grey (first year succulents) or reddish/dark brown (older stages) and shredding (Gunn & Patterson 2020, Muzika & Swearingen 2005). The leaves are 4-8 cm in length, simple, alternate and lanceolate- to oblong-shaped with smooth margins (Hickman 1993). The upper surface of the leaves is light green, the lower surface is silvery white (Deiter 2000). Branching occurs at ground level (just above the root crown) at moist, unshaded locations. It occurs above ground level in drier, shaded conditions (Lesica & Miles 2001). Plants begin to flower after three years and fruit on the twigs of the current year (Muzika & Swearingen 2005). In spring, creamy yellow, bisexual flowers appear (Picture 14, Picture 15). They are highly aromatic and insect-pollinated (Muzika & Swearingen 2005). In autumn, drupes appear, initially silvery but yellow-red when ripe (Gunn & Patterson 2020). These fruits are 1-1.5 cm long and contain a single seed (Young & Young 1992). Dispersal of the fruits is facilitated by frugivorous birds, vertebrates or fluvial transport (Borell 1962; Kindschy 1998; Pearce & Smith 2001; Verloove 2006b). The seeds are vital for three years and remain dormant until the right conditions (cool and moist stratification) are met to start germination (Gunn & Patterson 2022; Hamilton & Carpenter 1976; Hogue & La Croix 1970). *Elaeagnus angustifolia* can grow under a wide range of environmental conditions, including high levels of salinity and alkalinity in the soil or long periods of drought (Gunn & Patterson 2022).

Picture 15. *Elaeagnus angustifolia* – habitus (left) and flower (right).

The root system of *E. angustifolia* is extensive and deep, with many well-developed laterals (Stubbendieck et al. 2003; Zouhar 2005). Roots are only rarely deeper than 1.2 m (Yaeger 1935). However, some roots were found to be 12m deep (Zouhar 2005). Due to nitrogen-fixating symbiosis with *Frankia*, the species is capable of fixing nitrogen in the roots (Zitzer and Dawson 1992, Johnson 1995).

Although *E. angustifolia* establishes primarily by seeds in North America, vegetative propagation can also occur (Worwood et al. 2019). In some cases, in Flanders, it is probably birdsown (i.e. from seed). In other cases however, especially in the coastal dunes, it most often is a relic of cultivation (Verloove 2022a).

Following injury or top-kill, *E. angustifolia* can regrow from epicormic or adventitious buds (Picture 16). Epicormic buds are located below the bark and become active when the bark has been injured. These buds might result in growth of thicker stands than before (Worwood et al. 2019). Adventitious buds are present in meristematic tissue and result in regrowth on shoots and roots. *Elaeagnus. angustifolia* might also form root suckers (Picture 17), but only from roots that are at or near (less than 8 cm) the soil surface (Worwood et al. 2019).

Picture 16. Left: regrowth of *Elaeagnus angustifolia* from an individual epicormic bud (A) or clusters of epicormic buds (B). Left: regrowth of *E. angustifolia* from an adventitious bud within the cambium tissue of the root. Taken from Worwood et al. (2019).

5.8.4 Options for management

In Europe, *E. angustifolia* is not observed to form dense populations in invaded area (Baus et al. 2009). However, in North America it invades riparian area where it forms large naturalized stands with high stem densities (Katz & & Shafroth 2003). Most of the management practices described below are therefore based on experiences within those areas. Here, the key to succesful Russian olive control is repeated monitoring and follow-up treatment of any potential resprouts and seedlings. Ecological restoration by revegetating treated areas with native trees, shrubs and herbs can further help achieve a sustainable result (Gunn & Patterson 2020).

5.8.4.1 <u>Mechanical and manual</u>

A wide variety of mechanical treatments exist, but they often result in prolific basal sprouting (van Valkenburg et al. 2022, Picture 17). Hence, this method requires years of retreatment or should be combined with chemical control in order to be effective. The disadvantage of mechanical treatments is the potential disturbance to the site, especially in case heavy machinery is used.

Picture 17. Left: Root suckers of *Elaeagnus angustifolia*. Right: prolific basal sprouting of *E. angustifolia*, after a mechanical treatment and no chemical post-treatment. Taken from Gunn & Patterson (2020).

Mechanical control options are the following (based on Gunn and Patterson (2020)):

Pulling. Seedlings that are not yet one year old (< 1.2 cm in diameter) can be removed by hand pulling. Up to 10 cm of the root should be removed in order to be effective. All root fragments should be carefully collected and removed from the location. Bigger plants can be removed by winching and pulling with an excavator (cf. *L. barbarum*, 5.6.4.1). Should stumps remain, these can be removed with a stump grinder.

Mowing. If the site contains saplings that are smaller than 2.5 cm in diameter, mowing by a tractor and brush mower can be performed. This technique, however, should be repeated multiple times per year for multiple years. If treatment is not consistent, trees can become multistemmed and will grow more vigorously than before.

Digging. Saplings with a diameter of less than 9 cm can be treated by digging, using a shovel or hoe. To avoid sprouting of exposed root fragments, these should be buried by at least 7.5cm of soil (Worwood et al. 2019). Also, all root fragments need to be carefully removed from the site. If sprouting suckers appear, these should be removed or treated with herbicide.

Tilling. Repeated tillage might be applied to weaken seedlings and saplings of *E. angustifolia* and inhibit resprouting. As such, shallow root systems that not yet reached mature root depths will be damaged. This method should be repeated for several years.

Mechanical removal. Large trees with a diameter of more than 9cm can be cut down by a chain saw, an excavator or backhoe (USDA 2014). Due to extensive regrowth from epicormics and adventitious buds, this method alone is ineffective. Therefore, this method should be combined with a chemical treatment (see below).

5.8.4.2 Chemical

Herbicide applications can be effective in controlling *E. angustifolia.* The advised timing depends on the product and the technique. Herbicide applications envisage to kill the roots of the trees. There are several chemical techniques available which can be subdivided in (Gunn & Patterson 2020, also see this reference for more detailed information):

Foliar applications. All foliage and shoots are sprayed thoroughly with a herbicide. It is advisable to add a nonionic surfactant to tank mixes so the product can more easily be absorbed by the leaves. Adding dye will improve recognisability of treated trees. As plants actively move energy from the leaves to the root system during early fall, this method is most effective during that period. This method is not advisable for large trees or in case of sucker regrowth. In the latter case, there are too few leaves to absorb the herbicide compared to the large, underground root system.

Girdling with spraying. This method is advisable in case of single-stemmed trees. Two horizontal cuts are made within the bark and cambium layer by an axe or saw. The two cuts should be below each other (about 9 cm apart). The bark is removed between the two cuts and the product is immediately applied, according to the label information. The trees are left standing for two to three years. The best period to apply this technique is during summer.

Basal bark treatment. In case of small to medium-sized trees (diameter up to 15cm) with a smooth bark, the basal bark treatment can be applied. Then, the entire circumference of a tree is sprayed by a herbicide from ground level up to 40cm high. In order to improve absorption of the herbicide into the tree, ester formulations of herbicides should be applied in combination with a penetrating oil. This technique can be applied at any time of the year, when weather is dry.

Frill-cut treatment. Herbicides are injected into the tree along a “frill” into the bark at a downward angle. These frill cuts are made by a hatchet or an axe in the lower trunk area. Typically, one frill should be made per 2.5cm trunk diameter. All frills should be created at about the same height and 1cc of herbicide should be injected per frill. Extra product will be spilled in the environment. A treated tree should remain standing for at least one year to assure complete root death.

Recommended herbicides. Effective active ingredients against *E. angustifolia* are aminopyralid (Milestone), glyphosate sold (Roundup), triclopyr ester (Garlon 4 and Garlon 4 Ultra), imazapyr (Habitat) , Picloram (Tordon 22K, very effective in preventing sucker regrowth) and triclopyr ester with 2,4-D ester (Crossbow).

The most effective technique is to combine mechanical and chemical treatments. The following two can be distinguished (Gunn & Patterson 2020).

Cut-stump treatment. When large trees have been cut down, their remaining stumps are treated with herbicides. Trees should be cut 40cm in height so the remaining parts can still be removed after treatment. The herbicide should solely be applied to the rings directly inside the bark (where the cambium and phloem is), as the centre of the stump cannot translocate herbicides to the roots (where the xylem is). As illustrated by Patterson et al. (2018), 1 ml of 41% glyphosate concentrate per inch of trunk diameter results in 95% control until two years after treatment. If the applied herbicide does not freeze, this technique can be applied at any time of the year.

Picture 18. Example of cut-stump treatment. The herbicide is colored with blue dye and applied on the cambium layer of cut trees. Taken from Gun & Patterson (2020).

Basal-bark treatment combined with mechanical removal. First, the basal-bark treatment (with triclopyr ester in either diesel or MSO) is applied on a large tree to kill the epicormic buds of the lower trunk. Two weeks after the herbicide treatment, the tree top can be mechanically removed. This technique is most efficient if no shallow roots are present. Otherwise, these might develop new root suckers after treatment (Patterson et al. 2020).

5.8.4.3 Biological

Goat grazing has proven to be an effective practice for Russian olive seedling removal (Gunn & Patterson 2020). Katz & & Shafroth (2003) suggest targeted grazing (or temporary inundation) to limit initial seedling establishment.

Biocontrol agents are not yet being applied, but the potential of the stem mining weevil *Temnocerus elaeagni,* the gelechiid moth *Anarsia eleagnella* and the eriophyid mite *Aceria angustifoliae* is being investigated (Gunn & Patterson 2020). Permission to release the latter after host specificity testing was obtained in Canada, where Russian olive is particularly invasive in sensitive riparian habits, by a group lead by CABI. To the project team focused on natural enemies that specifically attack the flower buds, flowers or seeds of the tree in order to slow its spread without harming established trees (https://news.agropages.com/News/NewsDetail---42707.htm).

5.9 SNOWBERRY (*SYMPHORICARPOS ALBUS*)

5.9.1 Species profile

Union List	☐ Yes	☒ No
Environment	☐ marine	☐ freshwater
	☐ brackish	☒ terrestrial

Natura 2000 susceptibility

☐ 1110 - Sandbanks
☐ 1130 - Estuaries
☐ 1140 - Mudflats and sandflats
☐ 1210 - Annual vegetation of drift lines *
☐ 1230 - Vegetated sea cliffs of coasts *
☐ 1310 - Annuals colonising mud and sand
☐ 1320 - *Spartina* swards
☐ 1330 - Atlantic salt meadows
☐ 2110 - Embryonic shifting dunes
☐ 2120 - Shifting dunes along shoreline (white dunes)
☒ 2130 - Fixed coastal dunes with herbs (grey dunes)
☐ 2140 - Decalcified dunes with *Empetrum* *
☐ 21A0 - Machairs *
☐ 2150 - Atlantic decalcified fixed dunes
☐ 2190 - Humid dune slacks
☒ 2160 - Dunes with *Hippophae rhamnoides*
☒ 2170 - Dunes with *Salix repens* ssp. *argentea*
☒ 2180 - Wooded dunes of the Atlantic region

Occurrence in Atlantic coastal zone (Number of occupied 10km²-grid cells)

Belgium	17 (89%)	United Kingdom	620 (44%)
France	47 (10%)	Denmark	89 (82%)
Ireland	22 (5%)	Germany	10 (7%)
Netherlands	116 (57%)	Portugal	0
Spain	0		

Impact scoring (max score across habitats)

	Score 1	2	3	4	5	Confidence Low	Medium	High
Introduction	☐	☐	☐	☐	☒	☐	☐	☒
Establishment	☐	☒	☐	☐	☐	☐	☒	☐
Spread	☐	☐	☒	☐	☐	☐	☒	☐
Environmental impact	☐	☐	☒	☐	☐	☐	☒	☐

Overall impact score per habitat

(Salty) habitats 1110-1330	--
(Sandy) habitats 2110-50/-90	90
(Shrubby) habitats 2160-80	60

Impact mechanisms

☒ Competition	☐ Nutrient cycling
☐ Hybridization	☒ Physical modification of habitat
☒ Toxicity / poisoning	☐ Disruption of natural succession
☐ Interactions with other IAS	☐ Disruption of food webs

Distribution

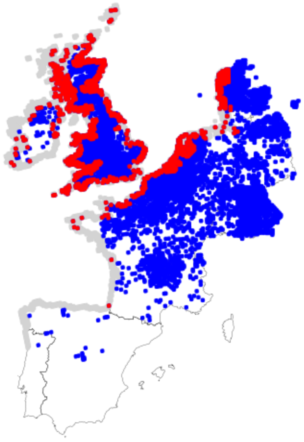


Figure 49. Distribution of *Symphoricarpos albus* within (red dots) and outside (blue dots) the European Atlantic coastal zone (in grey).

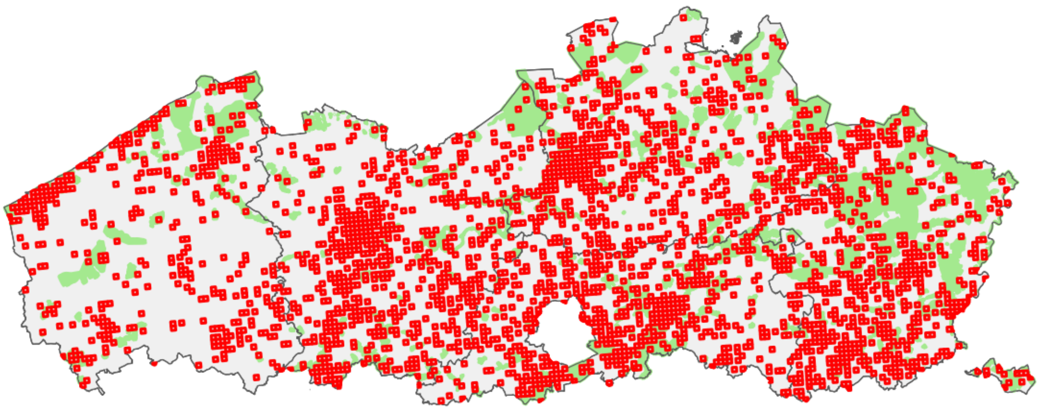


Figure 50. Distribution of *Symphoricarpos albus* in Flanders since 1950. NATURA2000 areas (EU Bird and Habitat Directive) in green.

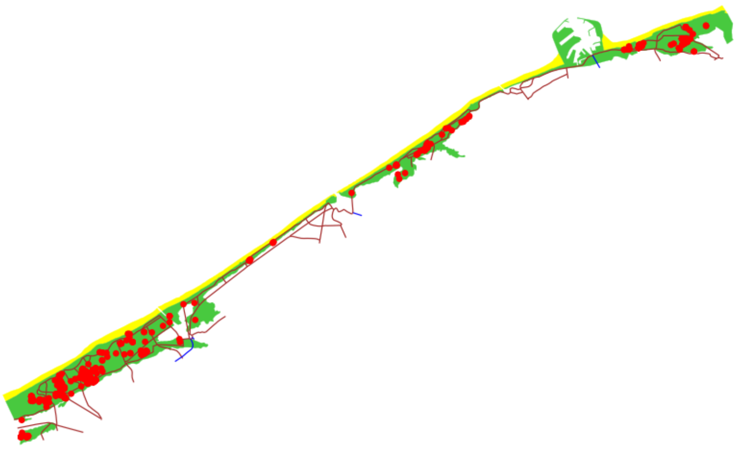


Figure 51. Distribution of *Symphoricarpos albus* in the Flemish coastal area (2007-2022) based on detailed plant surveys (Provoost et al. 2010, 2014, 2020) and the citizen science platform www.waarnemingen.be (Vanreusel et al. 2022). Beaches (yellow), coastal dunes (green) and major roads (brown) are shown for orientation.

5.9.2 Invasion history and distribution

Symphoricarpos albus began to grow wild in Flanders mid-nineteenth century and is now widespread across the region (Figure 50), although the exact status of many of the entries is not always clear and some of it probably relates to relics of ancient cultures. At regional level, snowberry appears to show a marked preference for the heavier loamy soils (Van Landuyt et al. 2006) but it is not uncommon in the coastal dunes (Figure 51). In gardens, it can quickly proliferate and it is therefore often dumped with garden waste. Snowberry grows best in shaded, moist, nutrient-rich sites in Flanders and often occurs in the shrub layer of deciduous, human-incluenced forests and thickets. Snowberry is often used in mixed shrub plantings with *Ligustrum ovalifolium*, *Berberis aquifolium*, *Prunus laurocerasus* and other alien species.

S. albus is a widely naturalised escape from, or relic of, cultivation. Verloove (2002) reports it is usually found in man-made habitats, near old parks and estates, cemeteries, hedges or woodlands, yet is sometimes also seen in semi-natural habitats such as coastal dunes. It usually grows in rather shady, dry or slightly humid soils. According to Verloove (2022d) the usual taxon in cultivation and in the wild in western Europe is the var. *laevigatus,* native to western North America, whereas the eastern var. *albus* (syn.: *S. racemosus*) is very rare in cultivation. This is confirmed by Gilbert (1995) who states modern cultivars are mostly hybrids produced in the Netherlands that have *S. albus* var. *laevigatus* as one of the parents.

During INBO surveys, *Symphoricarpos* species were found in coastal dunes on over 400 locations, covering about 1 ha.

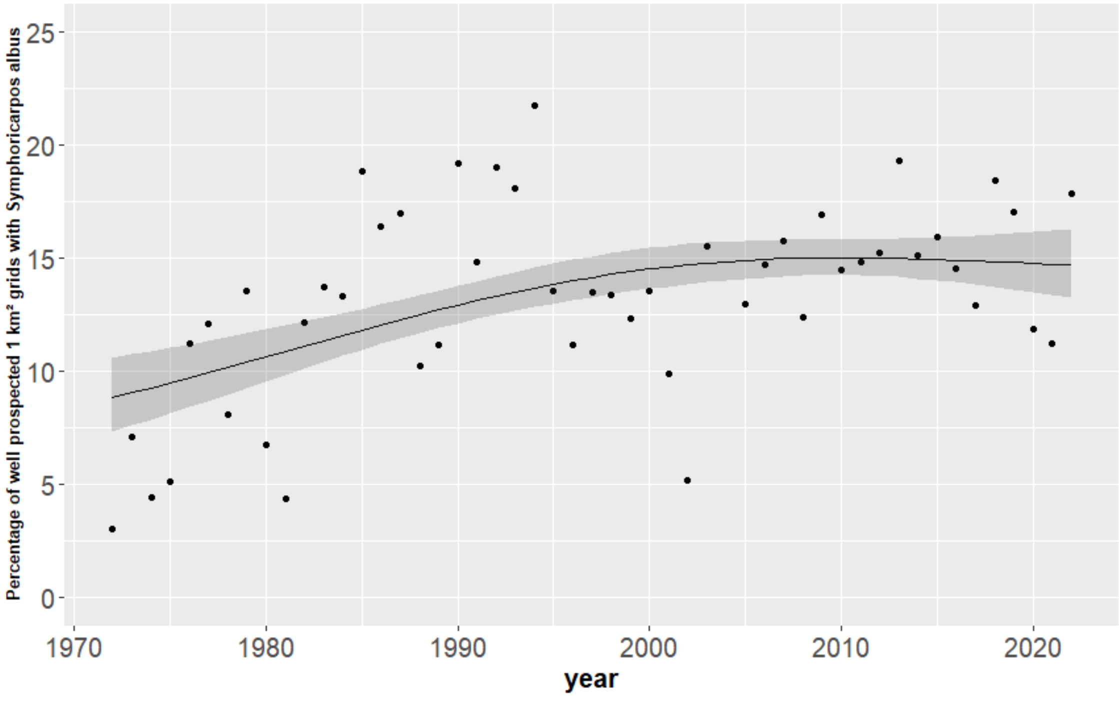


Figure 52. Trend in the percentage of well prospected x1km squares in Flanders where *Symphoricarpos albus* was recorded based on the floristic surveys in Florabank (Van Landuyt et al. 2012).

5.9.3 Management profile

S. albus is a bushy, rhizomatous, insect-pollinated, thicket-forming perennial shrub with hard-to-break stems. The root system is fibrous and shallow and can extend for several meters. Its rhizomes and clusters of stem bases are persistent and produce numerous growing points of meristematic tissue that can vegetatively grow into additional aerial stems and new rhizomes (Hullick and Manske 2005). Shoot elongation continues throughout the summer until August when the current year's growth becomes woody. Flowering commences in early June and lasts till late September.

