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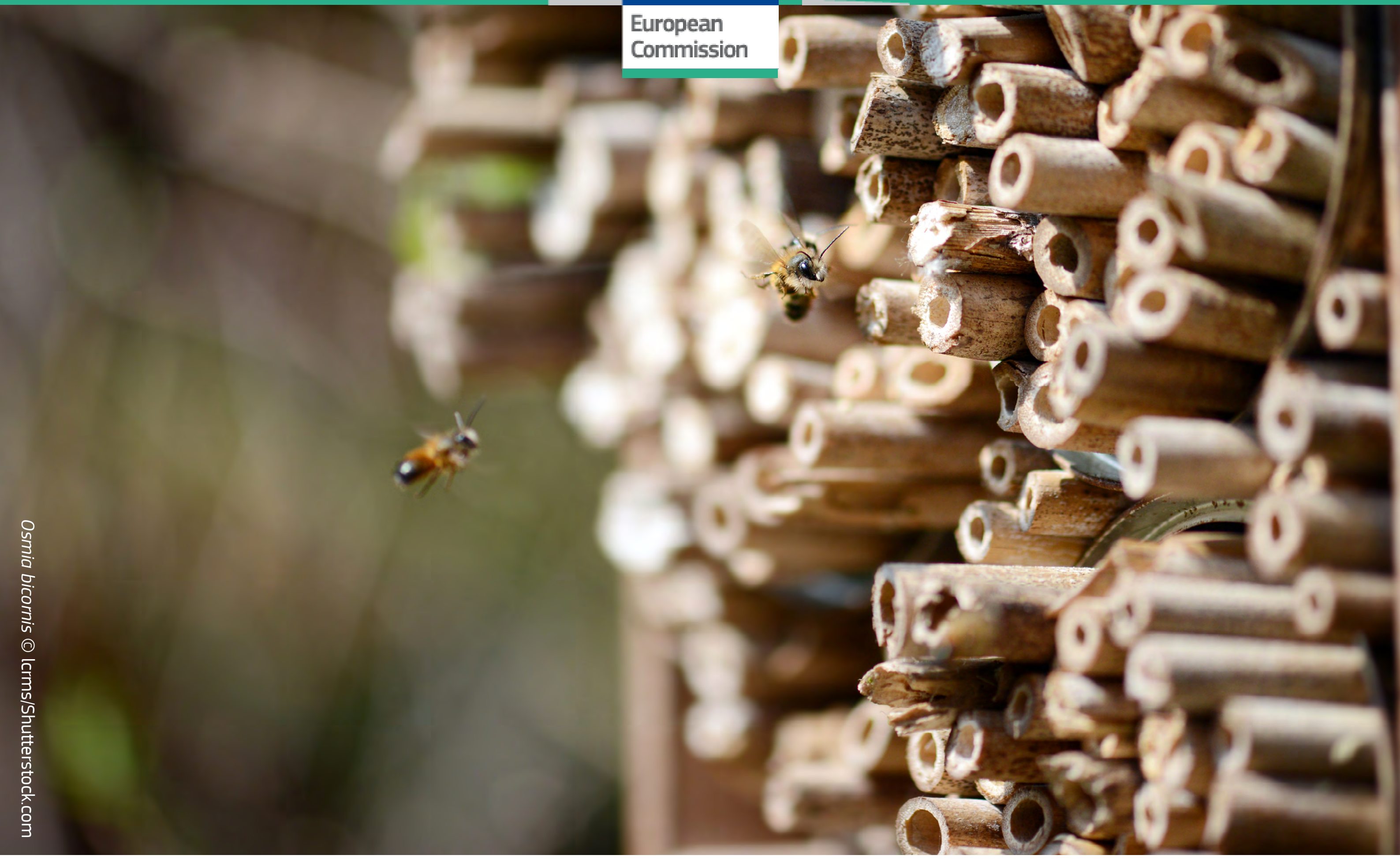

Osmia bicornis © lcrms/Shutterstock.com

Managing invasive alien species to protect wild pollinators

Environment

Managing invasive alien species to **protect** wild pollinators

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What should you know about **pollinators**?

What is pollination?

Pollination – the transfer of grains of pollen between flowers on different plants of the same species – is an essential step in the reproduction process of most flowering plants, including many plants we rely on for food and materials. This process takes place as insects and other animals move from plant to plant, facilitating pollen dispersal; those species that actively seek pollen as a source of food are the most effective pollinators. Without pollinators, many plants could not set seed and reproduce, causing vegetation diversity to decline, depriving many animal species of a primary source of food and unleashing knock-on effects along trophic chains[1]. In addition, pollination is thought to be a key factor in the diversification and evolution of many plants and animals[2].

What are pollinators?

Some pollinators need little introduction; the decline of honeybees (*Apis mellifera*) gained public attention some time ago. Honeybees are often assumed to provide the majority of pollination services to agriculture, but actually most pollination is brought about by wild pollinators[3]. In Europe, pollinators are primarily insects - including bees, hoverflies, butterflies, moths, beetles and other fly species. Whilst the conservation of our European honeybee is important because of their link to our cultural heritage and to honey production, there is a crucial need to extend conservation efforts to wild pollinator species to protect ecosystem health, build resilience, and underpin plant diversity – particularly considering the current and anticipated impacts of climate change.

Apis Mellifera © Codega/Shutterstock.com

Pollinators are declining...

Insect declines are being systematically described around the world, and Europe is no exception. Populations of wild pollinators - i.e. bees, hoverflies, moths, butterflies and beetles - have declined significantly across Europe over the last few decades[4-6]. For example, in Germany seasonal declines over 27 years of more than 75% of total flying insect biomass were recently estimated[5], while systematic monitoring in some EU Member States has shown declines of some 75% since 1990 and of about 40% in the abundance of grassland butterfly species across the EU[6]. Furthermore, the European Red List of Bees[7] published in 2014 concluded that at the EU-27 level, over 9% of wild bee species are threatened with extinction, and >50% of Europe's wild bee species are not sufficiently known to assess their conservation status. Insects are at the base of the food chain for many other animals and wild pollinators provide vital and efficient pollination services.

The importance of pollinators for society and why their conservation matters

Pollinators are a diverse and widespread part of our biodiversity. Without pollination services, we would lose many fruits, nuts and vegetables from our diets, and many other important food stuffs and materials, such as vegetable oils, cotton and flax. Besides these material benefits, society benefits in multiple ways directly or indirectly from the services of pollinators and their influence on ecosystem quality, including our health and well-being, our sport and recreation, education, tourism and culture.

Aglais io (Peacock Butterfly) © Kenneth Allen wikimedia commons

Invasive alien species and pollinators

Why this guidance document? Who is it for?

The main objective of this booklet is to provide technical guidance on the most relevant management measures that can be adopted to prevent the introduction and spread, support early detection and promote eradication or control of invasive alien species (IAS) that are considered harmful to native wild pollinators in Europe. The target audience is any entity responsible for managing IAS, authorities engaged in IAS policy-making and European residents seeking to prevent the introduction and spread of IAS, monitor new incursions, and eradicate or control IAS populations.