Symphoricarpus albus spreads through suckering (stems arising adventitiously from the rhizomes). The process is described by Gilbert (1995): the production of specialized woody underground stems arise from the base of clumps, running horizontally through the soil at a depth of 2-5 cm for up to 60 cm, then turn up to become an aerial stem. Eventually, much thicker, vertical, cord-like roots are produced from these woody suckers near the point where they turn up. The same author also states that it is actually rare for the species to spread rapidly and aggressively, and this depends much on the surrounding vegetation. Spread is very slow in shaded woodland conditions and on closed grasslands, yet can be rapid on well lit, semi-open habitats such as riversides, waste places and on railway banks. Interestingly, not all hybrids seem to sucker.

The numerous berries, poisonous to humans in large quantities (Lewis 1979), contain abundant seed, but the species supposedly rarely regenerates from seed, possibly because of complex requirements for breaking seed dormancy and the resulting low germination rates (Gilbert 1995, Booy et al. 2015). In the UK, although e.g. greenfinch, blackbird, collared dove and robin are known to feed on fallen berries, the fruits were reported rather unattractive to birds possibly because birds are not used to native species with white berries (Snow & Snow 1988, Radford 1980), contrary to the reddish fruits of *S. orbiculatus* (Gilbert 1995).

5.9.4 Options for management

Much of what is known on snowberry control actually concerns western snowberry *S. occidentalis,* native to Canada and the northern and central United States, and much research was performed in the context of grazed prairies where the suppression of wildfires and the implementation of traditional grazing practices favoured western snowberry. Therefore, this information is not necessarily relevant to the context of *S. albus* in the Atlantic coastal dunes. The species are very closely related Caprifoliaceae and have similar life histories, yet, in case information is derived this is clearly mentioned here.

5.9.4.1 Mechanical and manual

At locations where disturbance is a concern (with regards to native vegetation, or terrain usage), winching and pulling are probably good options to remove above- and belowground biomass (see the approach for *L. barbarum*, 5.5.4). In less sensitive locations, large excavators or bulldozers can be used to control large infestations.

van Valkenburg et al. (2022) consider snowberry mechanically “ineradicable” for the plant roots deeply among the roots of other woody species and the roots have high regenerative capacity, yet they state the species can be suppressed and controlled with intensive management.

Mowing was described as totally ineffective for western snowberry *S. occidentalis* control regarldless of the mowing date (McCarty 1967). Also, mowing was reported to release young, succulent sprouts.

5.9.4.2 Chemical

Western snowberry may be eradicated by spraying with a glyphosate-based herbicide, which must be applied when the plant is in full leaf. Several applications may be required (http://www.habitas.org.uk/invasive/species.asp?item=4329). McCarty (1967) described a control experiment of western snowberry (*S. occidentalis*) on *Poa pratensis* grasslands using 2,4-dichIorophenoxyacetic acid (2,4-D) sprayed in early full foliage (mid-May in Nebraska) and notes that timely spraying should result in effective control, with however some herbaceous shoots reported two years after treatment. This regrowth was controlled using grazing.

The important principles for succesful herbicide treatment of *Symphoricarpos* are (1) herbicides must enter the leaf tissue through the stomata or penetrate the cuticle layer, to be absorbed through leaf tissue by diffusion to be moved to the vascular system within the leaf, and (2) the herbicides must be translocated from the leaves downward through the phloem to the metabolically active sites of the crowns and rhizomes (Hullick and Manske 2005). Therefore, timing of application is critical for successful chemical management. Western snowberry has only a brief vulnerable stage for herbicide to be effective, from about 10 June until 20 June (note this period can differ in Belgian coastal dunes), at a time herbicide penetration into leaf tissue is decreasing (but still happening) ánd downward herbicide translocation is increasing (so product can reach the roots). Bad timing might still results in killing the aerial stems, but belowground plant parts will receive little, if any, damage (Hullick and Manske 2005). The rhizomes and the stem base clusters on the crowns can recover from one application and by the third growing season post treatment can produce sucker stems equal to the density of the aerial stems on areas that received no treatment.

Leaf penetration of herbicides can be improved with wetting agents, and these surfactants should be added to all foliage-active herbicide spray mixtures (Manske 2006).

5.9.4.3 Biological

Smart et al. (2006) compared the effects of grazing by sheep or goats in a grazing regime of 3-5 days in late June in eastern South Dakota at an intensity of 4.5-6.2 Animal Unit Month (AUM). During the grazing period, goats reduced both height and foliar cover of western snowberry more than did sheep. They conclude goats could be an acceptable alternative to herbicides for control yet mention heavy defoliation of other plants as side effect. In a study using cattle, Reed et al. (2019) found that mob grazing (short duration, high density) decreased snowberry patch volumes by ≥ 45% compared to no change in rotational grazing (low stocking densities for a longer time period) and increased snowberry cover in non-grazed areas.

No information was found on operational biocontrol programmes for snowberry. It is known however that some native insect guilds occurring on the related native common honeysuckle *Lonicera periclymenum* (leaf miners, sawfly larvae, caterpillars) have found their way to *S. albus* but without noticeable effects on plant fitness (Gilbert 1995).

5.10 (FALSE) VIRGINIA CREEPER (*PARTHENOCISSUS QUINQUEFOLIA, P. INSERTA*)

5.10.1 Species profile

Union List	☐ Yes	☒ No
Environment	☐ marine	☐ freshwater
	☐ brackish	☒ terrestrial
Natura 2000 susceptibility	☐ 1110 - Sandbanks	
	☐ 1130 - Estuaries	
	☐ 1140 - Mudflats and sandflats	
	☐ 1210 - Annual vegetation of drift lines *	
	☐ 1230 - Vegetated sea cliffs of coasts *	
	☐ 1310 - Annuals colonising mud and sand	
	☐ 1320 - *Spartina* swards	
	☐ 1330 - Atlantic salt meadows	
	☐ 2110 - Embryonic shifting dunes	
	☐ 2120 - Shifting dunes along shoreline (white dunes)	
	☒ 2130 - Fixed coastal dunes with herbs (grey dunes)	
	☐ 2140 - Decalcified dunes with *Empetrum* *	
	☐ 21A0 - Machairs *	
	☐ 2150 - Atlantic decalcified fixed dunes	
	☐ 2190 - Humid dune slacks	
	☒ 2160 - Dunes with *Hippophae rhamnoides*	
	☒ 2170 - Dunes with *Salix repens* ssp. *argentea*	
	☒ 2180 - Wooded dunes of the Atlantic region	

Occurrence in Atlantic coastal zone (Number of occupied 10km²-grid cells (*P. quinquefolia/P. inserta* respectively)				
	Belgium	6/11 (32/58%)	United Kingdom	189/44 (13/3%)
	France	24/70 (5/16%)	Denmark	3/8 (3/7%)
	Ireland	0/0	Germany	26/5 (18/3%)
	Netherlands	85/18 (42/9%)	Portugal	0/0
	Spain	1/1 (0.5/0.5%)		

Impact scoring (max score across habitats)	**Score**	**Confidence**
	1 2 3 4 5	Low Medium High
Introduction	☐ ☐ ☐ ☐ ☒	☐ ☐ ☒
Establishment	☐ ☒ ☐ ☐ ☐	☐ ☒ ☐
Spread	☐ ☐ ☒ ☐ ☐	☐ ☐ ☒
Environmental impact	☐ ☐ ☒ ☐ ☐	☐ ☒ ☐

Overall impact score per habitat		
	(Salty) habitats 1110-1330	--
	(Sandy) habitats 2110-50/-90	90
	(Shrubby) habitats 2160-80	90

Impact mechanisms		
	☒ Competition	☐ Nutrient cycling
	☐ Hybridization	☒ Physical modification of habitat
	☐ Toxicity / poisoning	☐ Disruption of natural succession
	☐ Interactions with other IAS	☐ Disruption of food webs

Distribution

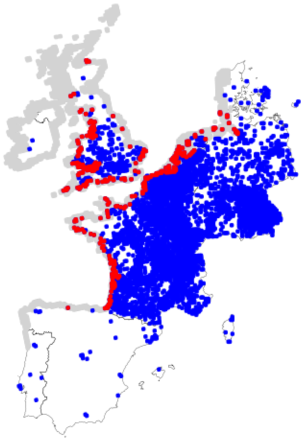


Figure 53. Distribution of *Parthenocissus quinquefolia* and *P. inserta* within (red dots) and outside (blue dots) the European Atlantic coastal zone (in grey).

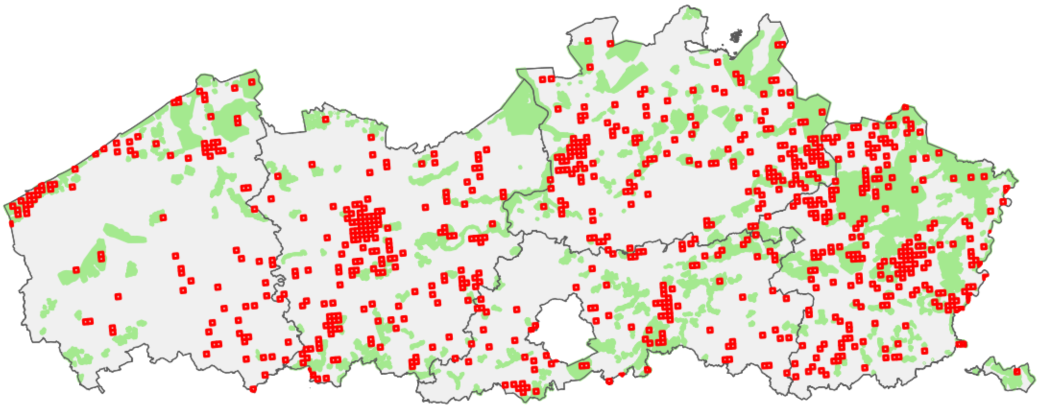


Figure 54. Distribution of *Parthenocissus quinquefolia* and *P. inserta* in Flanders since 1950. NATURA2000 areas (EU Bird and Habitat Directive) in green.

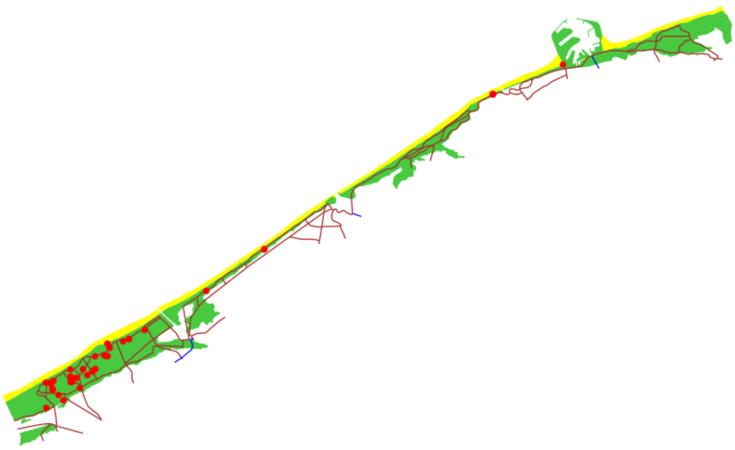


Figure 55. Distribution of *Parthenocissus quinquefolia* and *P. inserta* in the Flemish coastal area (2007-2022) based on detailed plant surveys (Provoost et al. 2010, 2014, 2020) and the citizen science platform www.waarnemingen.be (Vanreusel et al. 2022). Beaches (yellow), coastal dunes (green) and major roads (brown) are shown for orientation.

5.10.2 Invasion history and distribution

According to Verloove (2022), in Belgium, *Parthenocissus quinquefolia* (Virginia creeper) is much rarer in cultivation and as an escape than *P. inserta* (false Virginia creeper) and was previously confused. *P. inserta* (syn. *P. vitacea*) is very commonly grown as an ornamental. Old records are almost exclusively from old walls or hedges and are probably mere relics of cultivation. In the past decades however, the species is much increasing and naturalized throughout Belgium, usually in disturbed habitats (Verloove 2002, 2006; Figure 56), but also increasingly in natural habitats such as woodlands and coastal dunes (Figure 54, Figure 55, Figure 56). It often builds massive stands and is likely to become a very invasive species in a near future (Verloove 2022c). Many populations originate from garden waste but both creeper species are also dispersed by birds which can happen over large distances.

During INBO surveys, *Parthenocissus* spp. were found invading coastal dunes on 40 locations, covering about 1200 m².

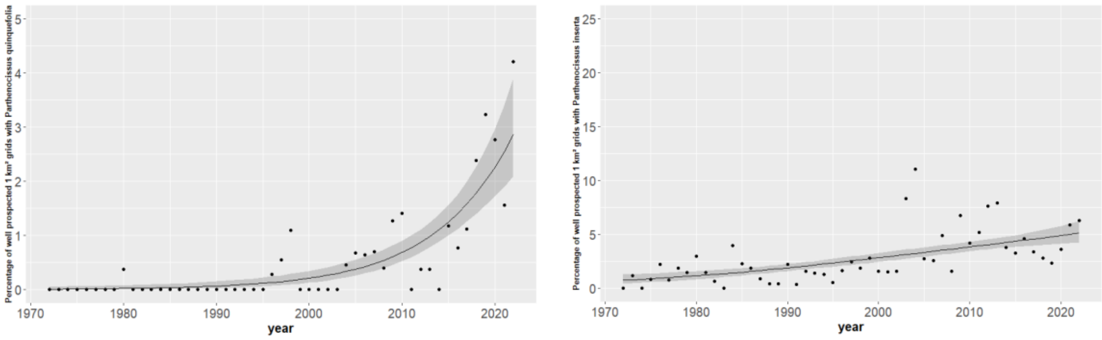


Figure 56. Trend in the percentage of well prospected 1x1km squares in Flanders where Parthenocissus quinquefolia (left) and *P. inserta* were recorded based on the floristic surveys in Florabank (Van Landuyt et al. 2012).

5.10.3 Management profile

Creepers are woody vines (like the native *Humulus lupulus* or *Clematis vitalba*) that can act as transformer species by forming dense curtains covering and outcompeting native vegetation such as shrubs and trees. They were and are introduced for ornamental purposes, in gardens, hedges and as wall cover. Panasenko and Anishchenko (2018) mention ecological effects of *Parthenocissus* on species diversity as well as species turnover in native pine forest vegetations through active vegetative reproduction, allelopathic effects on native species and decreased illumination of ground cover. *Parthenocissus inserta* can form dense carpets in dune systems, suffocating native vegetations (van Valkenburg 2022).

P. quinquefolia is known to spread by berries, but also vegetatively by root and stem fragments. One important plant characteristic for management is the capacity to regrow stems and roots from pieces of cut stems, which warrants application of strict biosecurity when removing *Parthenocissus* stands as well as appropriate disposal of plant material (Strgulc Krajšek et al. 2020). Plants are known to be salt tolerant.

Picture 19. Leaves of *Parthenocissus quinquefolia* here with *Humulus lupulus* and *Reynoutria japonica* (left) and *Parthenocissus inserta* (right). Apart from the sharper dentition on the leaf margin, the best character is the presence of adhesive disks on the tendrils in *P. quinquefolia*. Excellent drawings can be found on the webpage of Harper (2022) and in Booy et al. (2015).

5.10.4 Options for management

5.10.4.1 Mechanical and manual

Small infestations of *Parthenocissus* can be controlled by cutting all the foliage and stems and digging out the roots (Dickens et al. 2015). Young plants can simply be removed by manual pulling which is mostly performed in spring. Wearing protective gloves is advisable. After a few growing seasons however, the roots will have become more extensive and shovels are needed to dig out the entire root system. Van Valkenburg et al. (2022) note that control of *P. quinquefolia* first requires pulling or cutting the vine loose from the tree. In August and September, leaves are still clearly visible so that creeping stems can also be removed more effectively (van Valkenburg et al. 2022).

Removing larger stands of *Parthenocissus* is costly and difficult. Regular pruning and mowing will not rid an area of creepers but it can buy time in preventing spread to other areas. This should ideally be done before the flowering season. Ground cover can be reduced by burning in early spring, eliminating seedlings and sprouts, or cutting at the base of stems (JuYing et al., 2004), but this is probably of little relevance to coastal dunes.

In an experiment, Strgulc Krajšek et al. (2020) showed that composting nor (plastic) bagging represent suitable disposal methods that prevent regeneration of new stems from 15cm long stem fragments after five months. Only dried plant fragments (at room temperature in the dark) did not develop roots, while the number of rooted fragments in plastic bag treatment was almost the same as in the control group. To a lesser extent, some of the composted fragments also developed roots. Moreover, when fragments were treated with a garden shredder, some

>1cm long fragments equally showed rooting. Rather non-intuitively, the authors conclude that composting *Parthenocissus* on not too big (< 0.25 m^3), open compost heaps is to be the preferred method of plant disposal as other methods (such as composting with a closed lid or bagging) in fact prevent dehydration.

5.10.4.2 Chemical

The herbicides imazapyr and triclopyr have been successfully used to control infestations of *P. quinquefolia* (Dickens et al. 2015), although Tworkoski and Young (1990) report that satisfactory control was only obtained after two applications of the herbicide. In general, some sources mention that once established, creepers will most often not be controlled with a single herbicide application, and multiple applications will be necessary to achieve acceptable control (Rojas-Sandoval 2017). Tworkoski et al. (1988) reported triclopyr esters (1.1kg/ha) were more effective than triclopyr with amines (2,4 D) for control in orchards. Richardson et al. (2009) also concluded triclopyr-containing treatments were an effective removal tool for Virginia creeper in Christmas tree plantations, with the highest control ratios reached for combinations of triclopyr with clopyralid or 2,4-D.

In all cases where imazapyr and triclopyr were used, the herbicide was applied directly on the leaves in the period from mid-July to early October prior to leaf color change (Dickens et al. 2015). Glyphosate also strongly inhibits growth of the plant (Wu et al., 2004). Besançon (2017) advises to wet minimum 50% of the plant with a 1% glyphosate solution for effective control with spot treatment and advises against “pruning out” the vine during the dormant season. The same glyphosate concentration can be used for cut-stump treatment in late summer and early fall. Kelbel (2012) suggests the best method of control is **mechanical removal at the end of the year followed by chemical application in the first half of the next growing season** on the new green growth.

Some UK gardening websites refer to late summer and fall as the best periods for herbicide application and refer to application of a mixture of 20 percent white vinegar with 80 percent water. No scientific evaluation of this mixture was found.

5.10.4.3 Biological

No information was found on biological control options for *Parthenocissus* spp.

6 MANAGEMENT PLANNING

6.1 IMPLEMENTING RAPID RESPONSE MECHANISMS

One important way in which the risk screening exercise presented here can be used, is to prepare lists per country or area with high impact species that are not present yet on the territory, or that only have a limited distribution (see 3.1.1, Table 9).

It is generally acknowledged that rapid removal action on such species represents the most appropriate response towards newly emerging alien plant species and can prevent increasing management costs (e.g. case *Carpobrotus* below) (Wittenberg and Cock 2001, Adriaens et al. 2018). For Union List species of the IAS Regulation, Member States have such rapid eradication obligations for species new for the territory.

Several challenges need to be tackled when implementing early detection and rapid response mechanisms (EDRR, cf. Mooney et al. 2013, Burgos-Rodríguez & Burgiel 2020, Reaser 2020):

- Awareness on and identification skills for high risk species with managers, scientists, the naturalist community etc.
- Surveillance work in areas at risk that can rapidly detect and report potentially problematic species;
- Rapid dataflows to early warning systems (cf. Groom et al. 2017);
- The drafting of contingency plans for specific (sets of) species;
- Outlining rapid response protocols that specify mandates, roles and responsibilities of different actors involved, from whistle blowers that signal first detections up to the responsible management party;
- Budgeting rapid response actions in the face of uncertainty on such rare events;
- Potentially a more structural approach, involving the formation of Rapid Action Teams (RATs) i.e. competently trained, mostly in-house, first responders;
- Capacity building for the technicity of removal actions on a highly diverse set of species;
- Keeping good records of actions undertaken through standardized occurrence and management reporting so future risk screenings and response actions can learn from previous experience.

Case: rapid removal of *Carpobrotus* in the Belgian coastal dunes

Early July 2017, the presence of *Carpobrotus* sp. was reported in the coastal dune region of Belgium for the first time. Following a swift investigation from the Agency for Nature and Forests, it was established that the plants were deliberately planted in a road verge by a local resident. This resident was apparently dissatisfied with the “sparse” appearance of the verge and wanted to “improve it with beautiful flowering plants” from a southern holiday destination.

That same month, the patch of plants, which was already of considerable size (picture), was removed by the authorities. The resident was sanctioned by the inspection services, under the ban on introducing (any) alien species into the wild.

The introduction had happened within 400 metres of a high-value NATURA2000 area (IJzermonding). The reserve includes various types of dune grasslands, saline habitats and artificially paved structures (e.g. dikes), which might have proven susceptible to establishment of *Carpobrotus*.

It cannot be underemphasized how little the effort of the current removal was in comparison to a supposed *laissez-faire* scenario. If the species were to establish firmly in the Belgian coastal dunes, thus extending its northward range, authorities might by now have been confronted with dramatically raised management costs. Since this incident, no *Carpobrotus* was reported in the Belgian coastal dunes.

Well-intentioned, but illegal and ecologically risky: *Carpobrotus* in the vicinity of the NATURA2000 area Ijzermonding at the time of rapid removal (July 2017) (Photo: C. Houthoofd).

6.2 MANAGING ESTABLISHED INVADERS - THE BRADLEY METHOD

In terms of the organisation of a removal campaign, in Australia, the **Bradley Method** is advocated for protected areas such as nature reserves (often within a context of budgetary constraints) with sensitive native plant populations (Bradley 1971). It advises a level of action in the following hierarchy (Fuller and Barbe 1985):

1. preventing deterioration of good areas with lots of native plants,
2. improving the next best area where native vegetation is pushing against a mixture of weeds and natives,
3. holding the advantage gained i.e. resist the temptation to push deeper into heavily infested areas before the regenerating natives have stabilized cleared areas,
4. cautiously moving into the highly invaded areas.

This implies **removal actions should start with the best stands of native vegetation (the least invaded) and working towards those stands with the worst weed infestation**. The general idea behind is that native plants can stabilize the vegetation in cleared areas, before working deeper into the center of the most densely invaded patches (Fuller and Barbe 1985).

Of course, in case budgets (and machinery) are available, larger source populations could move up the priority list and many other consideration come into play when making a decision on which areas or populations to tackle first (cf. 2.4.4). Often however, removal operations tend to be focused on areas where the problem appears to be worst, rather than using a more strategic approach to spend available resources.

To really carefully plan management interventions, it is necessary to define clear objectives, operational targets, metrics of success and probably a strategic model-informed approach which takes into account available budget and manpower, as well as the landscape and invasion dynamics of the (potentially multiple) managed species. This is especially the case in settings such as IAS shrubs in dunes where removal is followed by reinvasion from other areas that might impair on achieving the management targets (e.g. cleared areas, contained populations). In the absence of such strategic planning tools, however, the Bradley method can be a useful framework for guiding management planning.

6.3 PRIORITY SPECIES AND AREAS FOR INVASIVE PLANTS MANAGEMENT IN FLEMISH COASTAL DUNES

Here, we present heat maps for a selection of the most invasive plant species along the Belgian coast, hoping these maps can assist in management planning. We used data from PINK (Provoost et al. 2010, 2014) and BEK (Provoost et al. 2020), and additional data from the citizen science platform www.waarnemingen.be (in total 15,560 point occurences were used). The maps were produced in ArcGIS10 using the Dot density function, using a 50m search radius, 25m pixel size and the represented species' area for each point as a value input.

A distinction was made between herbaceous species (*Cerastium tomentosum, C. helmsii, Gaillardia* species*, Heracleum mantegazzianum, Lagarosiphon major, Lathyrus latyfolius, Vinca major* and *Solidago* species) and woody species (*Rosa rugosa, Berberis aquifolium, Prunus serotina, Lycium barbarum, Ligustrum ovalifolium, Eleagnus* species*, Cotoneaster* species*, …*) because of the different management approaches these distinct groups require.

As the same legend was used for both growth forms, the maps immediately make clear that the herbaceous plants (figure 44) are less represented than the woody plants (figure 45). High densities of herbaceous plants are first related to small distance garden escapes (mainly *Gaillardia* species). This pattern is most obvious in Koksijde (Schipgat, St-André and Oostvoorduinen). These species are easily tackled by hand pulling. A second pattern is caused by the amphibious *C. helmsii* and invasive macrophytes like *L. major*. Sustainable removal of *C. helmsii* is without doubt the biggest IAS challenge along the coast because of its high reproduction rate from very tiny plant parts and the formation of seeds (D'hondt et al. 2016, Scheers et al. 2020, van der Loop et al. 2021).

The large majority of problematic invasive alien species consists of shrubs and - to a lesser extent - trees. *Populus* species *P*. x *Canadensis*, *P. alba* and *P. x canescens* are not included in the maps because total eradication is not considered a feasible management target, at least not within a relatively short timeframe. These species make up a large part of the dune woodland and removal would imply a substantial decline of woodland habitat.

The woody plant density map (Figure 58) largely results from the contribution of only ten species/genera. In descending order of surface area these are *Rosa rugosa, Berberis aquifolium, Prunus serotina, Elaeagnus* species*, Lycium barbarum, Ligustrum ovalifolium, Syringa vulgaris, Cotoneaster* species*, Tamarix* species *and Symphoricarpus* species. The other woody species cover areas less than 1ha along the coast. Especially *B. aquifolium* and *P. serotina* and (still) to a lesser extent *Cotoneaster* impose a major management challenge because of the massive and random dispersal by birds. They certainly require management priority. The other top 10 species mainly result from plantings and subsequent vegetative spread. Therefore they appear more clustered which should facilitate their removal. Hotspots of woody IAS are found at smaller sites surrounded by urban areas (e.g. Noordduinen, Plaatsduinen, Simliduinen, Warandeduinen,…), in the fringes of larger areas (east part of De Westhoek, west part of Zwinduinen and in the narrow dunes along the middle coast (Middelkerke up to Bredene).

Finally, we want to highlight the presence of *Reynoutria* species, which cover nearly 1 ha along the Belgian coast. The coast is therefore one of the few regions in Flanders where complete eradication of *Reynoutria* could still represent an achievable goal. Potential methods for removal are described in Thoonen and Willems (2018).

Figure 57. Density map of herbaceaous invasive species along the Belgian coast (upper pane west coast, middle pane middle coast, lower pane east coast).

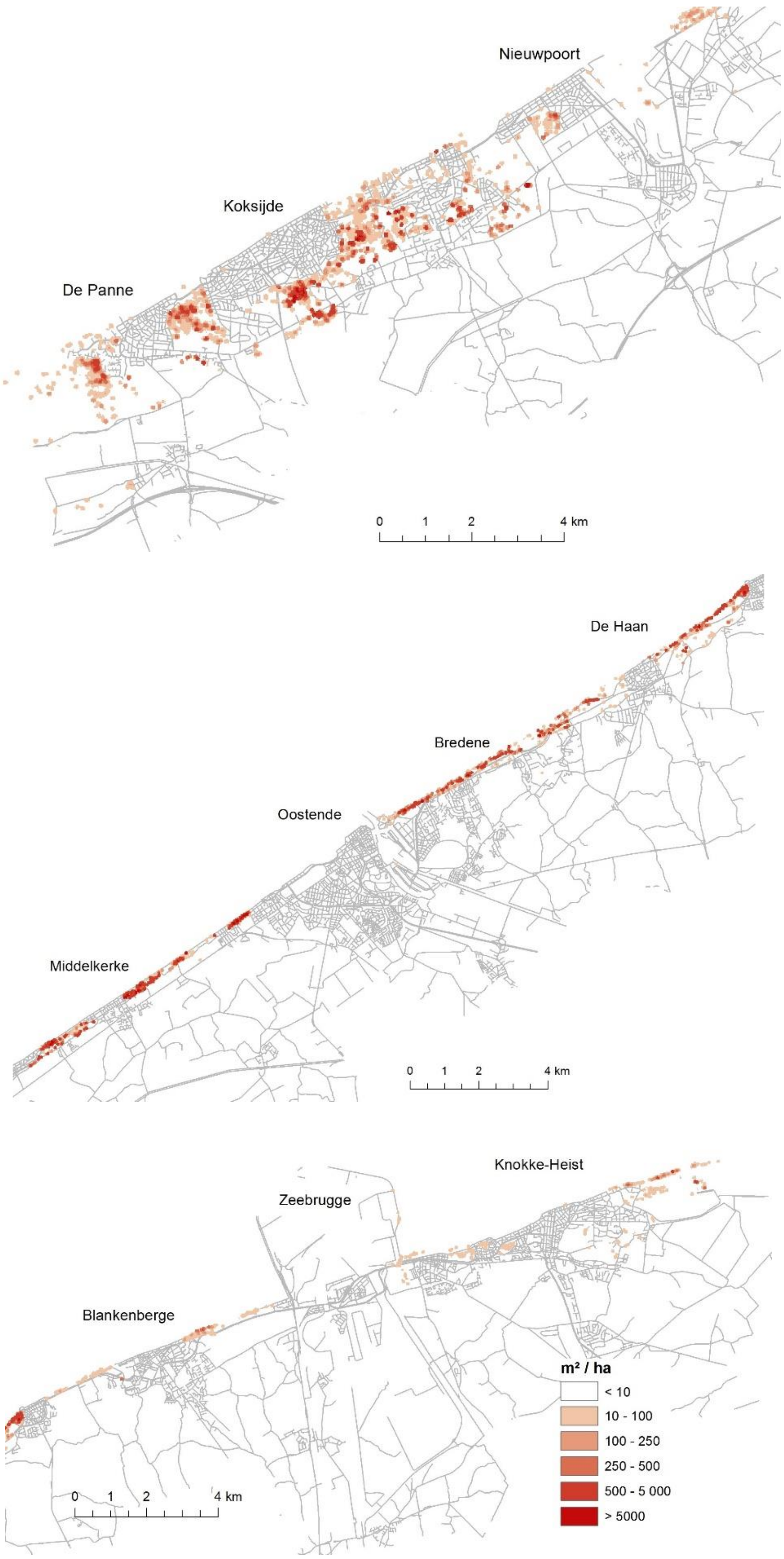


Figure 58. Density map of woody invasive species along the Belgian coast (upper pane west coast, middle pane middle coast, lower pane east coast).

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8 ANNEXES

ANNEX 1. PROGRAMME OF THE WORKSHOP *ASSESSMENT OF CURRENT AND FUTURE INVASIVE ALIEN SPECIES IN EUROPEAN COASTAL DUNE ECOSYSTEMS* (DE PANNE, BELGIUM, 19-21 MAY 2022)

Day 1 (19 May 2022)

09:00-09:15 **Welcome and Introduction to workshop** (Reinhardt Strubbe, ANB)

09:15-9:45 **Introduction to Horizon Scanning of protected dune areas** (Tim Adriaens & Bram D'hondt, INBO)

Q&A

9:45-10:30 Examples of IAS problems in dune habitats

IAS in coastal dunes of Belgium (Reinhardt Strubbe, ANB)

IAS on Sand Dunes in Wales - Sands of LIFE project (Kahtryn Hewitt, Sands of LIFE)

IAS in coastal dunes of France (Benoît Delangue, Conservatoire botanique national de Bailleul)

10h30 Coffee break

10:45-11:15 Examples of IAS problems in dune habitats

IAS in coastal dunes of northwest Iberia (Berea Rodríguez Addesso, Universidade de Vigo)

IAS in the coastal dunes of the UK and Ireland (John Houston)

IAS and conservation status of in coastal dunes: perspectives from the Belgian NATURA 2000 monitoring (Patrik Oosterlynck, INBO)

11h30 – 12h00: Introduction to the breakout groups (revision of reactions to species list)

12:00 Lunch

13:15-15:00 Breakout sessions per ecoseries (salty, sandy, shrubby) group to discuss species and scores

Break-out salty (1110 - Sandbanks, 1130 - Estuaries, 1140 - Mudflats and sandflats, 1310 - Annuals colonising mud and sand, 1320 - *Spartina* swards, 1330 - Atlantic salt meadows)

Break-out sandy (2110 - Embryonic shifting dunes, 2120 - Shifting dunes along shoreline (white dunes), 2130 - Fixed coastal dunes with herbs (grey dunes), 2150 - Atlantic decalcified fixed dunes, 2190 - Humid dune slacks)

Break-out shrubby (2160 - Dunes with *Hippophae rhamnoides*, 2170 - Dunes with *Salix repens*, 2180 - Wooded dunes of the Atlantic region)

15:00 Coffee break

15:30-16:45 Breakout sessions ecoseries (continued)

16:45-17:15 Feedback from break-out groups in plenary (common issues with scoring)

17:15-17:30 Closure of Day 1

19:00 Dinner

20:30 Evening walk with natterjack toad spotting (optional)

Day 2 (20 May 2022)

09:00-10:30: Presentations summarizing group progress: overview of high ranking species (by each of the group leaders)

Overview of high ranking species - Halophytic dune habitats (salty)

Overview of high ranking species - Embryonic dunes, sand dunes and dune grassland (sandy)

Overview of high ranking species - dune forest and scrub (shrubby)

10:30 Coffee break

10:45-12:00 Plenary discussion for **consensus building across groups**

12:00 Lunch

13:30-15:00 Management case studies: knowledge exchange on management techniques used to tackle a range of IAS (e.g. *Crassula helmsii*, *Berberis aquifolium*, *Cotoneaster*, *Rosa rugosa*, *Crocosmia x crocosmiiflora*, *Phormium*, *Prunus serotina*, *Pinus nigra*, Bamboo, *Rhododendron*, *Buddleia*, *Vaccinium corymbosum*, *Aronia*,...)

Experiences on IAS removal in Belgian dunes by excavation and drum sieving (Reinhardt Strubbe, ANB)

Eradicating problematic alien species from dunes on the Wadden Island, The Netherlands (Janneke van der Loop, Stichting Bargerveen)

IAS management in Dutch dunes, examples from the Amsterdam dunes (Luc Geelen, Waternet)

Management techniques for removing a range of key IAS from sand dunes in Wales (Kathryn Hewitt & Jake Burton, Natural Resources Wales)

Control trials for invasive Oregon grape, can we go without herbicides (Sam Provoost, INBO)

15:00 coffee break

15:15-16:15 Management prioritization exercise (moderated by Tim Adriaens)

16:15 Wrap-up and next steps:

consolidation of the consensus list

dissemination

risk assessment needs

management priorities

knowledge gaps

capacity building

dune roadmap (John Houston)

AOB

16:45 End of day 2

19:00 Dinner

Day 3 (21 May 2022) AlienCSI Bioblitz

9:00 Welcome with coffee

Introduction to bioblitzes and the COST action AlienCSI (Tim Adriaens, INBO)

Instructions to bioblitz, use of the data in IAS management (Reinhardt Strubbe, ANB)

ObsIdentify Challenge (Hannes Ledegen, Natuurpunt)

10:00-16:00 Bioblitz

16:00 End of bioblitz with feedback on experience

ANNEX 2. PARTICIPANTS AND CONTRIBUTORS THE WORKSHOP *ASSESSMENT OF CURRENT AND FUTURE INVASIVE ALIEN SPECIES IN EUROPEAN COASTAL DUNE ECOSYSTEMS* (DE PANNE, BELGIUM, 19-21 MAY 2022), THEIR SELF-ASSESSED PROFILE AND FAMILIARITY WITH THE DUNE ECOSERIES (1 = I HAVE ONLY LITTLE EXPERIENCE, 5 = I KNOW THIS HABITAT VERY WELL). PARTICIPANTS MARKED WITH * ATTENDED THE WORKSHOP ONLINE AND/OR CONTRIBUTED TO THE ASSESSMENT OF THE INITIAL LONGLIST OF SPECIES. PARTICIPANTS MARKED WITH ° CONTRIBUTED TO POST-WORKSHOP SCORING OF UNSCORED SPECIES.

Name	Affiliation	Country	Profile	tidal salt marsh	embryonic, mobile sand dunes & dune grassland	dune scrub & woodland
Arnaud Jacobs	National Scientific Secretariat on Invasive Alien Species	Belgium	Public research or academia, Government	1	1	1
Benoît Delangue	National Botanic Conservatory of Bailleul	France	Private sector	1	4	4
Berea Rodríguez Addesso	Universidade de Vigo	Spain	Public research or academia	1	2	2
Bram D'hondt°	Research Institute for Nature and Forest	Belgium	Public research or academia, Government	4	4	4
Bruce Osborne	University College Dublin	Ireland	Public research or academia	4	4	4
Debby Deconinck	Agency for Nature and Forest	Belgium	Government	1	1	1
Edward Vercruysse°	Research Institute for Nature and Forest	Belgium	Government	4	5	4
Frédérique Steen	Research Institute for Nature and Forest	Belgium	Public research or academia, Government	1	1	1
Guy Vileyn	Agentschap voor Natuur en Bos	Belgium	Government	1	4	4
Indra Jacobs	Research Institute for Nature and Forest	Belgium	Public research or academia, Government	5	5	5
Isabelle Spall	Dynamic Dunscapes	United Kingdom	NGO	2	4	2
Jake Burton	Sands of LIFE Natural Resources Wales	United Kingdom	Government	1	4	4
Jane Reniers	National Scientific Secretariat on	Belgium	Government	1	1	1

	Invasive Alien Species					
Janneke van der loop	Stichting Bargerveen	The Netherlands	NGO	2	2	4
Jasmijn Hillaert°	Research Institute for Nature and Forest	Belgium	Public research or academia, Government	1	2	2
Jodey Peyton*	Centre for Ecology and Hydrology	United Kingdom	NGO	2	2	2
Johan Lamaire	Agency for Nature and Forest	Belgium	Government	1	4	4
Johannes Jansen°	Research Institute for Nature and Forest	Belgium	Public research or academia, Government	5	5	5
John Houston	Independent/ retired	United Kingdom	Public research or academia	1	5	4
Julie Creer	Natural Resources Wales	United Kingdom	Coastal Ecologist	-	-	-
Kathryn Hewitt	Sands of LIFE Natural Resources Wales	United Kingdom	Government	1	5	5
Kris Lesage	Agency for Nature and Forest	Belgium	Government	1	2	4
Louise Denning*	Dynamic Dunescapes	United Kingdom	NGO	-	-	-
Luc Geelen	Waternet	The Netherlands	Government	1	5	5
Maike Isermann*	Lower Saxon Wadden Sea National Park Authority	Germany	Government	1	5	5
Marc Leten	Agency for Nature and Forest	Belgium	Public research or academia	5	5	5
Marilena Onete*	Institute of Biology Bucharest	Romania	Public research or academia	-	-	-
Mark Spencer*	Natural History Museum	United Kingdom	Public research or academia	-	-	-
Marta Pérez Diz	Universidade de Vigo	Spain	Public research or academia	2	2	2
Martijn van de Loo	Soontiëns Ecology	The Netherlands	Private sector	2	2	2
Natalie Hunt	Natural England	United Kingdom		-	-	-
Noa Núñez González	University of Vigo	Spain	Public research or academia	2	2	2
Owen Mountford*	Plant ecologist	United Kingdom	Public research or academia	-	-	-

Pablo Gonzalez-Moreno*	University of Cordoba	Spain	Public research or academia	1	2	4
Patrik Oosterlynck	Research Institute for Nature and Forest	Belgium	Public research or academia, Government	2	2	2
Reinhardt Strubbe	Agency for Nature and Forest	Belgium	Government	3	4	3
Reverend Paul Rooney	Liverpool Hope University	United Kingdom	Public research or academia	2	5	5
Robbe Paredis°	Research Institute for Nature and Forest	Belgium	Public research or academia	4	4	4
Sam Provoost°	Research Institute for Nature and Forest	Belgium	Public research or academia, Government	5	5	5
Sander Carael	Agency for Nature and Forest	Belgium	Government	1	1	1
Siobhan.Murphy	Natural England	United Kingdom	Government	-	-	-
Tim Adriaens°	Research Institute for Nature and Forest	Belgium	Public research or academia	1	5	2
Trevor Renals*	Environment Agency	United Kingdom	Government	-	-	-
Verity Pitts	Natural England	United Kingdom	Government	-	-	-
Wayne Dawson*	Durham University	United Kingdom	Public research or academia	1	4	2
Wouter Van Landuyt°	Research Institute for Nature and Forest	Belgium	Public research or academia	5	5	5

ANNEX 3. RISK SCORES OF THE SHORTLIST.

Provided are the taxa, the risk scores of the "salty", "sandy" and "shrubby" habitat groups (each score is the product of the scores for introduction, establishment, spread and impact), the maximum of these scores, and the number of occupied grid cells within the Atlantic coastal region as an indication of the extent of their range. Species are ranked based on the maximum of scores across the habitat groups. Union list species of the IAS Regulation are marked in bold.