This guidance stems from Action 8A of the EU Pollinators Initiative (EPI)[1] and is one of a series of documents to be produced under the Initiative that will provide recommendations to different sectors and stakeholders on how they can better contribute to conserve wild pollinators.

What are Invasive Alien Species (IAS)?

Alien, or non-native, species are animals, plants, or other organisms introduced by humans, either intentionally or accidentally, into areas outside their natural range. Alien species that establish populations and cause severe impacts to biodiversity and ecosystems, are known as '*invasive*' alien species.

Due to the increase in the movement of people and goods around the world, the introduction of species to new areas is increasing and is one of the top threats driving biodiversity loss. Invasive alien species also have a strong negative impact on ecosystem services, economic activities and human livelihoods around the world. Common 'pathways' of introduction of IAS include the release of fish for fisheries into the wild, escape from farms and horticulture, transport within ship ballast water, and the spread through man-made corridors such as canals. The most effective and cost efficient way to mitigate the impacts from IAS is to prevent their introduction in the first place, through the management of these pathways, for example through regulation of trade of certain species, or by implementing biosecurity procedures to reduce the risk of unintentional introductions.

[1] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52018DC0395

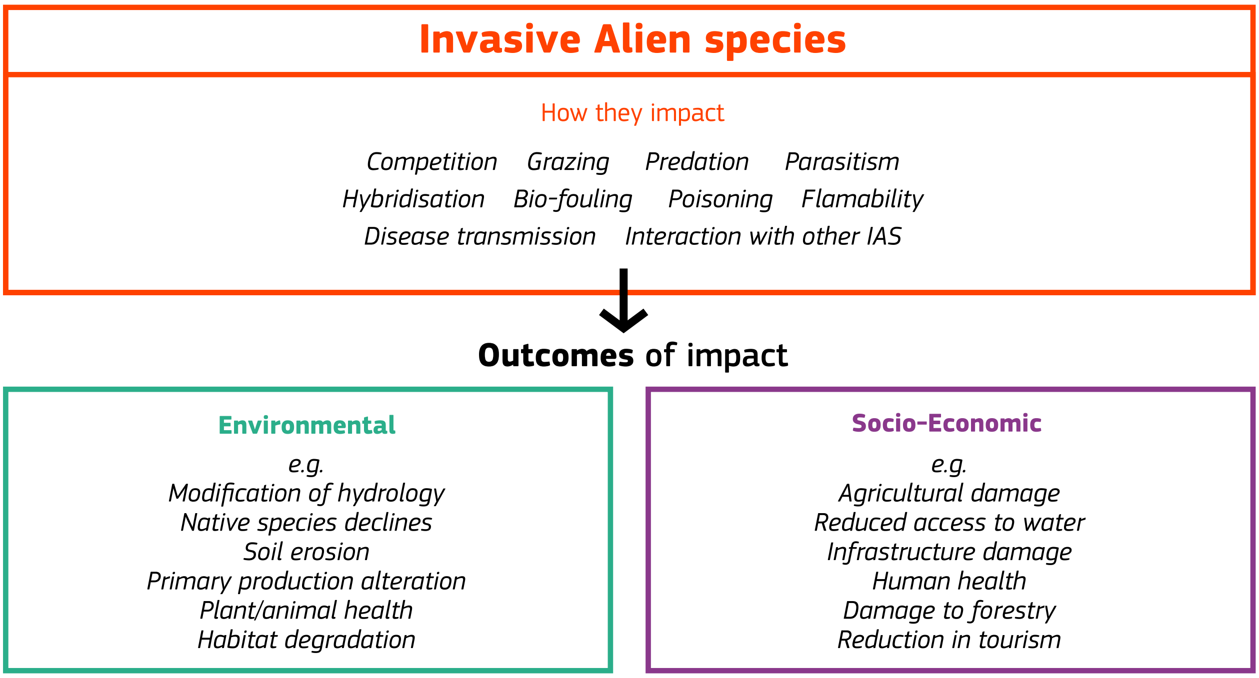


Figure 1. How IAS lead to environmental and socio-economic impacts.

***Rattus norvegicus* (Norway rat)** © Jean-Jeaques Boujot CC by-sa Flickr. The Norway rat, along with other rat species, has been introduced around the world primarily as a stowaway on boats. They have caused or contributed to the extinction of native mammals, birds, reptiles and invertebrates, especially on islands through predation. They can carry and transmit diseases to humans, eat food crops and spoil human food stores.

***Eichhornia crassipes* (Water hyacinth)** © Ajmain Fayek Swapnil CC by-sa 2.0 Flickr. Water hyacinth, native to South America, is a popular ornamental plant that has been widely introduced across five continents. It is a fast growing plant that can form dense floating mats that block light and reduce oxygen levels in the water, severely altering aquatic ecosystems. These mats also block waterways preventing navigation, fishing and recreation activities, and also provide a breeding ground for disease transmitting mosquitos.

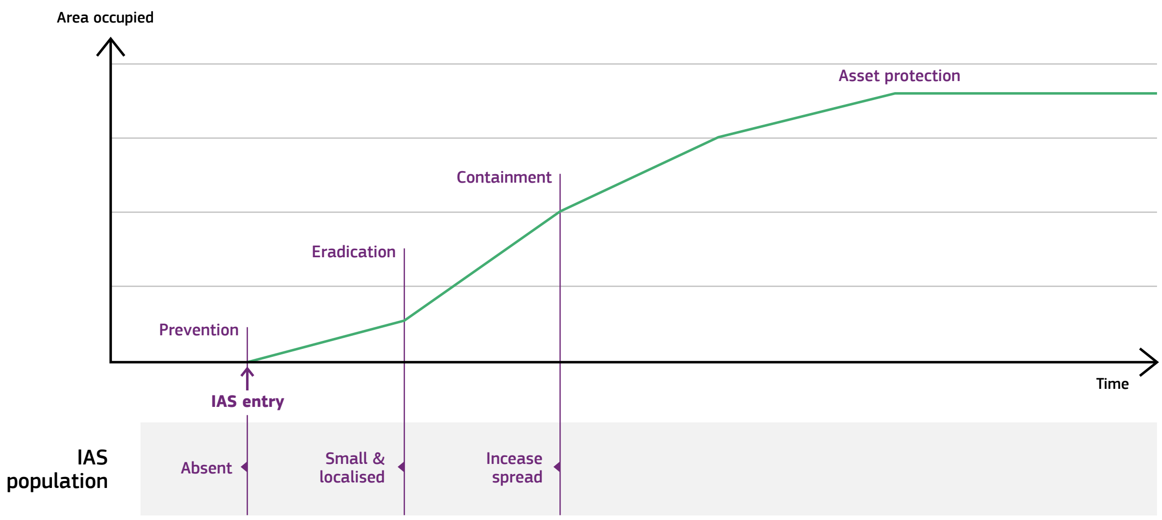


Figure 2. Species invasion curve with appropriate management responses at different stages of invasion. Once an IAS has arrived, it is critical that the species is detected early, monitored and, if necessary, eradicated or contained. If an IAS becomes established and widespread, it can be very costly and difficult to eradicate, and often mitigation of its impacts is the only viable option. Adapted from Invasive Plants and Animals Policy Framework, State of Victoria, Department of Primary Industries, 2010.

Invasive Alien Species in Europe

The number of IAS in the EU increased by 76% between 1970 and 2007 [8]. According to the European Commission's science and knowledge service, the Joint Research Centre's European Alien Species Information Network (EASIN) there are currently records of 14,000 alien species within Europe. This includes species that have originated outside the EU, but also those that are native to one part of the EU, but have been introduced to another. In 2009, the economic impacts of IAS in the EU were estimated to be **€12.5 billion per year**, which included financial losses and the costs to manage these species [9]. In 2015, a study found that one in five threatened species within the EU were directly affected by IAS, and that IAS were the third most severe threat overall [10].

Also in 2015, the European Union Regulation (No 1143/2014) on the prevention and management of the introduction and spread of invasive alien species entered into force (Annex I). A key instrument of this Regulation is the List of IAS of Union concern, which includes species for which concerted measures (on prevention of introductions, surveillance, early detection, rapid eradication and control) are required across the EU. Currently, there are 66 species on this list, 36 species of plants and 30 species of animals, although this number is dynamic.

Gunnera tinctoria **(Giant rhubarb)** © Kevin Smith. Giant rhubarb, native to South America, is a species of Union concern and is currently established in five EU Member States through escaping and spreading from private and public gardens. It is a large herbaceous plant producing a high number of seeds, and forms dense colonies that shade out and suppress native vegetation, block drainage channels and streams, degrade agricultural land, and obstruct access to recreation and natural areas.

Procambarus clarkii **(Red swamp crayfish)** © Gail Hampshire Flickr CC BY 2.0. The red swamp crayfish is a freshwater crayfish native to North America, which is the most widely introduced crayfish in the world, mostly due to aquaculture practices and the aquarium trade. It is also a species of Union concern, currently present in ten EU Member States, but actively spreading. The species severely affects the structure and functioning of natural aquatic ecosystems, it is a vector of multiple parasites and diseases and it has been shown to affect fishermen's livelihoods.

Pollinators and invasive alien species

Wild pollinators face an array of different threats, including land-use change, pollution, and invasive species. IAS can have both negative and positive impacts upon pollinators. In general, native wild pollinators are potentially affected by the below IAS impact mechanisms [see 11]:

Ecosystem modification

When invasive alien plants dominate an area they transform the availability of nectar and pollen, often from a diverse suite of floral species that may provide nutrition at different times of year. While the invasive plant may provide nutrition, it may only do so for a certain part of the year and this may only favour certain pollinator groups or species, usually those with generalist feeding behaviours, negatively affecting those specialised pollinator species.

Competition and hybridisation

When invasive alien pollinators establish they can compete or hybridise with native pollinators. This is most often seen with managed domesticated alien pollinator species that are usually social and possess generalist feeding and nesting behaviours. These managed pollinators are often introduced recurrently, and once they escape and establish in the wild, they can directly compete with native wild pollinators for resources, or hybridise with them.

Predation — Invasive alien species once established can exert strong pressure on native pollinators through predation. There have been numerous recorded pollinator extinctions, particularly on islands, due to this interaction. In addition IAS with aggressive or territorial behaviour (e.g. some ant species) can displace and deter native pollinators.

Disease transmission and parasitism — The movement of domesticated pollinators to areas outside their native range has resulted in the transfer of their pathogens and parasites to native pollinators.

IAS currently impacting native wild pollinators in Europe

Below are lists of different groups of IAS for which evidence could be found of their impacts upon pollinators within the EU.

Invasive bees and wasps

Invasive alien species		Native pollinators impacted		Impact mechanism
*Apis mellifera carnica**	carniolan honeybee	*Apis mellifera* sub-species	Western honeybee	Hybridisation
*Apis mellifera ligustica**	Italian bee	*Apis mellifera* sub-species	Western honeybee	Hybridisation
Megachile sculpturalis	giant resin bee	*Osmia* spp., *Xylocopa* spp.	bees	Competition
*Bombus terrestris**	buff-tailed bumblebee	*Bombus canariensis, B. madeirensis*	bumblebees	Hybridisation
Vespa velutina nigrithorax	Asian hornet	Apidae, Halictidae, Vespidae, Muscidae, Calliphoridae, Syrphidae	bees, wasps, hoverflies	Competition, Predation
*Cotesia glomerata**	white butterfly parasite	*Pieris cheiranthi, P. wollastoni*	butterflies	Parasitism

* Species partly native in the EU

Invasive butterflies

Invasive alien species		Native pollinators impacted		Impact mechanism
Cacyreus marshalli	geranium bronze	*Aricia nicias, Eumedonia eumedon*	butterflies	Competition
*Pararge aegeria**	speckled wood	*Pararge xiphia*	Madeiran speckled wood	Competition
*Pieris rapae**	small cabbage white	*Pieris wollastoni*	Madeiran large whites	Competition, Transmission of diseases

* Species partly native in the EU

Invasive beetles and mites

Invasive alien species		Native pollinators impacted		Impact mechanism
Aethina tumida	small hive beetle	*Apis mellifera*	Western honeybee	Parasitism
Varroa destructor	Varroa mite	*Apis mellifera*	Western honeybee	Parasitism, Transmission of diseases

Invasive Ants

Invasive alien species		Native pollinators impacted		Impact mechanism
Lasius neglectus	invasive garden ant	***Lasius grandis,*** **multiple butterflies**	ants, butterflies	Competition
Linepithema humile	Argentine ant	***Camponotus cruentatus, C. piceus, Eristalis tenax***	ants, hoverflies	Competition

Invasive Plants and Fungi

Invasive alien species		Native pollinators impacted		Impact mechanism
Lupinus polyphyllus	large-leaved lupine	**Hesperioidea, Papilionoidea**	butterflies	Ecosystem stress/modification
Rhododendron ponticum*	common rhododendron	***Apis mellifera, Andrena carantonica***	bees	Poisoning/Toxicity
Solidago **spp.**	goldenrods	***Coenonympha oedippus***	butterflies	Ecosystem stress/modification
Solidago canadensis	Canada goldenrod	**Apidae, Andrenidae, Collettidae, Melittidae, Halictidae, Megachilidae, mutiple butterflies, Syrphidae, *Bombus* spp.**	bees, bumblebees, butterflies, hoverflies	Ecosystem stress/modification
Solidago gigantea	giant goldenrod	***Colias myrmidone,*** **multiple butterflies and bees, Syrphidae**	bees, butterflies, hoverflies	Ecosystem stress/modification
Nosema ceranae	Asian Nosema pathogen	***Andrena ventralis, Apis mellifera, Heriades truncorum, Osmia bicornis, O. cornuta, Bombus*** **spp.**	bees, bumblebees	Parasitism

* Species partly native in the EU

Examples of IAS that are harmful to wild pollinators in Europe, and recommended management measures

The following IAS have been identified as examples of some of the most potentially harmful to wild pollinators within Europe, these guidelines will be expanded in the future to cover additional species. Below we provide a summary of the characteristics and impacts of these IAS and, in line with the EU Regulation on IAS (Annex I), the most effective or available measures that can be taken to prevent their introduction and spread, support surveillance and early detection, rapidly eradicate, and manage established populations. More details on the management recommendations summarised below for each invasive alien species can be found online.