TaxonName	salties	sandies	shrubbies	max(score)	occupancy
Campylopus introflexus	.	625	.	625	1535
Carpobrotus acinaciformis	625	500	375	625	26
Carpobrotus edulis	625	500	375	625	347
Heracleum mantegazzianum	.	625	500	625	879
Solidago canadensis	.	625	120	625	517
Solidago gigantea	.	625	24	625	461
Crassula helmsii	.	625	.	625	426
Paspalum vaginatum	625	.	.	625	32
Prunus serotina	.	225	625	625	388
Rosa rugosa	300	625	500	625	1442
Rubus armeniacus	.	625	.	625	400
Ailanthus altissima	.	625	300	625	343
Senecio inaequidens	.	500	.	500	458
Berberis darwinii	.	500	400	500	229
Tradescantia fluminensis	.	500	.	500	127
Acacia dealbata	.	135	500	500	317
Acacia longifolia	.	135	500	500	32
Acacia saligna	.	135	500	500	3
Lupinus arboreus	.	500	375	500	184
Crocosmia crocosmiiflora	.	400	500	500	419
Spartina anglica	500	.	.	500	491
Acaena novae-zelandiae	.	500	500	500	88
Cotoneaster horizontalis	.	500	150	500	761
Prunus laurocerasus	.	.	500	500	1580
Gaillardia pulchella	.	400	.	400	62
Berberis thunbergii	.	.	400	400	265
Cornus sericea	.	.	400	400	334
Equisetum hyemale affine	.	375	400	400	29
Ludwigia grandiflora	.	400	.	400	148
Spartina alterniflora	400	.	.	400	26
Acaena anserinifolia	.	400	400	400	27
Acaena ovalifolia	.	400	400	400	53
Cotoneaster ascendens	.	400	225	400	.
Cotoneaster divaricatus	.	400	225	400	67
Cotoneaster hjelmqvistii	.	400	225	400	98
Cotoneaster integrifolius	.	400	225	400	315
Cotoneaster microphyllus	.	400	225	400	84
Cotoneaster suecicus	.	400	225	400	22
Opuntia stricta	375	240	.	375	2

Myriophyllum aquaticum	.	375	.	375	331
Oxalis pes-caprae	64	375	.	375	109
Cotoneaster bullatus	.	225	375	375	429
Cotoneaster dielsianus	.	225	375	375	40
Cotoneaster frigidus	.	225	375	375	82
Cotoneaster nitens	.	225	375	375	3
Cotoneaster pannosus	.	225	375	375	8
Cotoneaster rehderi	.	225	375	375	.
Cotoneaster sternianus	.	225	375	375	.
Cotoneaster watereri	.	225	375	375	8
Lycium barbarum	.	375	60	375	529
Atriplex micrantha	320	.	.	320	9
Lonicera japonica	.	.	320	320	416
Lonicera maackii	.	.	320	320	4
Lonicera nitida	.	.	320	320	435
Gunnera tinctoria	.	320	.	320	406
Ludwigia peploides	.	320	.	320	56
Ludwigia peploides montevidensis	.	320	.	320	6
Phytolacca americana	.	320	60	320	417
Lophocolea semiteres	.	300	300	300	127
Alternanthera philoxeroides	300	36	.	300	2
Arctotheca calendula	225	300	.	300	134
Delairea odorata	.	.	300	300	91
Ipomoea indica	.	200	300	300	72
Ligustrum ovalifolium	.	300	100	300	835
Reynoutria bohemica	.	300	300	300	46
Reynoutria japonica	.	300	300	300	1791
Amelanchier lamarckii	.	240	300	300	248
Populus balsamifera	.	300	.	300	223
Populus balsamifera trichocarpa	.	300	144	300	15
Populus jackii	.	300	.	300	38
Aronia prunifolia	.	256	256	256	27
Ambrosia artemisiifolia	.	250	.	250	323
Claytonia perfoliata	.	30	250	250	621
Spartina x townsendii	250	.	.	250	79
Mesembryanthemum cordifolium	240	192	180	240	20
Alternanthera sessilis	240	24	.	240	1
Cotula coronopifolia	240	.	.	240	326
Gaultheria shallon	.	240	96	240	153
Vaccinium macrocarpum	.	240	240	240	43
Ribes sanguineum	.	.	240	240	784
Lindernia dubia	.	240	.	240	18
Ligustrum lucidum	.	240	120	240	60
Pinus contorta	.	240	240	240	511
Koenigia polystachya	.	180	240	240	318
Rosa multiflora	.	.	240	240	221
Tetragonia tetragonioides	.	225	.	225	55

Tetragonia tetragonoides	.	225	.	225	22
Araujia sericifera	.	225	.	225	77
Gaillardia x grandiflora	.	225	.	225	6
Elodea nuttallii	.	225	.	225	572
Fallopia sachalinensis	.	225	.	225	277
Spartina patens	200	.	.	200	1
Acaena caesiiglauca	.	128	200	200	1
Gaultheria mucronata	.	192	128	192	17
Gaultheria procumbens	.	192	128	192	13
Ligustrum japonicum	.	192	72	192	6
Amelanchier spicata	.	192	192	192	75
Lemna minuta	.	180	.	180	639
Robinia pseudoacacia	.	54	180	180	824
Myriophyllum heterophyllum	.	180	.	180	11
Fuchsia magellanica	.	.	180	180	908
Arundo donax	180	.	.	180	118
Spiraea douglasii	.	180	180	180	154
Conyza bilbaoana	.	160	.	160	8
Passiflora caerulea	.	160	4	160	253
Solanum chenopodioides	160	80	.	160	99
Solanum linnaeanum	160	80	.	160	3
Solanum physalifolium nitidibaccatum	160	80	.	160	3
Solanum sarrachoides	160	80	.	160	24
Solanum triflorum	160	80	.	160	93
Fallopia baldschuanica	.	5	150	150	410
Symphoricarpos orbiculatus	.	.	144	144	22
Ipomoea purpurea	.	144	144	144	91
Rhus typhina	.	135	40	135	505
Acacia melanoxylon	.	135	.	135	61
Melia azedarach	.	.	135	135	107
Ribes aureum	.	128	128	128	62
Erigeron bonariensis	.	125	.	125	155
Erigeron canadensis	.	125	.	125	933
Erigeron sumatrensis	.	125	.	125	524
Datura stramonium	.	125	.	125	998
Ambrosia psilostachya	.	120	.	120	34
Quercus rubra	.	.	120	120	624
Eschscholzia californica	.	120	.	120	650
Zantedeschia aethiopica	48	108	.	108	425
Pinus radiata	.	108	108	108	200
Azolla filiculoides	.	100	.	100	527
Olearia macrodonta	.	96	96	96	107
Elaeagnus ebbingei	.	96	96	96	6
Gunnera manicata	.	96	.	96	7
Vitex rotundifolia	.	96	.	96	0
Ligustrum vicaryi	.	96	32	96	1
Lantana camara	.	72	96	96	10

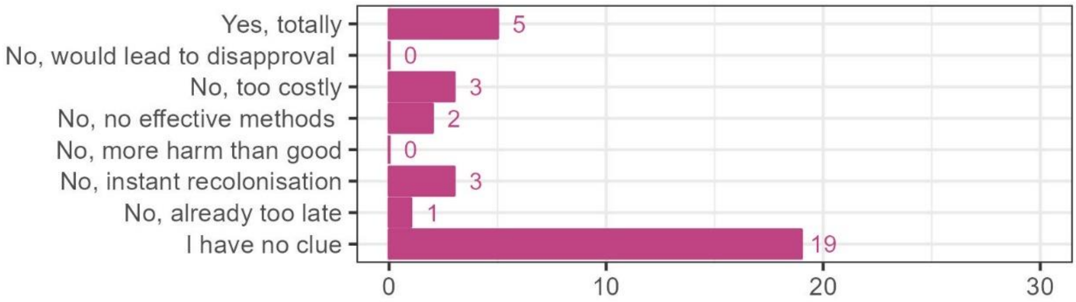
Symphoricarpos albus	.	90	60	90	921
Parthenocissus quinquefolia	.	90	90	90	334
Parthenocissus vitacea	.	90	90	90	157
Hydrocotyle ranunculoides	.	81	.	81	151
Amelanchier alnifolia	.	81	81	81	6
Parthenocissus inserta (Kern.) Fritsch	.	81	.	81	159
Lonicera tatarica	.	.	80	80	154
Euonymus japonicus	.	.	80	80	344
Deutzia scabra	.	.	80	80	54
Buddleja davidii	.	80	40	80	1321
Artemisia verlotiorum	.	72	.	72	138
Catalpa bignonioides	.	.	72	72	75
Juglans nigra	.	.	72	72	52
Cenchrus echinatus	72	18	.	72	1
Nassella tenuissima	.	72	.	72	56
Euonymus fortunei	.	.	64	64	480
Leucaena leucocephala	.	64	64	64	2
Casuarina equisetifolia	60	48	60	60	4
Stachys byzantina	.	60	.	60	400
Phyllostachys aurea	.	60	60	60	7
Phyllostachys nigra	.	60	60	60	10
Impatiens capensis	.	54	.	54	97
Catalpa erubescens	.	.	54	54	2
Kalanchoe x houghtonii	.	54	.	54	1
Agave americana	.	48	.	48	269
Asparagus asparagoides	.	4	48	48	1
Phormium tenax	.	.	48	48	179
Casuarina cunninghamiana	.	48	48	48	2
Buddleja globosa	.	48	24	48	187
Chamaecyparis lawsoniana	.	.	45	45	523
Agapanthus praecox	.	36	36	36	96
Agapanthus praecox orientalis	.	36	36	36	14
Symphytum hidcotense	.	.	36	36	34
Scaevola taccada	15	36	.	36	1
Pittosporum crassifolium	36	.	36	36	14
Ceratostigma plumbaginoides	36	36	.	36	126
Anemanthele lessoniana	.	32	.	32	16
Miscanthus sinensis	32	12	12	32	44
Nassella neesiana	.	27	.	27	2
Washingtonia robusta	.	.	24	24	2
Lupinus polyphyllus	.	24	.	24	493
Lupinus regalis	.	24	.	24	3
Sarracenia purpurea	.	24	.	24	23
Tolmiea menziesii	.	8	24	24	162
Cotula anthemoides	6	18	.	18	1
Argemone mexicana	.	18	.	18	7
Smilax rotundifolia	.	.	18	18	1

Drosanthemum floribundum	.	16	.	16	16
Tagetes erecta	.	16	.	16	295
Amsinckia micrantha	.	12	.	12	214
Hydrocotyle novae-zeelandiae	.	8	.	8	1
Thunbergia alata	.	4	4	4	6
Hydrocotyle moschata	.	4	.	4	1
Disphyma crassifolium	192	144	.	.	.
Amaranthus albus	27	.	.	.	.
Amaranthus blitoides	27	.	.	.	.
Amaranthus caudatus	27	.	.	.	.
Amaranthus cruentus	27	.	.	.	.
Amaranthus deflexus	27	.	.	.	.
Amaranthus hybridus	27	.	.	.	.
Amaranthus hybridus hybridus	27	.	.	.	.
Amaranthus hypochondriacus	27	.	.	.	.
Amaranthus muricatus	27	.	.	.	.
Amaranthus palmeri	27	.	.	.	.
Amaranthus powellii	27	.	.	.	.
Amaranthus quitensis	27	.	.	.	.
Amaranthus ralletii	27	.	.	.	.
Amaranthus retroflexus	27	.	.	.	.
Amaranthus spinosus	27	.	.	.	.
Amaranthus standleyanus	27	.	.	.	.
Amaranthus thunbergii	27	.	.	.	.
Amaranthus tuberculatus	27	.	.	.	.
Amaranthus viridis	27	.	.	.	.
Schinus molle	.	320	.	.	.
Schinus terebinthifolia	.	256	.	.	.
Hydrocotyle bonariensis	240	.	.	.	.
Asclepias syriaca	.	192	.	.	.
Yucca aloifolia	.	375	.	.	.
Yucca filamentosa	.	375	.	.	.
Yucca flaccida	375	.	.	.	.
Yucca gloriosa	375	375	.	.	.
Aloe arborescens	240	240	.	.	.
Baccharis halimifolia	625	500	.	.	.
Solidago altissima	.	625	.	.	.
Symphyotrichum novi-belgii	.	180	.	.	.
Impatiens glandulifera	.	300	.	.	.
Berberis aquifolium	.	625	.	.	.
Berberis julianae	.	500	.	.	.
Campsis radicans	.	.	.	.	.
Opuntia ficus-indica	500	400	.	.	.
Kalanchoe daigremontiana	.	16	.	.	.
Elaeagnus angustifolia	.	375	.	.	.
Vaccinium corymbosum	.	192	.	.	.
Crocosmia masoniorum	.	108	.	.	.

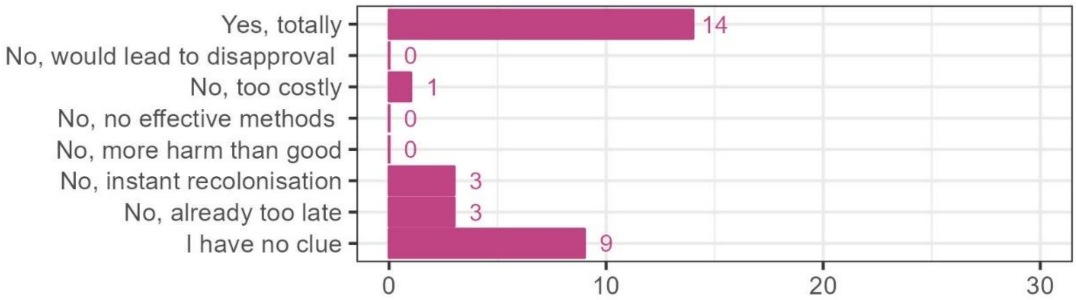
Crocosmia paniculata	.	108	.	.	.
Crocosmia pottsii	.	108	.	.	.
Spiranthes cernua x odorata	.	256	.	.	.
Mimulus guttatus	.	120	.	.	.
Picea sitchensis	.	240	.	.	.
Aronia melanocarpa	.	256	.	.	.
Cotoneaster franchetii	.	225	.	.	.
Cotoneaster simonsii	.	400	225	.	.
Pyracantha rogersiana	.	108	.	.	.
Acer negundo	.	240	.	.	.
Hedychium gardnerianum	.	96	.	.	.

ANNEX 4. QUALITATIVE ASSESSMENT OF ERADICATION FEASIBILITY OF SOME HIGH IMPACT IAS BY PARTICIPANTS AT THE WORKSHOP *ASSESSMENT OF CURRENT AND FUTURE INVASIVE ALIEN SPECIES IN EUROPEAN COASTAL DUNE ECOSYSTEMS* (DE PANNE, BELGIUM, 19-21 MAY 2022). THE BAR CHARTS PRESENT THE NUMBER OF RESPONSES PER CATEGORY IN RESPONSE TO THE SURVEY QUESTION "*I BELIEVE ERADICATING* SPECIES X *FROM THE ATLANTIC COASTAL AREA IS FEASIBLE*".

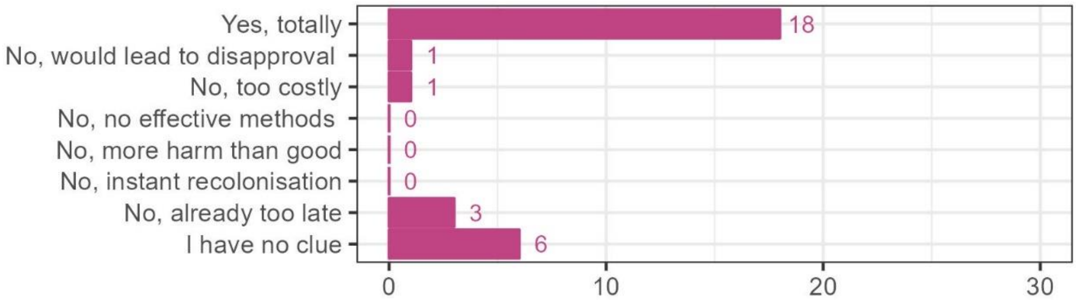
Acaena novae-zelandiae



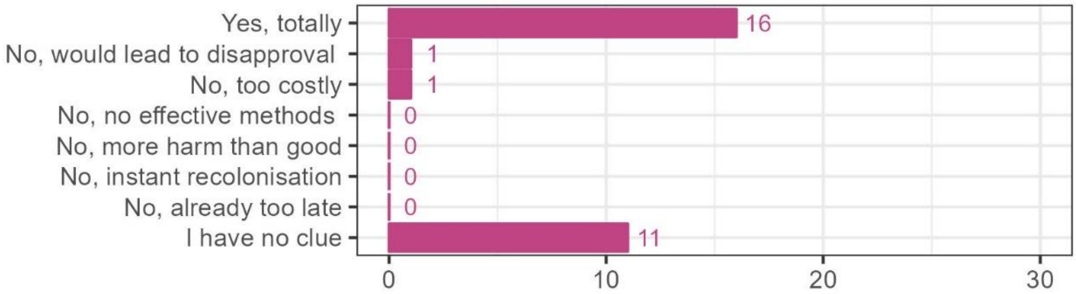
Ailanthus altissima



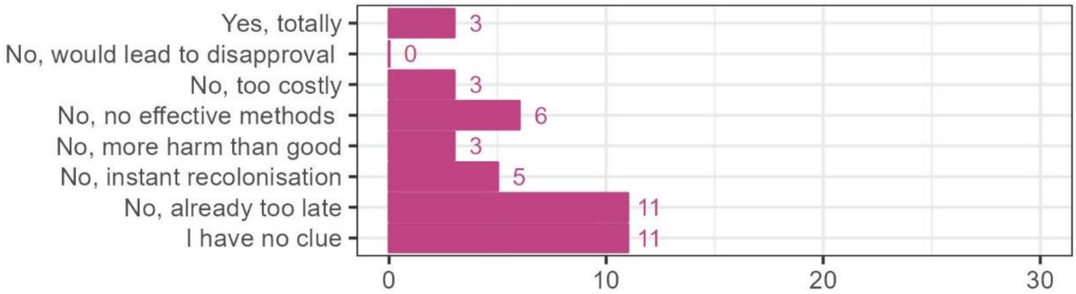
Baccharis halimifolia



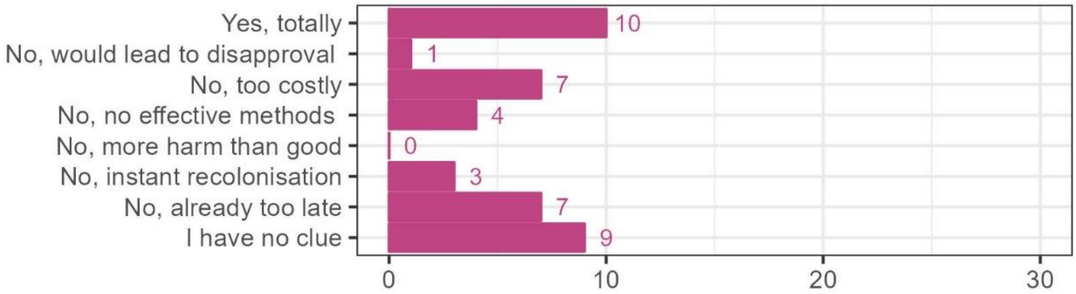
Berberis thunbergii



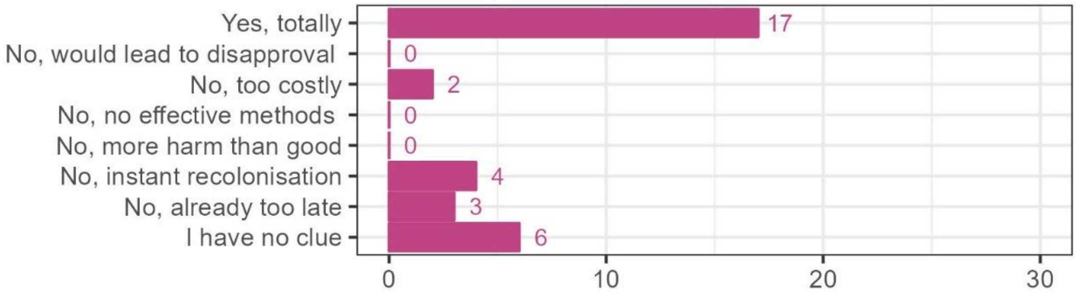
Campylopus introflexus



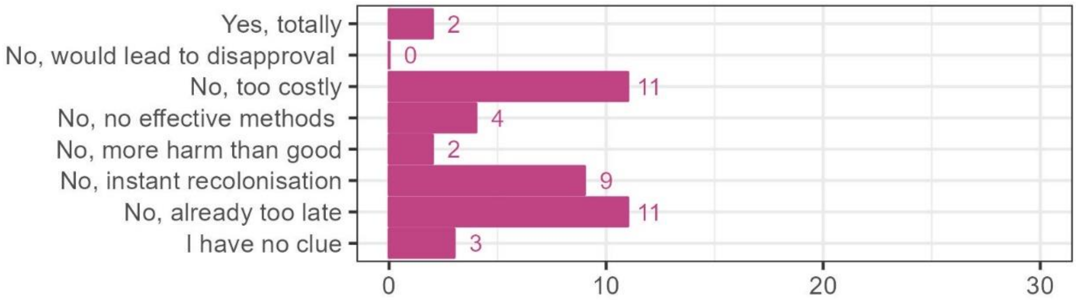
Carpobrotus acinaciformis/ edulis



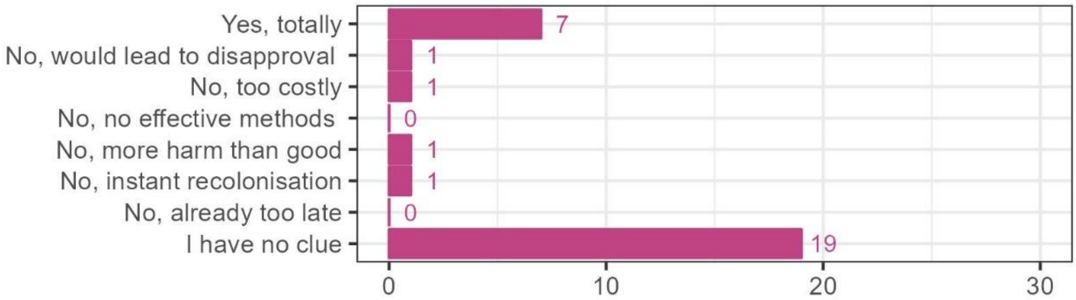
Cotoneaster spp.