The measures described below are relevant to address the species at different stages of the invasion process, within the context of the EU Regulation on IAS. This includes prevention of introduction and secondary spread, surveillance to support early detection, rapid eradication of new introductions, and control of established populations. Some of these measures, in particular for prevention, will not be relevant for those stakeholders responsible for action on the ground and will require national or even European level policy development or implementation.

These measures, while not ‘practical’, are included here as these may be the most cost-effective ways to mitigate the impacts from the IAS. For all measures discussed, it is important to note that EU/national/local legislation on the use of plant protection products and biocides needs to be respected, and authorities should check to ensure chemicals are licensed for use in their respective countries/regions.

Aethina tumida, *Varroa destructor*, and *Nosema ceranae* have not been selected here, as they are primarily a threat to domesticated pollinator populations and are covered by the apiculture guidance (see European Commission website).

Megachile sculpturalis (Giant resin bee)

Giant resin bees, *Megachile sculpturalis* (and *Megachile disjunctiformis*)

	Megachile sculpturalis	***Megachile disjunctiformis***
Native range	Both species are native to East Asia, including China, Korea, Taiwan and Japan.	
Pathway(s) of introduction into the EU	Both species have been introduced accidentally, likely with imports of wood products or other potential nesting materials.	
Distribution in the EU	France, Italy, Switzerland, Germany, Hungary, Slovenia, Austria, Spain	Italy
Native pollinators impacted	Solitary bees *Xylocopa* spp., *Lithurgus* spp., *Osmia* spp., *Megachile lagopoda*, and some *Anthidium* spp.	
Impacts	Potential negative impacts include competition with native bees for nesting sites and floral resources, pollination of invasive weeds, co-invasion with pathogens and parasites, genetic introgression, damage to buildings and changes to the structure of native pollination networks.	
Key species facts	Solitary and polylectic (collect pollen from the flowers of a variety of unrelated plants). Nest in pre-existing cavities in wood and stems of plants, including human infrastructures.	

Available management measures

Prevention of new introductions

Measure
Pre-border treatment and biosecurity checks on wood and wood packaging

Goal and description:

Currently all wood, wood and plant products, wooden packaging materials and dunnage used for goods imported into the EU are regulated by Regulation (EU) 2016/2031[2] (recently amended by Implementing Directive (EU) 2019/523)[3], which lists harmful organisms that need to be targeted by specific control measures, depending on the country of origin and the type of wood. All wood packaging needs to be treated according to the International Standards for Phytosanitary Measures No. 15 (ISPM 15) 'Regulation of wood packaging material in international trade' and be officially marked with the relevant ISPM 15 stamp. However, it is important to note that *Megachile* species are not specifically targeted by these legislative instruments, and therefore it is unknown if the measures put in place would address the risk of introduction for these species. In fact, both of these legislative instruments were likely in place when the first introduction of both *Megachile* species occurred.

[2] Regulation (EU) 2016/2031 https://eur-lex.europa.eu/eli/reg/2016/2031/2019-12-14

[3] Implementing Directive (EU) 2019/523 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32019L0523

Effectiveness:

While these existing biosecurity measures will likely reduce the risk of entry, they are not specifically targeted at *Megachile* species, and it is unlikely that further introductions will be prevented, as the species can nest in a wide variety of materials, including human made structures.

Effort required:

These measures are in place permanently.

Resources required:

Resources for inspection and quarantine are already in place across the EU.

Prevention of secondary spread

Measure

Restricting movement of nesting material, and encouraging the planting of native tree species

Goal and description:

The movement of nesting material containing individuals of the species, e.g. wood, boats and vehicles, is likely to facilitate the secondary spread of both *Megachile* species. However, there are no measures that could realistically be put in place to restrict the movement of vehicles, boats and other vectors that may carry potential nesting material.

In terms of natural spread, while the species are polylectic, studies have shown that there is a strong preference for Japanese pagoda tree (*Styphnolobium japonicum* (L.) Schott), which is widely planted in Europe, and for other alien plants with a native range that overlaps that of *M. sculpturalis*. Therefore stakeholders, including those with responsibility for public areas, should be encouraged, possibly through the agreement of sector specific codes of conduct, to plant native tree species, as the planting of *S. japonicum* could promote the natural spread of *M. sculpturalis*.

Effectiveness:

Restricting the movement of potential nesting material will be impossible to implement effectively across *M. sculpturalis* range within the EU. It could potentially be implemented for the highly restricted range of *M. disjunctiformis* (in Bologna, Italy), at least until an eradication feasibility assessment can be undertaken. However, even over such a small area it would likely be ineffective, as the species can nest in a wide variety of materials, including human made structures.

Therefore, the only measure that will potentially be effective in preventing secondary spread, is the implementation of codes of conduct to reduce the planting of *S. japonicum* (and other alien plants) as an ornamental, and promoting planting of native trees.

Effort required:

Such activities would need to be in place permanently. Commitment by stakeholders to a Code of Conduct needs to be maintained over time, as any decrease in effort will lead to a decline in its efficacy.

Resources required:

Resources would be needed to facilitate engagement between all the relevant stakeholders in the horticultural sector, in order to develop the Code of Conduct and its implementation, monitoring and evaluation strategy.

Osmia bicornis © lcrms/Shutterstock.com

Surveillance measures to support early detection

Measure

Expert-assisted citizen science programme, including the setting up of cavity-nest boxes 'trap nests'

Goal and description:

M. sculpturalis is a conspicuous and large bee species that can be easily differentiated from other bee species (at least in France), making it appropriate for citizen science surveillance.

The surveys of 'bee hotels' (human made bee cavity-nest boxes) and known stands of *S. japonicum*, in conjunction with surveys in natural areas (e.g. forests), have been recommended as an effective means of detecting the species in an area.

Effectiveness:

In France, an expert-led citizen science project has shown to be effective in assessing the ongoing range expansion of *M. sculpturalis*. This programme engaged with naturalist/entomologist networks and with agricultural high schools, to understand the spread of the species. While the purpose of this work was not strictly early detection, there is no reason to think that a similar target public could not be engaged to establish surveillance to support early detection within new areas and in EU Member States where the species is not yet recorded.

Effort required:

The measure would need to be in place permanently.

Resources required:

Resources required would include staff time, expertise and materials to undertake training of 'expert' citizen scientists and co-ordinate activities. A data recording system, with validation of observations, would need to be in place, or existing ones adapted. This measure may be able to take advantage of networks (e.g. bee keepers) and early detection programmes established for *Vespa velutina*, a species listed on the EU IAS Regulation.

If bee hotels (nest boxes) are created, they can be made of different nesting materials, such as sheltered bundles of hollow plant stems, bamboo or reeds (diameter no less than 10mm), or wood with drilled holes. An Italian survey found that *M. sculpturalis* preferred holes 12cm deep, with a diameter of 10-12mm.