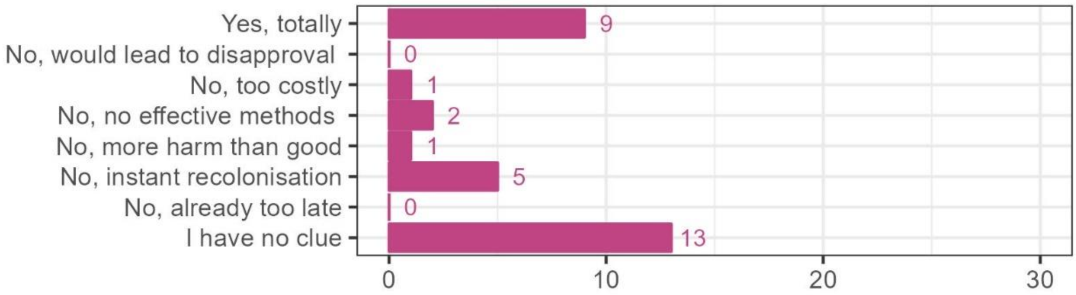
Crassula helmsii



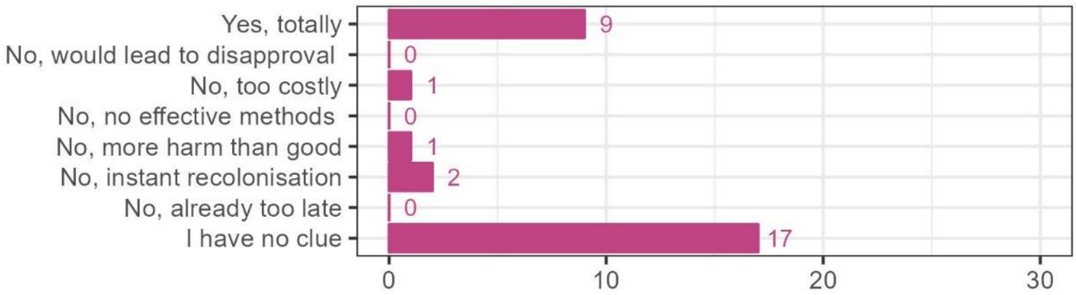
Crocosmia crocosmiiflora



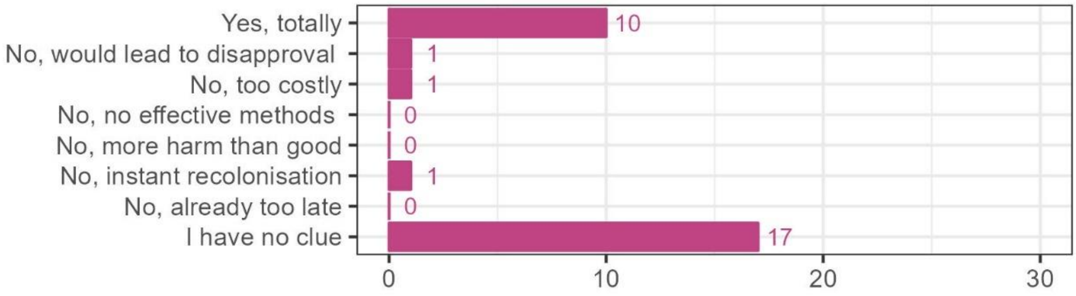
Equisetum hyemale affine



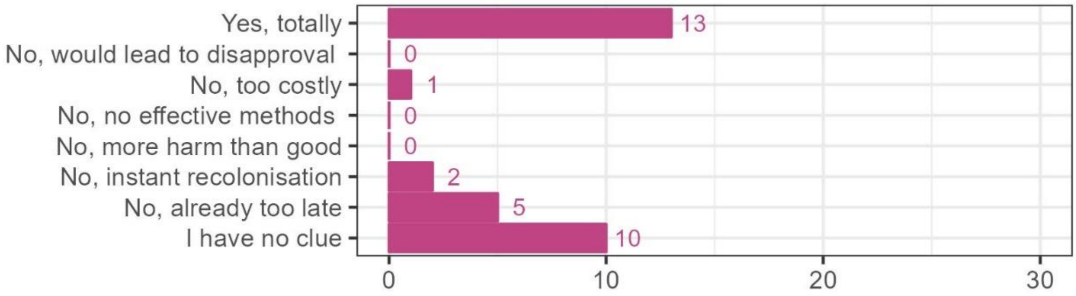
Ludwigia grandiflora



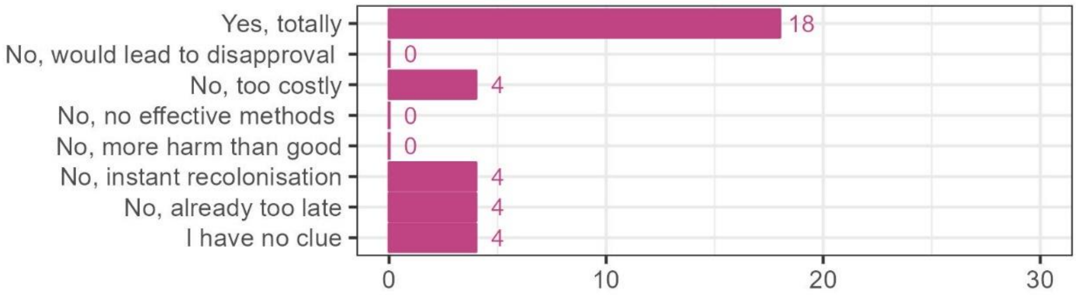
Lupinus arboreus



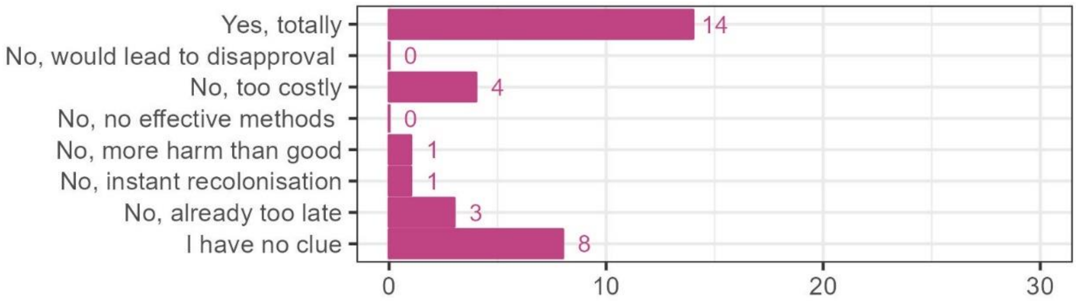
Lycium barbarum



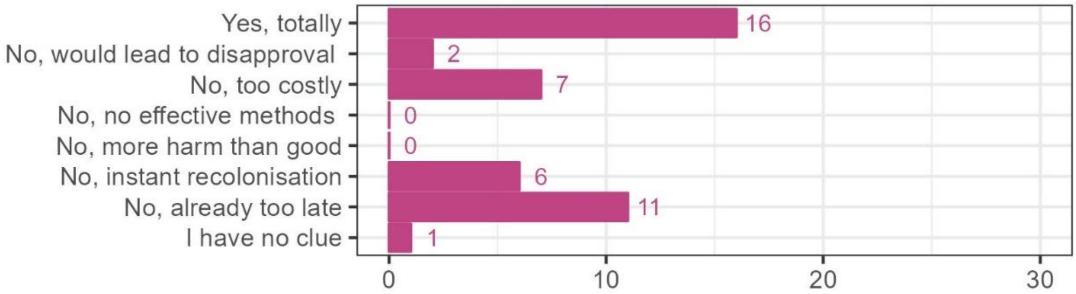
Mahonia aquifolium



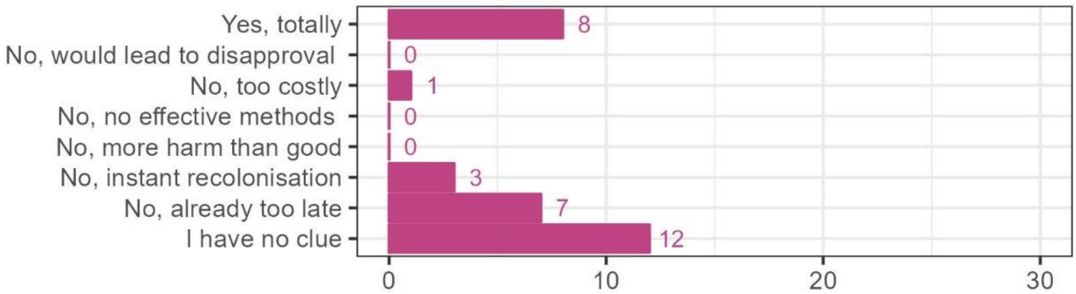
Picea sitchensis



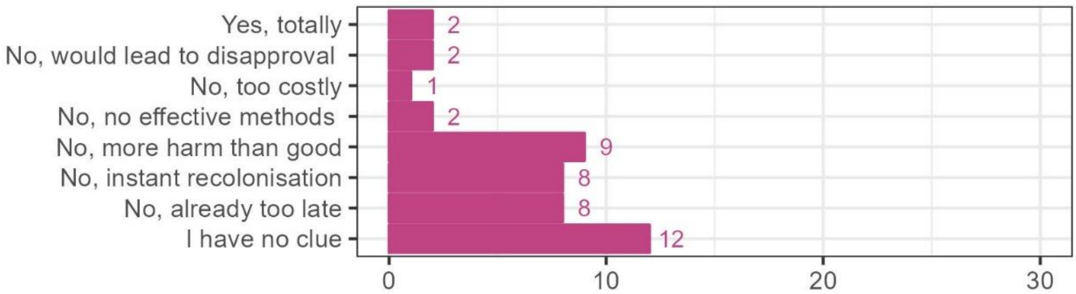
Rosa rugosa



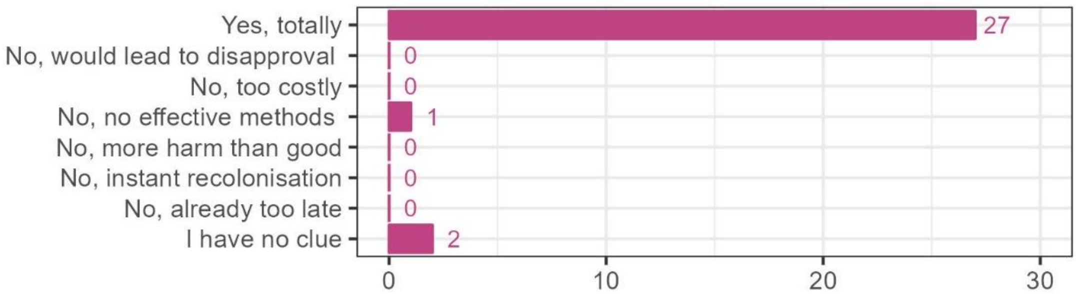
Solidago gigantea/ altissima



Spartina anglica



Yucca flaccida (= filamentosa)



ANNEX 5. HABITAT SUSCEPTIBILITY FOR ALIEN PLANT SPECIES AS IDENTIFIED IN THE FRAMEWORK OF THE WORKSHOP ASSESSMENT OF CURRENT AND FUTURE INVASIVE ALIEN SPECIES IN EUROPEAN COASTAL DUNE ECOSYSTEMS (DE PANNE, BELGIUM, 19-21 MAY 2022). SPECIES ARE FIRST RANKED BASED ON OVERALL ECOLOGICAL IMPACT SCORE, SECOND ON OCCURRENCE WITHIN THE ATLANTIC COASTAL REGION.

Species	**Salties**								**Sandies**							**Shrubbies**			**Occurrence in Atlantic coastal region**										
	1110 - Sandbanks	**1130 - Estuaries**	**1140 - Mudflats and sandflats**	**1210 - Annual vegetation of drift lines**	**1230 - Vegetated sea cliffs of coasts**	**1310 - Annuals colonising mud and sand**	**1320 - *Spartina* swards**	**1330 - Atlantic salt meadows**	**2110 - Embryonic shifting dunes**	**2120 - Shifting white dunes along shoreline**	**2130 - Fixed coastal grey dunes with herbs**	**2140 - Decalcified dunes with *Empetrum***	**21A0 - Machairs**	**2150 - Atlantic decalcified fixed dunes**	**2190 - Humid dune slacks**	**2160 - Dunes with *Hippophae rhamnoides***	**2170 - Dunes with *Salix repens* ssp. *argentea***	**2180 - Wooded dunes of the Atlantic region**	**Belgium**	**France**	**Ireland**	**Netherlands**	**Spain**	**United Kingdom**	**Denmark**	**Germany**	**Portugal**	**Atlantic coastal region**	**Maximum score**
Campylopus introflexus											1			1					15	58	210	131	14	1017	79	11	0	1535	625
Rosa rugosa								1	1	1	1	1	1	1		1	1	1	17	234	74	172	0	750	104	91	0	1442	625
Heracleum mantegazzianum											1	1			1	1		1	17	37	32	178	0	500	88	27	0	879	625
Solidago canadensis											1			1	1	1	1	1	17	43	3	109	8	272	48	16	1	517	625
Berberis aquifolium										1	1			1		1	1	1	17	144	0	127	20	129	5	37	0	479	625
Solidago gigantea											1			1	1	1	1	1	17	43	1	159	2	164	65	10	0	461	625
Crassula helmsii															1				16	15	9	85	0	297	1	3	0	426	625
Rubus armeniacus											1								12	0	0	114	0	174	87	13	0	400	625
Prunus serotina											1			1	1	1	1	1	18	31	1	141	10	30	99	58	0	388	625

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Species	Salties								Sandies							Shrubbies			Occurrence in Atlantic coastal region										
	1110 - Sandbanks	1130 - Estuaries	1140 - Mudflats and sandflats	1210 - Annual vegetation of drift lines	1230 - Vegetated sea cliffs of coasts	1310 - Annuals colonising mud and sand	1320 - *Spartina* swards	1330 - Atlantic salt meadows	2110 - Embryonic shifting dunes	2120 - Shifting white dunes along shoreline	2130 - Fixed coastal grey dunes with herbs	2140 - Decalcified dunes with *Empetrum*	21A0 - Machairs	2150 - Atlantic decalcified fixed dunes	2190 - Humid dune slacks	2160 - Dunes with *Hippophae rhamnoides*	2170 - Dunes with *Salix repens* ssp. *argentea*	2180 - Wooded dunes of the Atlantic region	Belgium	France	Ireland	Netherlands	Spain	United Kingdom	Denmark	Germany	Portugal	Atlantic coastal region	Maximum score
Carpobrotus edulis				1	1				1	1	1			1	1	1	1	1	1	166	5	3	55	101	0	0	16	347	625
Ailanthus altissima											1					1	1	1	13	170	1	53	32	62	0	5	7	343	625
Baccharis halimifolia		1			1	1		1	1	1	1	1		1	1	1	1		10	208	0	6	28	2	0	0	0	254	625
Paspalum vaginatum		1	1			1	1	1											0	13	0	0	18	0	0	0	1	32	625
Solidago altissima															1	1	1	1	1	0	0	0	0	0	0	0	0	1	625
Prunus laurocerasus																		1	15	350	111	166	134	691	15	84	14	1580	500
Cotoneaster horizontalis											1			1	1	1	1	1	14	112	23	73	7	500	8	24	0	761	500
Spartina anglica		1	1			1	1	1											9	79	3	87	0	252	16	45	0	491	500
Senecio inaequidens										1	1								19	98	3	177	9	104	6	39	3	458	500
Crocosmia crocosmiiflora											1			1	1	1	1		0	109	42	4	68	189	1	0	6	419	500
Acacia dealbata														1	1	1	1	1	0	216	1	0	82	3	0	0	15	317	500
Berberis darwinii											1			1	1	1	1	1	1	0	6	0	1	221	0	0	0	229	500
Lupinus arboreus											1			1	1	1			0	3	3	1	0	177	0	0	0	184	500

Species	Salties								Sandies							Shrubbies			Occurrence in Atlantic coastal region										
	1110 - Sandbanks	1130 - Estuaries	1140 - Mudflats and sandflats	1210 - Annual vegetation of drift lines	1230 - Vegetated sea cliffs of coasts	1310 - Annuals colonising mud and sand	1320 - *Spartina* swards	1330 - Atlantic salt meadows	2110 - Embryonic shifting dunes	2120 - Shifting white dunes along shoreline	2130 - Fixed coastal grey dunes with herbs	2140 - Decalcified dunes with *Empetrum*	21A0 - Machairs	2150 - Atlantic decalcified fixed dunes	2190 - Humid dune slacks	2160 - Dunes with *Hippophae rhamnoides*	2170 - Dunes with *Salix repens* ssp. *argentea*	2180 - Wooded dunes of the Atlantic region	Belgium	France	Ireland	Netherlands	Spain	United Kingdom	Denmark	Germany	Portugal	Atlantic coastal region	Maximum score
Tradescantia fluminensis															1				0	4	0	10	92	2	0	0	19	127	500
Acaena novae-zelandiae					1					1	1			1	1	1	1		0	0	2	1	0	85	0	0	0	88	500
Berberis julianae											1					1			10	0	0	41	0	19	0	2	0	72	500
Opuntia ficus-indica					1						1			1					0	32	0	0	15	0	0	0	3	50	500
Acacia longifolia														1	1	1	1	1	0	0	0	0	14	0	0	0	18	32	500
Acacia saligna														1	1	1	1	1	0	0	0	0	3	0	0	0	0	3	500
Cotoneaster ascendens											1			1		1													400
Cotoneaster simonsii											1			1		1			6	9	3	8	0	520	0	0	0	546	400
Cornus sericea																		1	15	3	2	99	2	180	30	3	0	334	400
Cotoneaster integrifolius											1			1		1	1	1	1	0	2	0	0	312	0	0	0	315	400
Berberis thunbergii																1			10	0	1	70	0	78	55	51	0	265	400
Ludwigia grandiflora															1				12	79	2	45	0	9	0	1	0	148	400
Cotoneaster hjelmqvistii											1			1		1	1	1	13	1	0	26	0	56	2	0	0	98	400

Species	Salties								Sandies							Shrubbies			Occurrence in Atlantic coastal region										
	1110 - Sandbanks	1130 - Estuaries	1140 - Mudflats and sandflats	1210 - Annual vegetation of drift lines	1230 - Vegetated sea cliffs of coasts	1310 - Annuals colonising mud and sand	1320 - *Spartina* swards	1330 - Atlantic salt meadows	2110 - Embryonic shifting dunes	2120 - Shifting white dunes along shoreline	2130 - Fixed coastal grey dunes with herbs	2140 - Decalcified dunes with *Empetrum*	21A0 - Machairs	2150 - Atlantic decalcified fixed dunes	2190 - Humid dune slacks	2160 - Dunes with *Hippophae rhamnoides*	2170 - Dunes with *Salix repens* ssp. *argentea*	2180 - Wooded dunes of the Atlantic region	Belgium	France	Ireland	Netherlands	Spain	United Kingdom	Denmark	Germany	Portugal	Atlantic coastal region	Maximum score
Cotoneaster microphyllus											1			1		1	1	1	0	1	1	0	0	82	0	0	0	84	400
Cotoneaster divaricatus											1			1		1			9	0	0	33	0	21	4	0	0	67	400
Gaillardia pulchella										1	1								4	45	1	6	2	2	0	2	0	62	400
Acaena ovalifolia											1	1		1		1	1	1	0	0	2	0	0	51	0	0	0	53	400
Equisetum hyemale affine															1	1			10	0	0	18	0	1	0	0	0	29	400
Acaena anserinifolia											1	1		1		1	1	1	0	0	0	0	0	27	0	0	0	27	400
Spartina alterniflora		1	1			1	1	1											0	16	0	0	1	2	7	0	0	26	400
Cotoneaster suecicus											1			1		1	1	1	2	0	0	0	0	12	8	0	0	22	400
Cotoneaster rehderi											1			1		1	1	1											375
Cotoneaster sternianus											1			1		1													375
Cotoneaster franchetii											1			1		1	1	1	10	269	21	23	14	246	0	4	0	587	375
Lycium barbarum										1	1			1		1	1		12	129	2	60	2	282	23	19	0	529	375
Cotoneaster bullatus											1			1		1	1	1	11	1	19	71	0	294	14	19	0	429	375
Myriophyllum aquaticum															1				12	93	7	36	3	176	0	1	3	331	375

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Species	Salties								Sandies							Shrubbies			Occurrence in Atlantic coastal region										
	1110 - Sandbanks	1130 - Estuaries	1140 - Mudflats and sandflats	1210 - Annual vegetation of drift lines	1230 - Vegetated sea cliffs of coasts	1310 - Annuals colonising mud and sand	1320 - *Spartina* swards	1330 - Atlantic salt meadows	2110 - Embryonic shifting dunes	2120 - Shifting white dunes along shoreline	2130 - Fixed coastal grey dunes with herbs	2140 - Decalcified dunes with *Empetrum*	21A0 - Machairs	2150 - Atlantic decalcified fixed dunes	2190 - Humid dune slacks	2160 - Dunes with *Hippophae rhamnoides*	2170 - Dunes with *Salix repens* ssp. *argentea*	2180 - Wooded dunes of the Atlantic region	Belgium	France	Ireland	Netherlands	Spain	United Kingdom	Denmark	Germany	Portugal	Atlantic coastal region	Maximum score
Yucca gloriosa					1					1	1					1			10	142	0	20	23	62	0	0	5	262	375
Elaeagnus angustifolia										1	1					1	1		14	146	0	47	15	5	0	2	0	229	375
Oxalis pes-caprae				1	1					1	1			1					0	9	0	2	70	12	0	0	16	109	375
Cotoneaster frigidus											1			1		1	1	1	0	0	0	0	0	82	0	0	0	82	375
Cotoneaster dielsianus											1			1		1	1	1	10	0	0	24	0	5	1	0	0	40	375
Yucca flaccida					1						1					1			8	0	0	12	1	0	0	0	0	21	375
Yucca filamentosa											1					1			0	16	0	0	1	1	0	0	0	18	375
Cotoneaster pannosus											1			1		1	1	1	0	0	0	0	4	4	0	0	0	8	375
Cotoneaster watereri											1			1		1	1	1	1	0	0	1	0	6	0	0	0	8	375
Yucca aloifolia											1					1			0	2	0	0	3	0	0	0	1	6	375
Cotoneaster nitens											1			1		1	1	1	0	0	0	1	0	2	0	0	0	3	375
Opuntia stricta					1						1			1					0	1	0	0	1	0	0	0	0	2	375
Lonicera nitida																		1	16	5	13	77	1	322	1	0	0	435	320

Species	Salties								Sandies							Shrubbies			Occurrence in Atlantic coastal region										
	1110 - Sandbanks	1130 - Estuaries	1140 - Mudflats and sandflats	1210 - Annual vegetation of drift lines	1230 - Vegetated sea cliffs of coasts	1310 - Annuals colonising mud and sand	1320 - *Spartina* swards	1330 - Atlantic salt meadows	2110 - Embryonic shifting dunes	2120 - Shifting white dunes along shoreline	2130 - Fixed coastal grey dunes with herbs	2140 - Decalcified dunes with *Empetrum*	21A0 - Machairs	2150 - Atlantic decalcified fixed dunes	2190 - Humid dune slacks	2160 - Dunes with *Hippophae rhamnoides*	2170 - Dunes with *Salix repens* ssp. *argentea*	2180 - Wooded dunes of the Atlantic region	Belgium	France	Ireland	Netherlands	Spain	United Kingdom	Denmark	Germany	Portugal	Atlantic coastal region	Maximum score
Phytolacca americana											1			1		1	1	1	6	183	0	106	76	8	0	19	19	417	320
Lonicera japonica																1			7	174	1	21	49	156	0	3	5	416	320
Gunnera tinctoria											1		1		1				1	100	65	4	0	234	1	0	1	406	320
Ludwigia peploides															1				3	45	0	8	0	0	0	0	0	56	320
Schinus molle															1	1	1	1	0	0	0	0	22	0	0	0	3	25	320
Atriplex micrantha				1				1											5	3	0	1	0	0	0	0	0	9	320
Lonicera maackii																		1	1	0	0	3	0	0	0	0	0	4	320
Reynoutria japonica											1			1	1	1			17	283	198	146	37	953	90	64	3	1791	300
Impatiens glandulifera															1				16	156	90	149	1	780	25	59	0	1276	300
Ligustrum ovalifolium											1			1		1	1	1	17	174	8	115	23	495	1	2	0	835	300
Amelanchier lamarckii											1			1		1	1	1	16	0	0	129	1	50	41	11	0	248	300
Populus balsamifera										1	1				1	1	1	1	10	6	0	33	0	155	17	2	0	223	300
Arctotheca calendula					1				1	1	1			1	1				2	31	0	1	83	3	0	0	14	134	300

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Species	Salties								Sandies							Shrubbies			Occurrence in Atlantic coastal region										
	1110 - Sandbanks	1130 - Estuaries	1140 - Mudflats and sandflats	1210 - Annual vegetation of drift lines	1230 - Vegetated sea cliffs of coasts	1310 - Annuals colonising mud and sand	1320 - *Spartina* swards	1330 - Atlantic salt meadows	2110 - Embryonic shifting dunes	2120 - Shifting white dunes along shoreline	2130 - Fixed coastal grey dunes with herbs	2140 - Decalcified dunes with *Empetrum*	21A0 - Machairs	2150 - Atlantic decalcified fixed dunes	2190 - Humid dune slacks	2160 - Dunes with *Hippophae rhamnoides*	2170 - Dunes with *Salix repens* ssp. *argentea*	2180 - Wooded dunes of the Atlantic region	Belgium	France	Ireland	Netherlands	Spain	United Kingdom	Denmark	Germany	Portugal	Atlantic coastal region	Maximum score
Lophocolea semiteres											1	1		1			1	1	7	0	0	31	0	88	1	0	0	127	300
Delairea odorata																	1	1	0	18	2	2	46	14	0	0	9	91	300
Ipomoea indica											1			1	1	1	1	1	0	12	0	0	47	0	0	0	13	72	300
Reynoutria bohemica											1				1	1			6	14	0	7	0	5	9	5	0	46	300
Populus jackii										1	1								3	0	0	1	0	5	29	0	0	38	300
Populus balsamifera trichocarpa										1	1				1	1	1	1	4	0	0	11	0	0	0	0	0	15	300
Alternanthera philoxeroides		1													1				0	1	0	0	1	0	0	0	0	2	300
Aronia prunifolia												1		1			1		1	1	0	24	0	0	1	0	0	27	256
Aronia melanocarpa												1			1			1	1	0	1	2	1	2	9	1	0	17	256
Schinus terebinthifolia															1	1	1	1	0	0	0	0	1	0	0	0	1	2	256
Spiranthes cernua x odorata															1				0	0	0	0	0	0	0	0	0	0	256
Claytonia perfoliata										1	1					1	1	1	18	111	0	166	1	240	17	68	0	621	250
Ambrosia artemisiifolia										1	1								17	50	0	119	5	101	11	18	2	323	250

Species	Salties								Sandies							Shrubbies			Occurrence in Atlantic coastal region										
	1110 - Sandbanks	1130 - Estuaries	1140 - Mudflats and sandflats	1210 - Annual vegetation of drift lines	1230 - Vegetated sea cliffs of coasts	1310 - Annuals colonising mud and sand	1320 - *Spartina* swards	1330 - Atlantic salt meadows	2110 - Embryonic shifting dunes	2120 - Shifting white dunes along shoreline	2130 - Fixed coastal grey dunes with herbs	2140 - Decalcified dunes with *Empetrum*	21A0 - Machairs	2150 - Atlantic decalcified fixed dunes	2190 - Humid dune slacks	2160 - Dunes with *Hippophae rhamnoides*	2170 - Dunes with *Salix repens* ssp. *argentea*	2180 - Wooded dunes of the Atlantic region	Belgium	France	Ireland	Netherlands	Spain	United Kingdom	Denmark	Germany	Portugal	Atlantic coastal region	Maximum score
Spartina x townsendii		1	1			1	1	1											7	53	0	2	0	1	15	1	0	79	250
Picea sitchensis											1	1		1		1	1	1	2	35	14	55	4	692	97	8	0	907	240
Ribes sanguineum																1	1		15	9	33	88	5	552	48	34	0	784	240
Pinus contorta											1			1		1			0	0	7	9	0	412	82	1	0	511	240
Cotula coronopifolia		1			1	1		1											14	49	1	139	30	44	16	25	8	326	240
Koenigia polystachya															1	1	1	1	6	45	22	20	0	225	0	0	0	318	240
Acer negundo											1				1			1	14	156	0	25	59	31	3	14	2	304	240
Rosa multiflora																		1	9	12	1	78	1	57	58	5	0	221	240
Gaultheria shallon											1			1	1	1	1	1	0	6	2	3	0	141	1	0	0	153	240
Aloe arborescens					1				1	1	1				1				0	27	0	0	61	1	0	0	10	99	240
Ligustrum lucidum											1			1		1	1	1	0	2	1	0	50	6	0	0	1	60	240
Vaccinium macrocarpum															1	1			1	0	0	32	0	10	0	0	0	43	240
Mesembryanthemum cordifolium					1										1	1	1	1	0	5	0	1	3	10	0	0	1	20	240

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Species	**Salties**								**Sandies**							**Shrubbies**			**Occurrence in Atlantic coastal region**										
	1110 - Sandbanks	**1130 - Estuaries**	**1140 - Mudflats and sandflats**	**1210 - Annual vegetation of drift lines**	**1230 - Vegetated sea cliffs of coasts**	**1310 - Annuals colonising mud and sand**	**1320 - *Spartina* swards**	**1330 - Atlantic salt meadows**	**2110 - Embryonic shifting dunes**	**2120 - Shifting white dunes along shoreline**	**2130 - Fixed coastal grey dunes with herbs**	**2140 - Decalcified dunes with *Empetrum***	**21A0 - Machairs**	**2150 - Atlantic decalcified fixed dunes**	**2190 - Humid dune slacks**	**2160 - Dunes with *Hippophae rhamnoides***	**2170 - Dunes with *Salix repens* ssp. *argentea***	**2180 - Wooded dunes of the Atlantic region**	**Belgium**	**France**	**Ireland**	**Netherlands**	**Spain**	**United Kingdom**	**Denmark**	**Germany**	**Portugal**	**Atlantic coastal region**	**Maximum score**
Lindernia dubia															1				2	10	0	4	2	0	0	0	0	18	240
Hydrocotyle bonariensis		1		1	1					1					1				0	0	0	0	5	0	0	0	7	12	240
Alternanthera sessilis		1													1				0	0	0	1	0	0	0	0	0	1	240
Elodea nuttallii															1				15	35	10	157	0	346	6	3	0	572	225
Fallopia sachalinensis											1	1		1					5	4	8	54	0	205	1	0	0	277	225
Araujia sericifera									1	1	1				1				0	35	0	0	28	1	0	0	13	77	225
Tetragonia tetragonioides									1	1	1			1	1				1	35	0	6	5	7	0	0	1	55	225
Gaillardia x grandiflora										1	1								2	2	0	0	0	2	0	0	0	6	225
Spartina patens		1	1			1	1	1											0	0	0	0	1	0	0	0	0	1	200
Acaena caesiiglauca											1	1		1		1	1	1	0	0	0	0	0	1	0	0	0	1	200
Amelanchier spicata											1			1		1	1	1	1	1	0	0	0	0	72	1	0	75	192
Disphyma crassifolium						1		1			1								0	0	0	0	2	28	0	0	0	30	192
Asclepias syriaca											1					1			1	9	0	9	0	0	0	1	0	20	192
Gaultheria mucronata											1			1		1	1	1	0	0	3	1	1	12	0	0	0	17	192

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Species	Salties								Sandies							Shrubbies			Occurrence in Atlantic coastal region										
	1110 - Sandbanks	1130 - Estuaries	1140 - Mudflats and sandflats	1210 - Annual vegetation of drift lines	1230 - Vegetated sea cliffs of coasts	1310 - Annuals colonising mud and sand	1320 - *Spartina* swards	1330 - Atlantic salt meadows	2110 - Embryonic shifting dunes	2120 - Shifting white dunes along shoreline	2130 - Fixed coastal grey dunes with herbs	2140 - Decalcified dunes with *Empetrum*	21A0 - Machairs	2150 - Atlantic decalcified fixed dunes	2190 - Humid dune slacks	2160 - Dunes with *Hippophae rhamnoides*	2170 - Dunes with *Salix repens* ssp. *argentea*	2180 - Wooded dunes of the Atlantic region	Belgium	France	Ireland	Netherlands	Spain	United Kingdom	Denmark	Germany	Portugal	Atlantic coastal region	Maximum score
Gaultheria procumbens												1		1	1	1	1	1	0	0	0	2	1	10	0	0	0	13	192
Vaccinium corymbosum												1		1	1	1	1	1	1	0	0	5	3	2	0	1	0	12	192
Ligustrum japonicum											1			1		1	1	1	0	2	0	0	3	1	0	0	0	6	192
Fuchsia magellanica																1	1	1	0	1	141	7	8	751	0	0	0	908	180
Robinia pseudoacacia											1			1		1	1	1	17	326	0	141	97	186	8	42	7	824	180
Lemna minuta											1				1				16	152	16	132	0	323	0	0	0	639	180
Symphyotrichum novi-belgii											1								6	35	2	27	2	303	26	8	0	409	180
Spiraea douglasii												1			1		1		4	28	0	8	1	102	11	0	0	154	180
Arundo donax		1						1											1	55	0	2	45	0	0	0	15	118	180
Myriophyllum heterophyllum															1				1	0	0	9	1	0	0	0	0	11	180
Passiflora caerulea															1	1	1	1	4	38	2	27	131	48	1	0	2	253	160
Solanum chenopodioides				1		1					1	1		1					2	55	0	3	26	3	0	1	9	99	160
Solanum triflorum				1		1				1	1	1		1					15	6	0	64	0	7	0	1	0	93	160
Solanum sarrachoides				1		1					1	1		1					3	2	0	2	0	17	0	0	0	24	160

Species	Salties								Sandies							Shrubbies			Occurrence in Atlantic coastal region										
	1110 - Sandbanks	1130 - Estuaries	1140 - Mudflats and sandflats	1210 - Annual vegetation of drift lines	1230 - Vegetated sea cliffs of coasts	1310 - Annuals colonising mud and sand	1320 - *Spartina* swards	1330 - Atlantic salt meadows	2110 - Embryonic shifting dunes	2120 - Shifting white dunes along shoreline	2130 - Fixed coastal grey dunes with herbs	2140 - Decalcified dunes with *Empetrum*	21A0 - Machairs	2150 - Atlantic decalcified fixed dunes	2190 - Humid dune slacks	2160 - Dunes with *Hippophae rhamnoides*	2170 - Dunes with *Salix repens* ssp. *argentea*	2180 - Wooded dunes of the Atlantic region	Belgium	France	Ireland	Netherlands	Spain	United Kingdom	Denmark	Germany	Portugal	Atlantic coastal region	Maximum score
Conyza bilbaoana											1								1	5	0	2	0	0	0	0	0	8	160
Solanum linnaeanum										1	1			1	1	1	1		0	0	0	0	3	0	0	0	0	3	160
Solanum physalifolium nitidibaccatum				1		1					1	1		1					3	0	0	0	0	0	0	0	0	3	160
Fallopia baldschuanica											1				1	1	1		13	57	2	66	9	256	5	2	0	410	150
Ipomoea purpurea											1			1	1	1	1	1	3	40	0	17	25	4	1	0	1	91	144
Symphoricarpos orbiculatus																		1	3	0	1	4	0	13	0	1	0	22	144
Rhus typhina															1	1	1	1	14	195	0	67	2	199	14	14	0	505	135
Melia azedarach																1	1	1	0	66	0	0	33	0	0	0	8	107	135
Acacia melanoxylon														1					0	3	0	0	39	3	0	0	16	61	135
Ribes aureum											1					1	1		8	8	0	11	0	28	0	7	0	62	128
Datura stramonium											1			1	1				18	311	0	157	92	301	38	63	18	998	125
Erigeron canadensis									1	1	1			1					19	307	4	192	23	251	99	33	5	933	125
Erigeron sumatrensis										1	1			1					18	244	3	117	17	117	0	0	8	524	125

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Species	Salties								Sandies							Shrubbies			Occurrence in Atlantic coastal region										
	1110 - Sandbanks	1130 - Estuaries	1140 - Mudflats and sandflats	1210 - Annual vegetation of drift lines	1230 - Vegetated sea cliffs of coasts	1310 - Annuals colonising mud and sand	1320 - *Spartina* swards	1330 - Atlantic salt meadows	2110 - Embryonic shifting dunes	2120 - Shifting white dunes along shoreline	2130 - Fixed coastal grey dunes with herbs	2140 - Decalcified dunes with *Empetrum*	21A0 - Machairs	2150 - Atlantic decalcified fixed dunes	2190 - Humid dune slacks	2160 - Dunes with *Hippophae rhamnoides*	2170 - Dunes with *Salix repens* ssp. *argentea*	2180 - Wooded dunes of the Atlantic region	Belgium	France	Ireland	Netherlands	Spain	United Kingdom	Denmark	Germany	Portugal	Atlantic coastal region	Maximum score
Erigeron bonariensis										1	1			1					8	52	0	62	6	20	0	0	7	155	125
Eschscholzia californica											1			1					17	334	5	89	4	185	10	2	4	650	120
Quercus rubra																		1	15	169	0	111	73	169	42	35	10	624	120
Mimulus guttatus															1				10	2	1	15	0	450	6	0	0	484	120
Ambrosia psilostachya										1	1								3	5	0	17	2	6	1	0	0	34	120
Hedychium gardnerianum															1		1	1	0	0	0	0	4	0	0	0	0	4	120
Zantedeschia aethiopica		1						1							1				1	22	9	2	123	250	0	0	18	425	108
Pinus radiata											1			1		1	1	1	0	30	6	0	15	149	0	0	0	200	108
Crocosmia paniculata											1			1	1	1	1		0	0	2	0	0	141	0	0	0	143	108
Crocosmia pottsii											1			1	1	1	1		0	0	0	0	0	61	0	0	0	61	108
Crocosmia masoniorum											1			1	1	1	1		0	0	2	0	0	27	0	0	0	29	108
Pyracantha rogersiana											1			1		1	1	1	0	0	0	0	0	7	0	0	0	7	108
Azolla filiculoides															1				14	102	19	126	2	264	0	0	0	527	100
Olearia macrodonta											1			1	1	1	1	1	0	0	10	0	1	96	0	0	0	107	96