Rapid eradication of new introductions and management of established populations

Measure

None known

No information can be found on measures for rapid eradication or management of established populations of *Megachile* species following early detection. The population of *M. disjunctiformis* in Italy is still currently in its very early stage of invasion and it is recommended that a feasibility study into the eradication (including identification of potential methods) of this species is undertaken, before it spreads.

Asian hornet, *Vespa velutina nigrithorax*

Vespa velutina (Asian hornet) © Gilles San Martin, Flickr, CC BY 2.0

	Vespa velutina nigrithorax
Native range	Southeast Asia
Pathway(s) of introduction into the EU	As a transport stowaway, probably in pottery, introduced into the EU in south eastern France in 2004.
Distribution in the EU	Established in Belgium, Spain, France, Italy, and Portugal. Recorded from Germany, and Netherlands.
Native pollinators impacted	Different pollinator groups, primarily bees and wasps (Hymenoptera; Apoidea and Vespoidae), and flies (Diptera; Muscidae, Calliphoridae, Syrphidae).
Impacts	Adults feed on nectar and fruit, but also prey upon many insects, including the native western honey bee (*Apis mellifera*), leading to economic losses of beekeepers. The species also competes with native European hornet (*V. crabro*).
Key species facts	Colonies are founded by a single queen, but numbers grow to an average of 6,000 individuals in the summer. In autumn potential queens (gynes) emerge and activities are focused on mating and dispersal. Nests can be built in a variety of locations, including trees, bushes, roofs and eves of buildings and even underground. It is important to note that the species is listed as an invasive alien species of Union concern under the European Union Regulation (No 1143/2014) obliging EU member states to act.

Available management measures

Prevention of new introductions

Measure

Public awareness campaigns

Goal and description:

The species can be introduced un-intentionally into a country via different pathways, including through the movement of wood, soil or other goods that are suitable for overwintering queens, as a hitchhiker on vehicles or freight containers, with fruit imports or even with honey bee colonies. As the species can be introduced through such a varied set of pathways, some of which are very difficult, if not impossible, to effectively manage, its introduction will be very difficult to prevent. The only realistic measure that could support prevention is through raising awareness of the species through a campaign targeting the general public and key stakeholder groups.

Effectiveness:

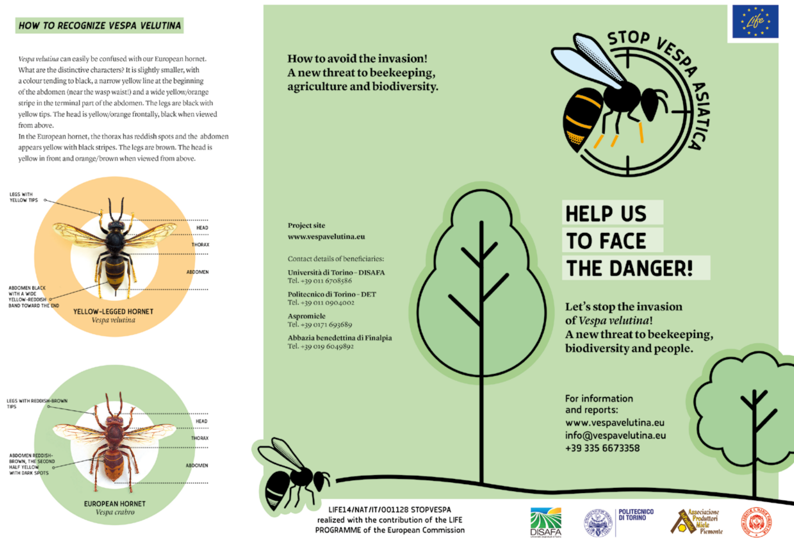
Public campaigns will increase the awareness of citizens on *V. v. nigrithorax*, increasing the possibility of preventing the unintentional introduction and spread of this species, although they are unlikely to be fully effective. This measure needs to be seen as part of an effective surveillance strategy, discussed below.

Effort required:

This measure needs to be applied indefinitely.

Resources required:

Resources needed include the production of leaflets and brochures, and dissemination of information through the media, newspapers, dedicated websites, etc. Such campaigns can be combined with other campaigns of IAS of national, regional or Union concern.



© Italy's StopVESPA campaign

Prevention of secondary spread

Measure

Engagement with key stakeholder groups including those involved in control/ management of the species

Goal and description:

Once introduced into a country, the species can spread via the same pathways as discussed above, and therefore the public awareness campaigns suggested will also be relevant here. In addition, once the species is established, it is important to engage with key stakeholder groups, so that they implement best practices to ensure they do not spread the species through their working activities.

This primarily includes: beekeepers (through beekeepers' associations), who may move bee hives that could contain Asian hornet individuals; institutions involved in the removal of Asian hornet nests, as individuals may survive the nest destruction process, therefore disposal procedures should avoid the transportation of nests or hornets into non-colonised areas.

Effectiveness:

Engagement with key stakeholder groups is important to establish good practices, which will effectively help prevent secondary spread of the species along these important pathways. However it is important to note that, while this measure is assessed as being effective, it will not stop all instances of secondary spread across all potential pathways.

Effort required:

This measure needs to be applied indefinitely.

Resources required:

Specific engagement activities would require the development and dissemination of information material, and possibly running training workshops. This material would need to inform the development of best practices to reduce the risk of spreading Asian hornet through the working practices of these key stakeholder groups.

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Surveillance measures to support early detection

Measure

Beekeepers surveillance strategy supported by citizen science

Goal and description:

Apiaries represent an attractive food resource for Asian hornets, and honey bees are known to be a primary prey species. Therefore beekeepers, who are often organised in beekeeper associations, are the key stakeholder group that should be involved in national surveillance strategies for this species. This can be done through regular observations for hunting Asian hornets (especially during summer when predation pressure is high), and the use of traps baited with sugary substances (especially during spring or autumn, when they are seeking carbohydrate substances).

This can be supported by citizen science, which has been used successfully to gather information on the spread of invasive species. While Asian hornets are conspicuous, they can be confused with the native European hornet, and therefore records need to be verified. Many biodiversity recording citizen science programmes exist across the EU, some specifically focused on invasive species (e.g. Invasive Alien Species Europe app for IAS of Union concern), and some even focused on the Asian hornet (e.g. Asian Hornet Watch app – see Annex II (Resources)). A public awareness campaign, as discussed above, will be needed to inform the public on the species and how to report sightings.

Effectiveness:

When combined together, beekeepers surveillance and citizen science programmes make for an effective early detection surveillance strategy. The effectiveness depends on the number of beekeepers and citizen scientists involved in the monitoring activities. Dissemination of awareness raising material and engagement activities with beekeepers and the general public, undertaken both by national authorities and beekeepers' associations, may increase their involvement.

Effort required:

This measure needs to be applied indefinitely.