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Species	Salties								Sandies							Shrubbies			Occurrence in Atlantic coastal region										
	1110 - Sandbanks	1130 - Estuaries	1140 - Mudflats and sandflats	1210 - Annual vegetation of drift lines	1230 - Vegetated sea cliffs of coasts	1310 - Annuals colonising mud and sand	1320 - *Spartina* swards	1330 - Atlantic salt meadows	2110 - Embryonic shifting dunes	2120 - Shifting white dunes along shoreline	2130 - Fixed coastal grey dunes with herbs	2140 - Decalcified dunes with *Empetrum*	21A0 - Machairs	2150 - Atlantic decalcified fixed dunes	2190 - Humid dune slacks	2160 - Dunes with *Hippophae rhamnoides*	2170 - Dunes with *Salix repens* ssp. *argentea*	2180 - Wooded dunes of the Atlantic region	Belgium	France	Ireland	Netherlands	Spain	United Kingdom	Denmark	Germany	Portugal	Atlantic coastal region	Maximum score
Campsis radicans																1	1	1	1	81	0	19	4	2	0	0	0	107	96
Lantana camara														1	1	1	1	1	0	0	0	0	5	0	0	0	5	10	96
Gunnera manicata															1				0	0	1	2	0	4	0	0	0	7	96
Elaeagnus ebbingei											1					1	1		0	1	0	0	0	5	0	0	0	6	96
Ligustrum vicaryi											1			1		1	1	1	0	0	0	0	1	0	0	0	0	1	96
Vitex rotundifolia									1	1									0	0	0	0	0	0	0	0	0	0	96
Symphoricarpos albus											1					1	1	1	17	47	22	116	0	620	89	10	0	921	90
Parthenocissus quinquefolia											1					1	1	1	6	24	0	85	1	189	3	26	0	334	90
Parthenocissus vitacea											1					1	1	1	11	70	0	18	1	44	8	5	0	157	90
Parthenocissus inserta																			12	77	0	20	1	44	0	5	0	159	81
Hydrocotyle ranunculoides															1				12	10	0	51	0	78	0	0	0	151	81
Amelanchier alnifolia											1			1		1	1	1	0	0	0	2	0	0	4	0	0	6	81
Buddleja davidii											1					1			18	300	50	149	78	688	7	24	7	1321	80

Species	Salties								Sandies							Shrubbies			Occurrence in Atlantic coastal region										
	1110 - Sandbanks	1130 - Estuaries	1140 - Mudflats and sandflats	1210 - Annual vegetation of drift lines	1230 - Vegetated sea cliffs of coasts	1310 - Annuals colonising mud and sand	1320 - *Spartina* swards	1330 - Atlantic salt meadows	2110 - Embryonic shifting dunes	2120 - Shifting white dunes along shoreline	2130 - Fixed coastal grey dunes with herbs	2140 - Decalcified dunes with *Empetrum*	21A0 - Machairs	2150 - Atlantic decalcified fixed dunes	2190 - Humid dune slacks	2160 - Dunes with *Hippophae rhamnoides*	2170 - Dunes with *Salix repens* ssp. *argentea*	2180 - Wooded dunes of the Atlantic region	Belgium	France	Ireland	Netherlands	Spain	United Kingdom	Denmark	Germany	Portugal	Atlantic coastal region	Maximum score
Euonymus japonicus																1			7	11	0	15	6	296	0	0	9	344	80
Lonicera tatarica																1			6	42	0	72	0	24	1	9	0	154	80
Deutzia scabra																1			8	0	0	25	0	21	0	0	0	54	80
Artemisia verlotiorum											1								8	82	0	20	5	22	0	0	1	138	72
Catalpa bignonioides																1	1	1	3	6	1	23	5	14	0	23	0	75	72
Nassella tenuissima											1			1	1				8	8	0	26	0	14	0	0	0	56	72
Juglans nigra																1	1	1	3	0	0	25	5	17	0	2	0	52	72
Cenchrus echinatus		1							1	1									1	0	0	0	0	0	0	0	0	1	72
Euonymus fortunei																1			7	25	0	74	3	320	0	39	12	480	64
Leucaena leucocephala														1	1	1	1	1	0	0	0	0	2	0	0	0	0	2	64
Stachys byzantina											1								12	212	1	77	1	88	9	0	0	400	60
Phyllostachys nigra															1	1	1	1	0	0	0	0	0	10	0	0	0	10	60
Phyllostachys aurea															1	1	1	1	0	0	0	0	6	1	0	0	0	7	60
Casuarina equisetifolia					1						1			1		1	1		0	0	0	0	4	0	0	0	0	4	60

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Species	Salties								Sandies							Shrubbies			Occurrence in Atlantic coastal region										
	1110 - Sandbanks	1130 - Estuaries	1140 - Mudflats and sandflats	1210 - Annual vegetation of drift lines	1230 - Vegetated sea cliffs of coasts	1310 - Annuals colonising mud and sand	1320 - *Spartina* swards	1330 - Atlantic salt meadows	2110 - Embryonic shifting dunes	2120 - Shifting white dunes along shoreline	2130 - Fixed coastal grey dunes with herbs	2140 - Decalcified dunes with *Empetrum*	21A0 - Machairs	2150 - Atlantic decalcified fixed dunes	2190 - Humid dune slacks	2160 - Dunes with *Hippophae rhamnoides*	2170 - Dunes with *Salix repens* ssp. *argentea*	2180 - Wooded dunes of the Atlantic region	Belgium	France	Ireland	Netherlands	Spain	United Kingdom	Denmark	Germany	Portugal	Atlantic coastal region	Maximum score
Impatiens capensis															1				0	4	0	39	0	54	0	0	0	97	54
Catalpa erubescens																1	1	1	0	0	1	0	1	0	0	0	0	2	54
Kalanchoe x houghtonii											1			1	1				0	0	0	0	0	0	0	0	1	1	54
Agave americana										1	1								0	173	0	0	70	12	0	0	14	269	48
Buddleja globosa											1							1	0	0	1	0	1	185	0	0	0	187	48
Phormium tenax																1	1	1	0	2	29	0	2	146	0	0	0	179	48
Casuarina cunninghamiana											1			1		1	1		0	0	0	0	2	0	0	0	0	2	48
Asparagus asparagoides					1						1			1		1	1	1	0	0	0	0	1	0	0	0	0	1	48
Chamaecyparis lawsoniana																1			9	52	19	24	2	400	5	9	3	523	45
Ceratostigma plumbaginoides					1										1				3	119	0	3	0	1	0	0	0	126	36
Agapanthus praecox											1			1	1	1	1	1	1	6	0	2	2	84	0	0	1	96	36
Symphytum hidcotense																			1	0	0	0	0	33	0	0	0	34	36
Pittosporum crassifolium					1												1	1	0	0	0	0	0	14	0	0	0	14	36

Species	Salties								Sandies							Shrubbies			Occurrence in Atlantic coastal region										
	1110 - Sandbanks	1130 - Estuaries	1140 - Mudflats and sandflats	1210 - Annual vegetation of drift lines	1230 - Vegetated sea cliffs of coasts	1310 - Annuals colonising mud and sand	1320 - *Spartina* swards	1330 - Atlantic salt meadows	2110 - Embryonic shifting dunes	2120 - Shifting white dunes along shoreline	2130 - Fixed coastal grey dunes with herbs	2140 - Decalcified dunes with *Empetrum*	21A0 - Machairs	2150 - Atlantic decalcified fixed dunes	2190 - Humid dune slacks	2160 - Dunes with *Hippophae rhamnoides*	2170 - Dunes with *Salix repens* ssp. *argentea*	2180 - Wooded dunes of the Atlantic region	Belgium	France	Ireland	Netherlands	Spain	United Kingdom	Denmark	Germany	Portugal	Atlantic coastal region	Maximum score
Scaevola taccada		1	1					1	1	1									0	1	0	0	0	0	0	0	0	1	36
Miscanthus sinensis		1													1	1	1		6	5	0	15	0	10	7	1	0	44	32
Anemanthele lessoniana											1			1					0	0	0	0	0	16	0	0	0	16	32
Amaranthus retroflexus				1															18	127	0	97	21	106	6	3	2	380	27
Amaranthus hybridus				1															15	131	0	70	7	47	0	0	0	270	27
Amaranthus deflexus				1															3	99	0	8	14	5	0	0	6	135	27
Amaranthus caudatus				1															3	45	0	27	1	41	1	0	0	118	27
Amaranthus albus				1															7	8	0	38	2	17	0	0	0	72	27
Amaranthus blitoides				1															8	5	0	28	3	4	0	0	0	48	27
Amaranthus hybridus hybridus				1															7	9	0	25	6	0	0	0	0	47	27
Amaranthus hypochondriacus				1															2	2	0	22	3	1	2	0	0	32	27
Amaranthus powellii				1															3	12	0	2	5	1	1	0	0	24	27
Amaranthus cruentus				1															2	4	0	6	6	5	0	0	0	23	27

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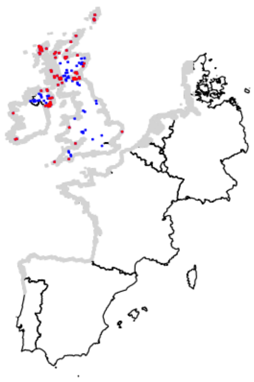
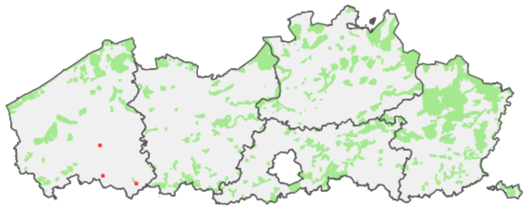
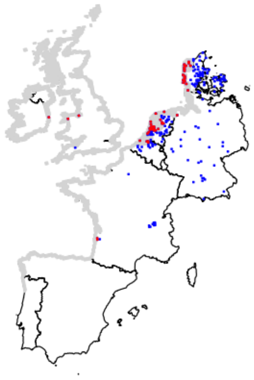
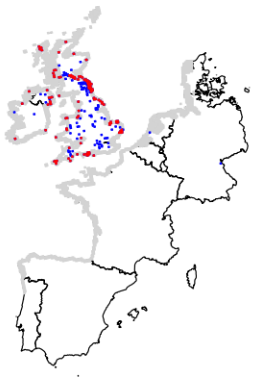
Species	Salties								Sandies							Shrubbies			Occurrence in Atlantic coastal region										
	1110 - Sandbanks	1130 - Estuaries	1140 - Mudflats and sandflats	1210 - Annual vegetation of drift lines	1230 - Vegetated sea cliffs of coasts	1310 - Annuals colonising mud and sand	1320 - *Spartina* swards	1330 - Atlantic salt meadows	2110 - Embryonic shifting dunes	2120 - Shifting white dunes along shoreline	2130 - Fixed coastal grey dunes with herbs	2140 - Decalcified dunes with *Empetrum*	21A0 - Machairs	2150 - Atlantic decalcified fixed dunes	2190 - Humid dune slacks	2160 - Dunes with *Hippophae rhamnoides*	2170 - Dunes with *Salix repens* ssp. *argentea*	2180 - Wooded dunes of the Atlantic region	Belgium	France	Ireland	Netherlands	Spain	United Kingdom	Denmark	Germany	Portugal	Atlantic coastal region	Maximum score
Amaranthus viridis				1															3	1	0	7	2	1	0	0	1	15	27
Amaranthus palmeri				1															2	0	0	6	0	1	1	0	0	10	27
Amaranthus spinosus				1															1	1	0	3	2	1	0	0	0	8	27
Amaranthus quitensis				1															0	0	0	5	1	1	0	0	0	7	27
Amaranthus standleyanus				1															0	0	0	6	0	1	0	0	0	7	27
Amaranthus thunbergii				1															0	0	0	1	0	2	0	0	0	3	27
Amaranthus tuberculatus				1															1	0	0	1	0	1	0	0	0	3	27
Nassella neesiana											1			1	1				0	0	0	0	1	1	0	0	0	2	27
Amaranthus muricatus				1															0	0	0	1	0	0	0	0	0	1	27
Amaranthus ralletii				1															0	1	0	0	0	0	0	0	0	1	27
Lupinus polyphyllus											1			1	1				15	108	0	121	0	106	91	52	0	493	24
Tolmiea menziesii											1							1	0	0	0	2	0	160	0	0	0	162	24
Sarracenia purpurea															1				0	8	0	2	0	12	1	0	0	23	24
Lupinus regalis											1			1	1				0	0	0	0	0	3	0	0	0	3	24

Species	Salties								Sandies							Shrubbies			Occurrence in Atlantic coastal region										
	1110 - Sandbanks	1130 - Estuaries	1140 - Mudflats and sandflats	1210 - Annual vegetation of drift lines	1230 - Vegetated sea cliffs of coasts	1310 - Annuals colonising mud and sand	1320 - *Spartina* swards	1330 - Atlantic salt meadows	2110 - Embryonic shifting dunes	2120 - Shifting white dunes along shoreline	2130 - Fixed coastal grey dunes with herbs	2140 - Decalcified dunes with *Empetrum*	21A0 - Machairs	2150 - Atlantic decalcified fixed dunes	2190 - Humid dune slacks	2160 - Dunes with *Hippophae rhamnoides*	2170 - Dunes with *Salix repens* ssp. *argentea*	2180 - Wooded dunes of the Atlantic region	Belgium	France	Ireland	Netherlands	Spain	United Kingdom	Denmark	Germany	Portugal	Atlantic coastal region	Maximum score
Washingtonia robusta																1	1	1	0	0	0	0	1	0	0	0	1	2	24
Argemone mexicana									1										0	4	0	1	0	2	0	0	0	7	18
Cotula anthemoides		1							1										0	0	0	0	0	1	0	0	0	1	18
Smilax rotundifolia																1	1	1	0	0	0	1	0	0	0	0	0	1	18
Tagetes erecta											1								7	98	13	2	51	103	3	10	8	295	16
Kalanchoe daigremontiana											1			1	1				0	0	0	0	31	0	0	0	0	31	16
Drosanthemum floribundum											1								0	2	0	0	2	12	0	0	0	16	16
Amsinckia micrantha											1								6	3	0	64	0	125	16	0	0	214	12
Hydrocotyle novae-zeelandiae															1				0	0	0	0	0	1	0	0	0	1	8
Thunbergia alata															1			1	0	1	0	5	0	0	0	0	0	6	4
Hydrocotyle moschata															1				0	0	0	0	0	1	0	0	0	1	4

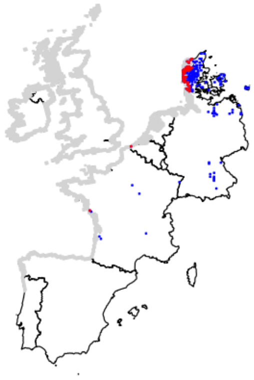
ANNEX 6. DISTRIBUTION MAPS FOR THE (POTENTIALLY) HIGH IMPACT DUNE INVADERS FOR THE EUROPEAN ATLANTIC COASTAL AREA IDENTIFIED AT THE WORKSHOP *ASSESSMENT OF CURRENT AND FUTURE INVASIVE ALIEN SPECIES IN EUROPEAN COASTAL DUNE ECOSYSTEMS* (DE PANNE, BELGIUM, 19-21 MAY 2022). MAPS ARE DEPICTED FOR PRIORITY SPECIES ACCORDING TO TABLE 5 (OVERALL PRIORITY SPP.) AND TABLES 6-8 (PRIORITY SPP. PER HABITAT GROUP).

Left: European distribution within (red dots) and outside (blue dots) the European Atlantic coastal zone (in grey). Right: Distribution (red dots) in the Flemish coastal area (2007-2022) based on detailed plant surveys (Provoost et al. 2010, 2014, 2020) and the citizen science platform www.waarnemingen.be (Vanreusel et al. 2022) within the dunes ecodistrict (www.geopunt.be). Beaches (yellow), coastal dunes (green) and major roads (brown) are shown for orientation (Data is based on the GBIF download https://doi.org/10.15468/dl.dycrsj). If the species was not reported in the Belgian coastal dunes, the distribution in Flanders is depicted instead.

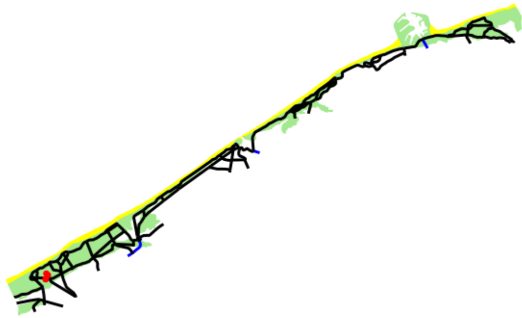
European Atlantic coastal area	**Belgian coastal dune area**
 *Acaena anserinifolia/ovalifolia*	not reported in Flanders

 *Acaena caesiiglauca*	 *Acaena caesiiglauca*
 *Acacia melanoxylon*	not reported in Flanders
 *Acaena novae-zelandiae*	not reported in Flanders

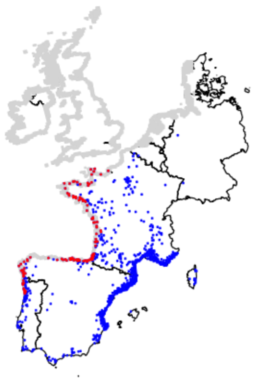
 *Aloe arborescens*	not reported in Flanders
 *Alternanthera philoxeroides*	not reported in Flanders
 *Alternanthera sessilis*	not reported in Flanders