Resources required:

Beekeepers and citizen scientists will undertake the monitoring activities voluntarily. Therefore, costs of the beekeepers strategy are mainly related to equipment costs for monitoring activities and staff costs for the management of the surveillance programme (e.g. screening of reports). The UK National Bee Unit[4] has information, including a video, on how to make your own Asian hornet monitoring trap. In terms of citizen science, resources are needed for the awareness raising campaign (see above), but also for the data recording infrastructure (e.g. smartphone app), and for the verification and coordination of records.

[4] Asian hornet page on UK National Bee Unit BeeBase http://www.nationalbeeunit.com/index.cfm?sectionid=117

Rapid eradication of new introductions

Measure
Nest location and destruction

Goal and description:

Once an individual(s) has been detected, a combination of measures needs to be applied in order to locate the nest, and then destroy it and all individuals. Visual observations can be used to track individuals back to the nest, which requires triangulation using two or three people. Harmonic radar or radio-tracking systems that track a 'tag' mounted on the thorax of the hornet can also be used. Thermal imaging is also a technology that could be potentially used to locate nests, especially in the morning and evening, when background temperatures of trees are lower. In terms of nest destruction, carbon dioxide can be applied into the nest during the night, when all hornets are present. Manual removal can also be undertaken by placing the nest in a container and destroying it off site. Lastly, insecticide can be applied, as long as it is persistent, so that all individuals, including those that are not in the nest during treatment, are affected. It is important that surveillance is undertaken in the area for at least 2 years before the eradication is confirmed.

Effectiveness:

This is a highly effective measure if the invasion is the result of a single founder queen. However, it is critical to locate and destroy the nest and all individuals before the birth of potential queens (gynes), which occurs in September. The visual, harmonic radar and radio-tracking techniques have all been proven to be effective in locating nests and the technological techniques, though requiring higher costs, are likely to provide quicker nest location than visual tracking. The radio tracking tags require a battery and may impede hornets' flying ability, whereas those used for harmonic radar are considerably smaller. Nest destruction is only effective if all individuals, especially queens, are destroyed, so that the colony does not relocate its nest.

Apis mellifera © santypan/Shutterstock.com

Effort required:

The measure should be applied indefinitely, and always immediately after the first detection of *V. v. nigrithorax* in a Member State, or in a new area where the species was not previously recorded.

Resources required:

In terms of locating nests, visual tracking requires staff time, while equipment costs are negligible. The technological methods potentially allow a reduction in the time required for nest detection (improving the probabilities of detecting nests before the reproductive phase of the colony), but cost more in terms of equipment. Previously trained staff and availability of equipment in a Member State (e.g. harmonic radar in Italy, radio-tracking in the UK) promotes an efficient use of the available resources. In terms of nest destruction, resources required include trained staff, and if required, carbon dioxide and pesticides.

Management of established populations

Measure

Long-term nest destruction strategy and trapping

Goal and description:

The aim of this measure is to develop a long-term control strategy of nest destruction, in order to reduce the environmental, social and economic impact of this species. This strategy could be coordinated at a local or national level, but the location of destroyed nests should be reported to a single information point, in order to ensure centralised supervision. Nest destruction methods are highlighted above, but will require increased capacity to remove a potentially high number of nests, so specialised teams should be trained and may include fire brigades, civil defence, or beekeepers. Traps can also be used, usually only for reducing impacts at local sites, and can be baited with carbohydrates (to catch queens during spring or autumn) or protein (to catch workers in summer and autumn).

Effectiveness:

The effectiveness of a nest destruction strategy depends upon the resources provided. It can be effective at reducing impacts to the public, and also to beekeepers, but is unlikely to contain the spread of the species.
Trapping is potentially effective at reducing populations of adults at local sites, but will not limit population spread. In addition, there are no species specific baits currently available, therefore trapping will also capture non-target native species.

Effort required:

This measure should be applied permanently after the establishment of Asian hornet within a country.

Resources required:

A long term management strategy requires dedicated resources, primarily for personnel costs, given that nest destruction operations should be performed by trained people or specialised services, but also for equipment and pesticides. The strategy also needs to be coordinated by a centralised body, who can analyse data and assess the effectiveness of the measures implemented.

Vespa velutina (Asian hornet) © Danel Solabarrieta, Flickr, CC BY SA 2.0

Linepithema humile (Argentine ant)
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Invasive garden ant, *Lasius neglectus* and Argentine ant, *Linepithema humile*

	Lasius neglectus	***Linepithema humile***
Native range	Turkey, Russia, Iran	Argentina, Uruguay, Paraguay, Bolivia and Brazil
Pathway(s) of introduction into the EU	Probably as a contaminant of soil and turf attached to potted plants.	As a hitchhiker on ship/boat.
Distribution in the EU	Belgium, Bulgaria, Denmark, Germany, Greece, Spain, France, Croatia, Italy, Hungary, Netherlands, Poland, Portugal, Romania	Belgium, Bulgaria, Czech Republic, Germany, Ireland, Greece, Spain, France, Italy, Netherlands, Austria, Poland, Portugal, Sweden
Native pollinators impacted	Many different pollinators groups including ants, butterflies, hoverflies.	
Impacts	Through competition and predation the species negatively affects native ants foraging on trees, and also other arthropods, such as Lepidoptera larvae.	One of the most invasive and damaging ant species in the world. Many reported impacts on different taxa, such as birds, reptiles, mammals and other invertebrates, with the most documented impacts being the competitive displacement of native ant species. Evidence of negative impacts through predation and competition on other native arthropod species, including pollinators.
Key species facts	Exploits a wide variety of food sources, but mainly feeds on insect prey and honeydew producing insects on trees.	Omnivorous, mainly feeds on honeydew and nectar.
	Both species form super-colonies in their introduced range, with no boundaries among nests, and forage and defend their territories collectively, promoting the establishment of highly abundant populations which can easily dominate entire habitats, monopolise resources, and spread quickly.	

Lasius neglectus © Phillip Buckham-Bonnett

Available management measures

Prevention of new introductions

Measure

Strengthen EU legislation on biosecurity, in particular on soil and growing media (as such, or attached to potted plants)

Goal and description:

The goal of this measure is to prevent new unintentional introductions of the species into the EU through the import of soil and other growing media, or potted plants. The EU's current plant health regulations that govern the import of these commodities now prohibits the import of soil and growing media as such[5] from all third countries, apart from Switzerland. However, the import of growing medium, attached to or associated with plants is still allowed, as long as certain phytosanitary requirements are met which target regulated plant health pests, but not specifically ants. The goal of this measure is to impose stricter restrictions on the import of growing media attached to plants imported from third countries, to reduce the risk of ants being unintentionally introduced as a contaminant. Additional phytosanitary inspections can also be implemented at a national level specifically with the aim of identifying plant imports contaminated with ants (and other invasive alien species).

Furthermore, more resources should be allocated to improve training of staff at border controls, to ensure that enough personnel and time are allocated to guarantee that inspections are undertaken at all times, and to allow for the collection of detailed information on plant products imports and their contaminants, so that the effectiveness of these measures can be improved.

Effectiveness:

The effectiveness of this measure is unknown, but if fully implemented, it has the potential to be effective in preventing unintentional introductions of ant species. A study has shown that European countries with gaps in border controls have been invaded by more quarantine alien insect species [12], indicating that undertaking proper inspection strategies at borders can be effective in preventing insect invasions.

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Effort required:

This measure should be implemented indefinitely.

Resources required:

Resources and capacity for the inspection of, and to implement biosecurity measures for, imported soil and growing media are already in place across the EU. These resources need to be increased so that inspections and biosecurity measures can be undertaken more often and, therefore, be more effective.

[5] Soil and growing media as such consists in whole or in part of soil or solid organic substances such as parts of plants, and humus, which includes peat or bark, other than that composed entirely of peat.

Prevention of secondary spread

Measure

Restricting movement of soil/growing media (as such, or attached to potted plants) and of garden wastes from areas infested with ants

Goal and description:

The movement of infested soil, garden and landscape materials is one of the most likely methods of secondary spread of both ant species. As such, after areas colonised by these ants are identified, if rapid eradication is not possible, best practices and protocols to restrict the movement of soil and other plant products from infested areas should be adopted in order to contain their spread. As the spread of these ant species is often associated with plant and soil exchange, implementation of these protocols should focus on activities with key sectors such as plant nurseries, garden centres, botanical gardens, demolition waste dumps, parks and cemeteries.

Effectiveness:

It is likely that the measure would only be partially effective, as it will be difficult to restrict all movements of soil and garden wastes even in confined areas, such as plant nurseries and research centres, but especially in more open areas, such as gardens and parks.

Effort required:

The measure would need to be applied until all ant invaded areas have been controlled or eradicated.

Resources required:

Implementation of this measure in infested areas would involve changes in operational procedures in different businesses and sectors, which might incur significant costs, particularly to nurseries and garden centres, if they cannot move plants. There will also be resources needed for training staff, undertaking inspections and for undertaking cleaning and disposal procedures.

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Surveillance measures to support early detection

Measure

Surveillance of high risk introduction areas, supported by public participation

Goal and description:

The objective of this measure is to implement long-term active monitoring programmes in areas at high risk of new introductions of these ant species. This will include ports of entry such as land borders, airports and shipping ports, and plant nurseries, garden centres, botanical gardens and construction waste dumps. The measure should be established and implemented by the responsible environmental authorities, who should produce and implement protocols for long-term monitoring and reporting ant incursions at an early stage. This can be supported by citizen science programmes with awareness raising activities, possibly targeting natural history groups.

Effectiveness:

This measure has the potential to be effective, and citizen science programmes have been shown to be effective at assisting early detection of other IAS.

Effort required:

This measure should be implemented indefinitely.

Resources required:

A comprehensive on the ground surveillance system would require extensive resourcing from responsible authorities, in order to monitor entry ports, as well as plant nurseries and other high risk sites. For citizen science initiatives, there will be the need to produce awareness raising materials and, if needed, to create and maintain a dedicated record submission system, e.g. a smart phone app.

Rapid eradication of new introductions

Measure

Fumigation coupled with chemical control

Goal and description:

This measure consists of the fumigation of ant colonies, coupled with the application of toxicant compounds (see details on chemical control below). It has been successfully applied to invasive garden ants found in tufa rock imported from Italy to the UK. The invasive ant colony was destroyed by fumigating the tufa with phosphine and treating the surrounding area with imidacloprid ant gel.

Effectiveness:

The measure has been shown to be effective for invasive garden ants, and there are no examples of its application for Argentine ants. However, some successful examples of rapid eradications of Argentine ants using only chemical control have been reported in small urban areas in Australia.

Effort required:

This measure should be implemented as soon as possible and follow up surveys are required to confirm eradication.

Resources required:

Expenses related to this measure are associated with the cost of purchasing the products needed, training staff and paying for staff time to apply them.

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Management of established populations

Measure
Chemical control

Goal and description:

Most long-term ant eradication and control programmes have relied almost exclusively on chemical control techniques using active compounds formulated in bait carriers. Campaigns can rely on the use of a single active compound, or on a combination of active compounds, with fipronil, hydramethylnon, or a combination of both being commonly used (although not approved for use in the EU). Bait type, size and dispersal method should be chosen according to the nesting, foraging strategy and behavioural traits of the specific ant species. Baits used to deliver active ingredients can be granular, liquid or gels. Ant eradication campaigns have used single or multiple methods to deliver bait, such as broadcasting bait by hand, drenching nests with an aqueous solution and using live insecticide-treated prey to deliver the toxicant. Chemical control can also be coupled with chemical or physical management of trees or other structures.

Effectiveness:

There are a number of reported cases from around the world where chemical control using different methods has successfully controlled, or eradicated Argentine ant or invasive garden ant populations.

Effort required:

Depending on the objective, repeated applications are usually needed and, if long term control is required, the measure may need to be ongoing.

Resources required:

Expenses related to this measure are associated with the cost of purchasing the chemical products needed, training staff and paying for staff time to apply them.

Lasius neglectus © Phillip Buckham-Bonnett

Common rhododendron, *Rhododendron ponticum*

Rhododendron ponticum (common rhododendron) © Irish Fireside CC by 2.0

	Rhododendron ponticum
Native range	*Rhododendron ponticum* ssp. *ponticum* is native to northern Turkey and the Caucasus (Georgia, Russia), with a disjunct range in Lebanon; *Rhododendron ponticum* ssp. *baeticum* is native to southern Spain and Portugal.
Pathway(s) of introduction into the EU	Ornamental trade
Distribution in the EU	Ireland
Native pollinators impacted	Bees and bumblebees
Impacts	Provides abundant floral nectar, which is only available as a food source to pollinators that can tolerate the neuro-toxin it produces (grayanotoxin). Impacts pollinators indirectly (if native floral resources are replaced by *R. ponticum*) and directly (if they consume *R. ponticum* nectar). Major reservoir for non-native fungal pathogens (*Phytophthora ramoroum* and *P. kernoviae*), which present a major risk to woodland and forestry trees (e.g. beech and larch), and to ornamental plants.
Key species facts	Aggressive coloniser in acidic soils that produce a high number of seeds, making it one of the worst invasive plants in Ireland, and also the UK. Plants can begin flowering as early as 10 years old.

Available management measures

Prevention of new introductions

Measure

Engagement with horticulture sector to organise public awareness raising activities

Goal and description:

An alternative to prohibiting the sale of the species, is engagement with the horticulture sector to raise awareness of the impacts of invasive alien species. The intended outcome would be a voluntary Code of Conduct on the sale of high risk species that importers, nurseries, retailers, and other horticulture professionals sign up to.

In addition, raising public awareness of the impacts of IAS in general, and in particular in relation to the risks posed to the environment by ornamental plants, can be used to reduce intentional introductions. Such campaigns, often run by or with environmental groups with established access to the public and other stakeholders, can raise awareness in regards to specific species that are a risk to certain Member States (or parts of), or can be more general and promote the purchasing of (alternative) native species, or 'gardening for wildlife'. The public can also be reached through labelling and awareness raising through the horticulture sector themselves (as part of the voluntary Code of Conduct).