Amelanchier spicata

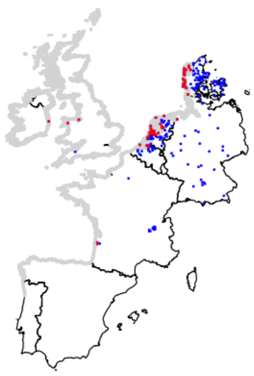


Amelanchier spicata

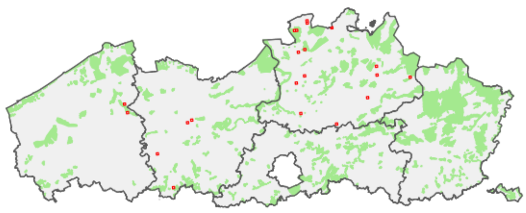


Araujia sericifera

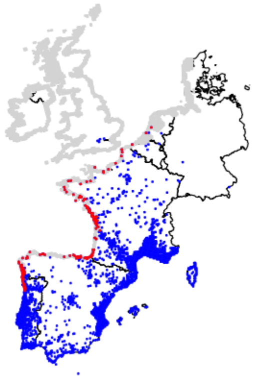
not reported in Flanders



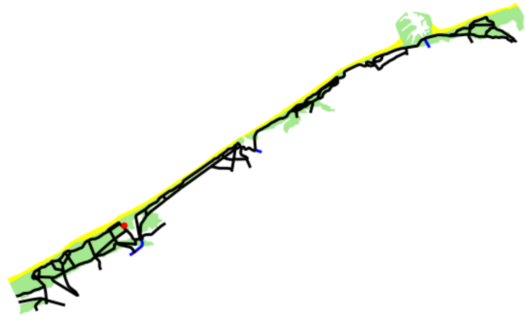
Aronia melanocarpa/prunifolia



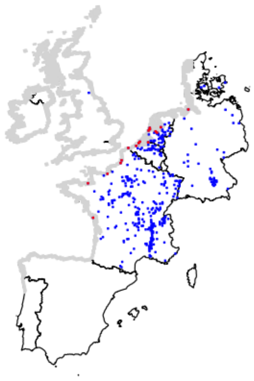
Aronia melanocarpa/prunifolia



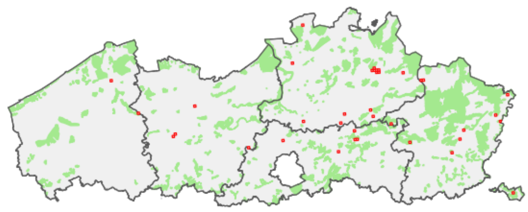
Arundo donax



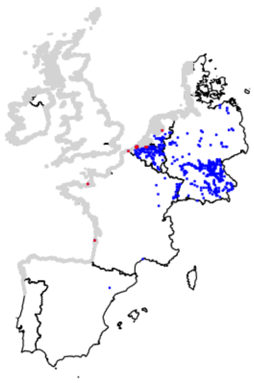
Arundo donax



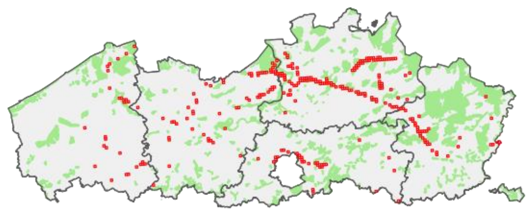
Asclepias syriaca



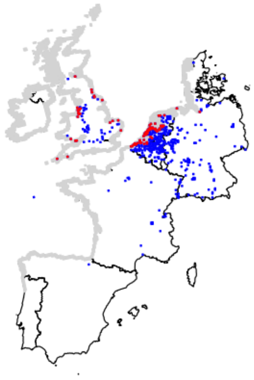
Asclepias syriaca



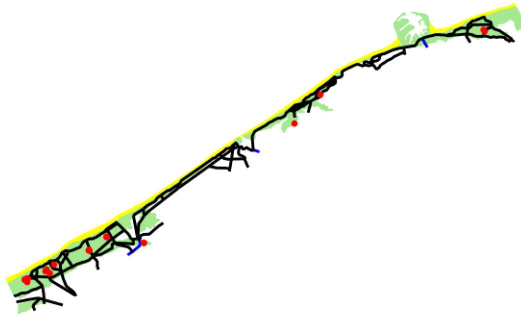
Atriplex micrantha



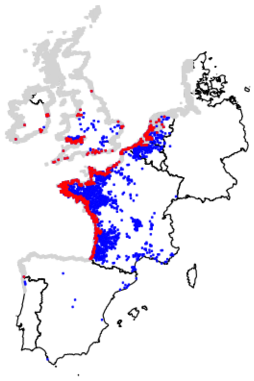
Atriplex micrantha



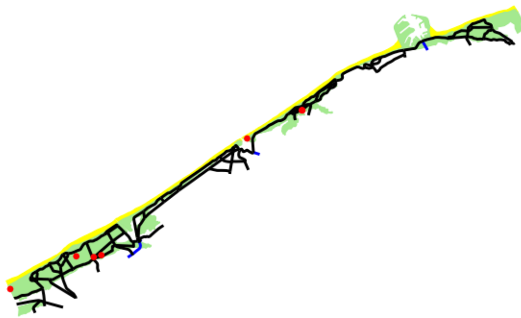
Berberis julianae



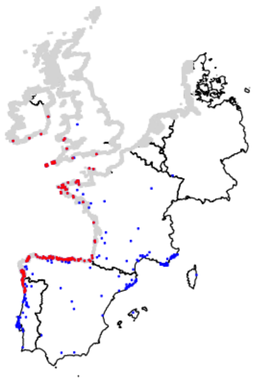
Berberis julianae



Conyza bilbaoana



Conyza bilbaoana

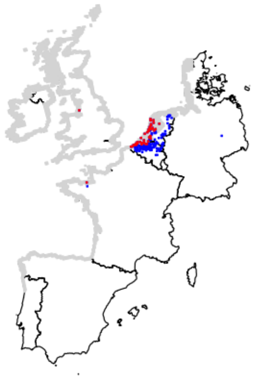


Delairea odorata

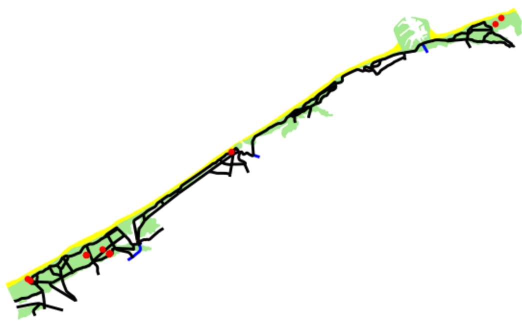
not reported in Flanders

Disphyma crassifolium

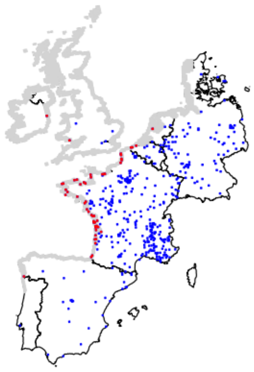
not reported in Flanders



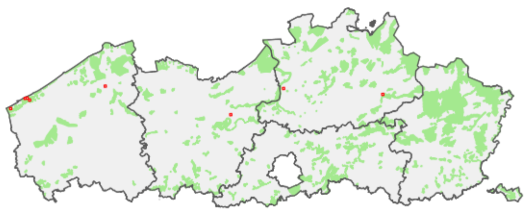
Equisetum hyemale affine



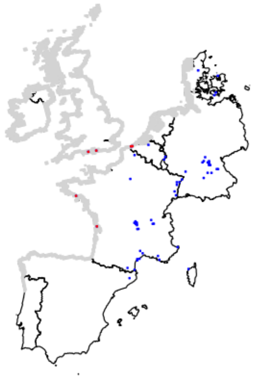
Equisetum hyemale affine



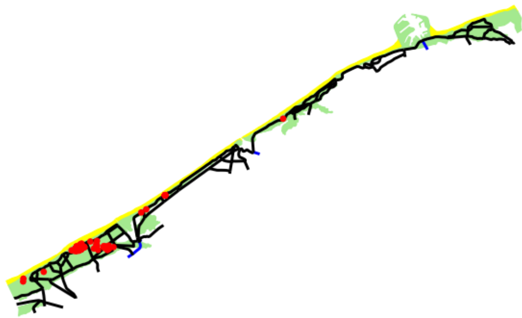
Gaillardia pulchella



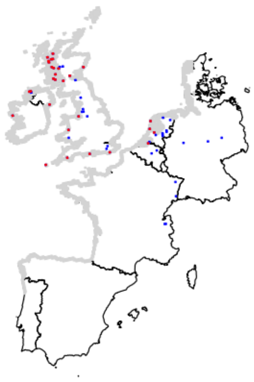
Gaillardia pulchella



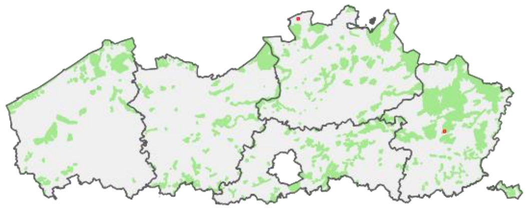
Gaillardia x grandiflora



Gaillardia x grandiflora



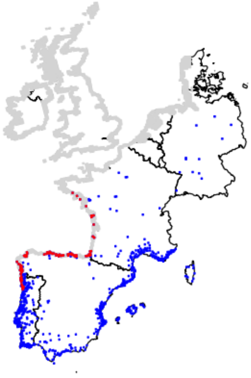
Gaultheria mucronata/procumbens



Gaultheria mucronata/procumbens

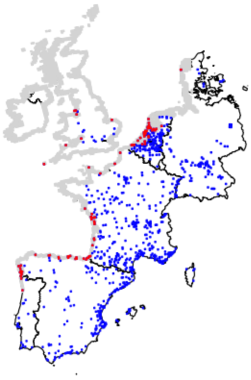
Hydrocotyle bonariensis

not reported in Flanders

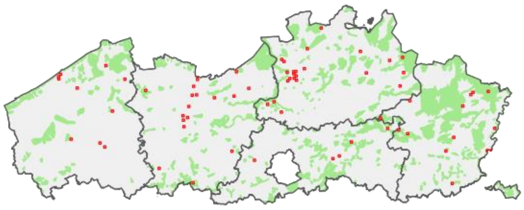


Ipomoea indica

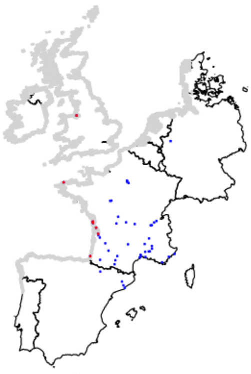
not reported in Flanders



Ipomoea purpurea

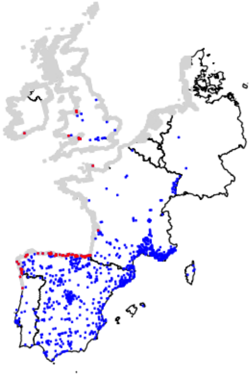
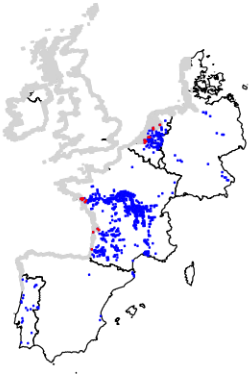
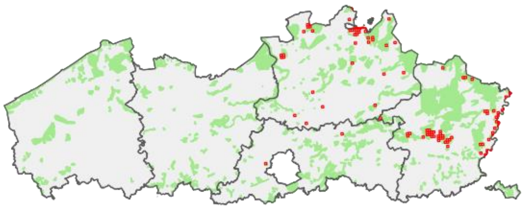
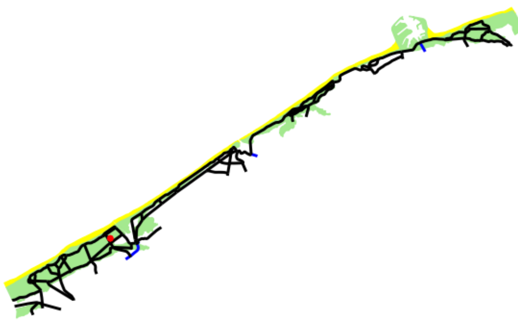


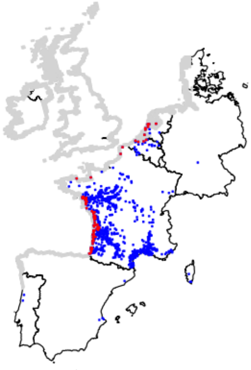
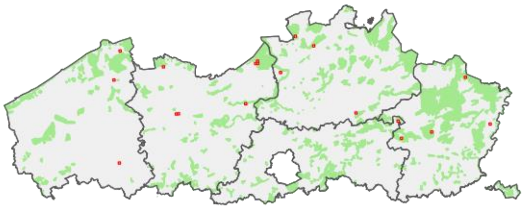
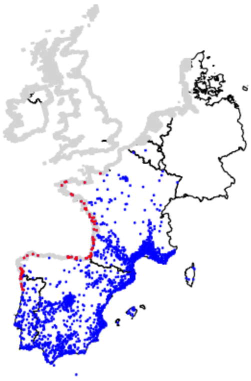
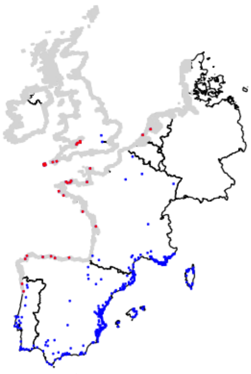
Ipomoea purpurea

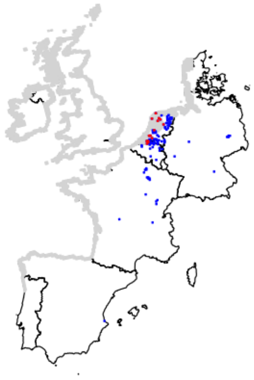
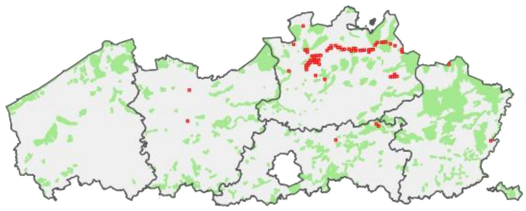
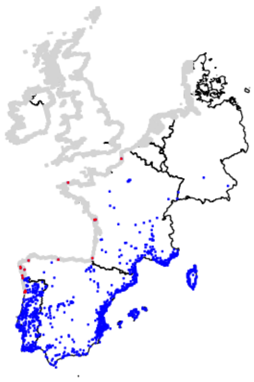
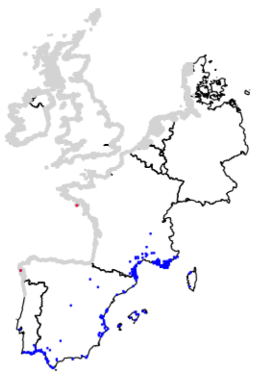


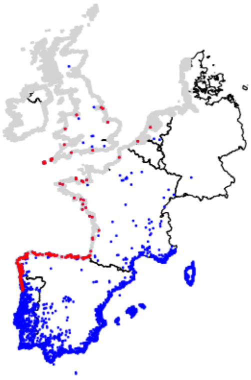
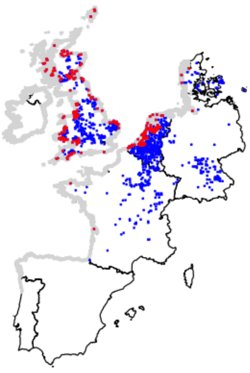
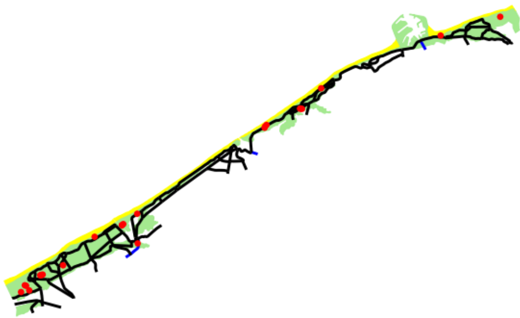
Ligustrum japonicum

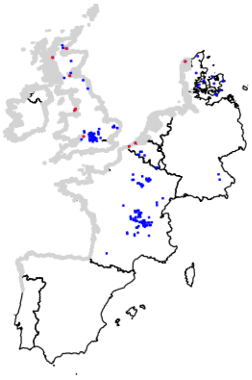
not reported in Flanders

 *Ligustrum lucidum*	not reported in Flanders
 *Lindernia dubia*	 *Lindernia dubia*
 *Lonicera maackii*	 *Lonicera maackii*

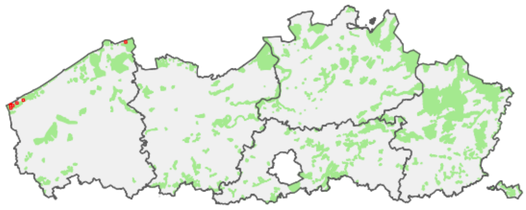
 *Ludwigia peploides*	 *Ludwigia peploides*
 *Melia azedarach*	not reported in Flanders
 *Mesembryanthemum cordifolium*	not reported in Flanders

 *Myriophyllum heterophyllum*	 *Myriophyllum heterophyllum*
 *Opuntia ficus-indica*	not reported in Flanders
 *Opuntia stricta*	not reported in Flanders

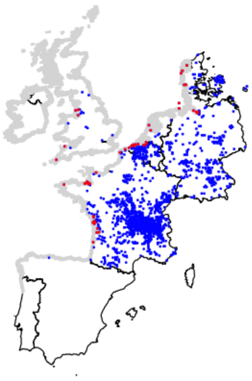
 *Oxalis pes-caprae*	not reported in Flanders
 *Paspalum vaginatum*	not reported in Flanders
 *Populus balsamifera trichocarpa*	 *Populus balsamifera trichocarpa*



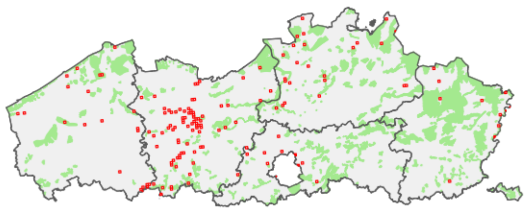
Populus jackii



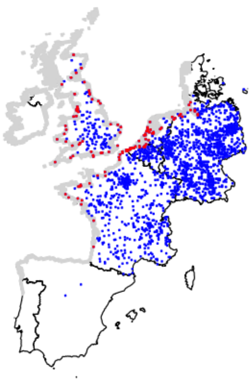
Populus jackii



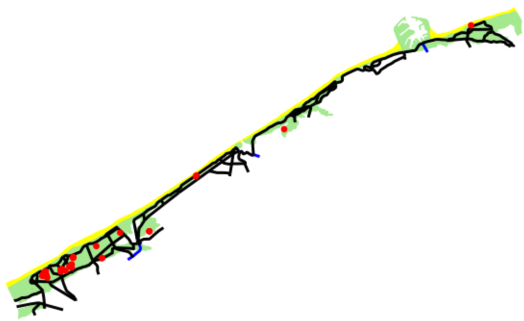
Reynoutria bohemica



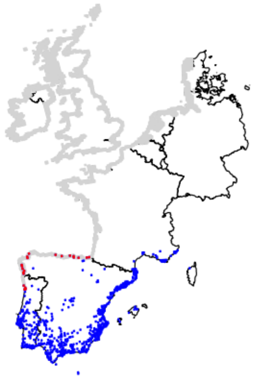
Reynoutria bohemica



Ribes aureum

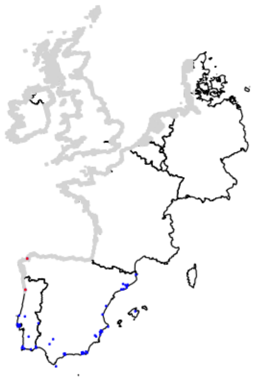


Ribes aureum



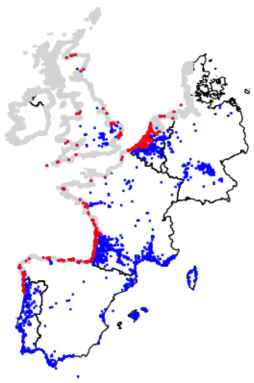
Schinus molle

not reported in Flanders

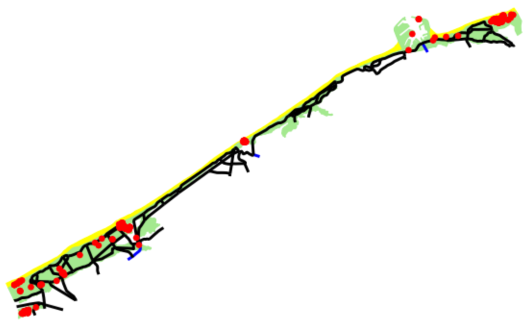


Schinus terebinthifolia

not reported in Flanders



Solanum spp. (5 spp.)

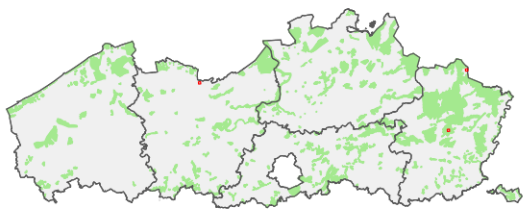


Solanum spp. (5 spp.)

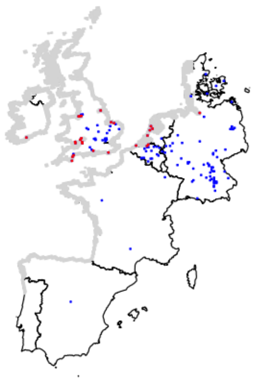
Spartina patens

not reported in Flanders

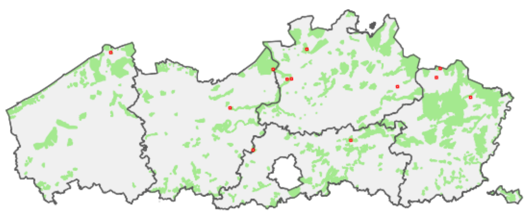
Spiranthes cernua x odorata



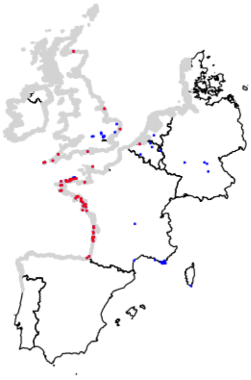
Spiranthes cernua x odorata



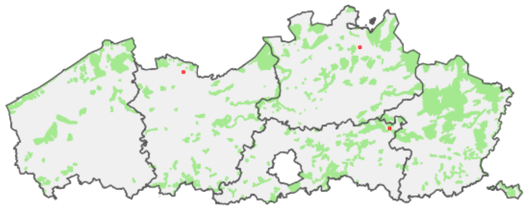
Symphoricarpos orbiculatus



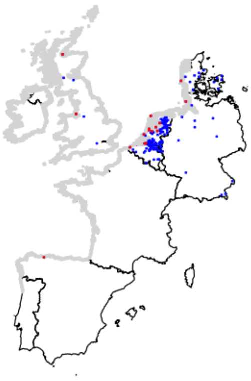
Symphoricarpos orbiculatus



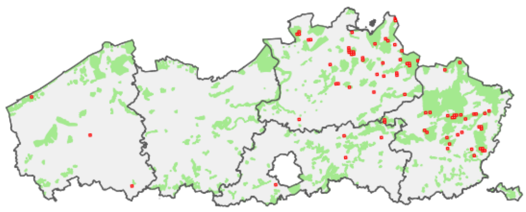
Tetragonia tetragonioides



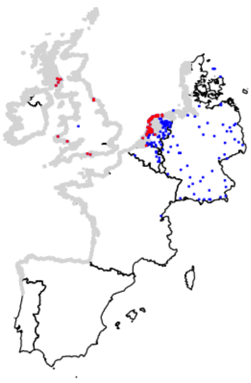
Tetragonia tetragonioides



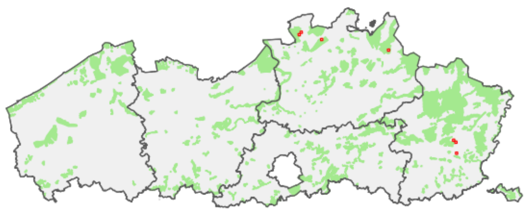
Vaccinium corymbosum



Vaccinium corymbosum



Vaccinium macrocarpum



Vaccinium macrocarpum