Effectiveness:

Little is known about the effectiveness of such horticultural codes of conduct; however, to be effective, public awareness campaigns require a well-developed implementation strategy and a great deal of effort, in particular by the horticultural sector bodies to ensure widespread adoption. The inclusion of monitoring and evaluation of their implementation and performance is also crucial, along with public disclosure, in order to provide the market incentive and social leverage for the adoption of the voluntary codes. In addition, they require evidence-based and independent advice (risk assessments) regarding which species need to be addressed.

Effort required:

Such activities would need to be in place permanently.

Resources required:

Resources are needed to facilitate engagement between governments, the horticultural sector and other relevant stakeholders to develop the codes of conduct and their implementation strategy. There then needs to be sustained long term funding to undertake public and horticultural sector engagement activities, species risk assessments, monitoring and evaluation, and reviewing and updating the various measures developed under the codes of conduct.

Prevention of secondary spread

Measure

Restriction of movement of soil and biosecurity measures on machinery and vehicles from infested sites, and the creation of quarantine areas

Goal and description:

In order to prevent secondary spread via movement of infected soil (with seeds), the adoption of best practices, potentially supported by regulations and certification schemes which restrict the movement of soil from infested areas, is needed. In addition, to reduce the risk of seeds being transported attached to vehicles, machinery, or equipment, it is necessary to inspect and clean all those that have been used within or close to infested areas.

In terms of natural secondary spread, the most effective control is through the eradication of the seed source population (see eradication measure below). However, minimising soil disturbance and the growth of bryophytes (which facilitate *Rhododendron* seed establishment) in high risk sites, would also reduce the opportunity for rhododendron to establish. Therefore, the use of 'quarantine' lines of unsuitable habitat that surround infested areas could prevent natural spread. Modelling has shown that a 150m wide quarantine line should contain a rhododendron population.

Effectiveness:

Restricting the movement of soil and applying biosecurity measures (inspection and cleaning of machinery etc.) will be effective at a site scale, but will not stop all instances of secondary spread of invasive plants from infested areas. This is particularly important as the species is widespread (but localised) in Ireland (and also UK), therefore these measures would need to be applied at sites where machinery or soil is being moved (e.g. where there is *Rhododendron* clearance work being undertaken) across a very large area. However, this could be a very effective measure for other countries where the species is not yet widely established, and where areas of conservation value are at risk.

In terms of the quarantine lines to prevent natural spread, the measure has not been tried in practice, though it is thought to be potentially effective.

Additional challenges that will reduce the effectiveness of any containment or control measures come from the fact that the species often occurs on private lands, including gardens where landowners cannot be forced to undertake control work (and may be unwilling for cost or other reasons), and therefore may continue to act as seed sources.

Effort required:

The measures would need to be in place until rhododendron infestations have been confirmed to be eradicated.

Resources required:

In terms of biosecurity measures, operations within areas that are infested (or near infested areas) would need access to trained staff to undertake inspections and cleaning activities, cleaning equipment, and quarantine areas. The quarantine lines would need to be supported by monitoring and rapid eradication capacity.

Surveillance measures to support early detection

Measure

Citizen science supported by active monitoring of vulnerable sites of conservation value

Goal and description:

R. ponticum is relatively easy to identify, and in the UK rhododendron biological distribution records are collected largely by citizen scientists. For countries and regions where the species is a potential threat, engaging with established citizen science networks (monitoring schemes), including those that are botanical and/or invasive species focused, and providing guidance on the species identification (see resources below), would support the early detection of the species. This would ideally be in conjunction with active monitoring of sites that are susceptible to invasions, e.g. sites of conservation value that are close to urban areas and that may harbour the species in private gardens.

Effectiveness:

These measures are known to be effective to understand the distribution and track the spread of the invasive species and therefore, if properly resourced, they should provide a relatively effective surveillance system to support early detection of the species.

Effort required:

The measures would need to be in place permanently.

Resources required:

For citizen science initiatives, resources for the production of materials for awareness raising, website/database and data recording smartphone apps are needed, although many already exist that could be used within Member States and at a European level. There are also staff costs associated with the validation, analysis and follow-up of submitted records.

Rapid eradication of new introductions

Measure

Hand pulling/digging of seedlings, and herbicide application of small bushes (although an integrated management plan should be followed)

Goal and description:

Rapid eradication methods follow the same protocols set out in the integrated management plan detailed below. Ideally, surveillance will detect early invasions of the species in the wild before they can reproduce (i.e. plants under 10 years old), or before they become major seed sources. Seedlings that have recently germinated and established are shallow rooted and can be manually hand pulled or dug out, and small bushes (<1.3m) can be treated with herbicide (foliar application).

Herbicide application, especially if applied in windy conditions, risks affecting non-target plants.

It is important to note that new occurrences in the wild are likely to be a result of secondary spread from mature bushes within private gardens and parks. Therefore, in addition to eradicating the new infestation, the source(s) of the seeds leading to the invasion in the wild would need to be identified and ideally removed.

Effectiveness:

For hand pulling/digging of seedlings, it is most effective in loose soils, especially when moist or wet. For herbicide application to small bushes (<1.3m height), all leaves need to be treated, as incomplete application will result in partial control and the bush will recover. The plants also need to be dry at the time of herbicide application and remain dry for a sufficient time to allow the herbicide to be absorbed into the plant (at least 6 hours, preferably longer).

Effort required:

Hand pulling/digging of seedlings can be applied at any time of the year. For herbicide (foliar) application, spraying is not 100% effective and, therefore, two or more treatments will be required. In general, it should be applied in frost-free and rain-free conditions.

Resources required:

For pulling/digging seedlings, gloves, bags, forestry mattocks or other hand tools are needed. For herbicide application, a knapsack sprayer at low pressure, or spot gun (for small seedlings only), can be used. It is necessary to have access to clean water close to the treatment site, and to use the correct safety clothing.

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Management of established populations

Measure

Integrated management plan (physical and chemical measures)

Goal and description:

The UK's Forestry Commission [13] and the Irish National Parks and Wildlife Service [14] have both published best practice guidance on the development and implementation of management plans to control rhododendron. In general, they provide guidance on how to map and prioritise areas for management, how to choose the most effective and safest methods to use on individual plants (depends upon the size, life stage, and accessibility of the target bush), and highlight the critical need for post-initial treatment surveys, and also for follow up or ongoing treatments.

Measures for seedlings and small bushes are described above in the rapid eradication section. Mechanical flailing followed by foliar application is recommended for medium sized bushes (>1.3m height) with no access to stems, where machine access is possible. Flailing will not kill the plants, and regrowth will occur from the stumps, which then need to be treated with herbicide foliar application, as discussed above. Manually cutting the stumps so that no live branches or shoots remain, can be undertaken where flailing cannot. Cutting stumps will also not kill the plants, and therefore, a herbicide needs to be applied as soon as possible, on the same day as cutting. For larger mature bushes where there is access to the stem, a drill or axe can be used to create a reservoir in the stem to apply the herbicide.

Effectiveness:

Broad scale management plans have been developed and undertaken in a number of sites in the UK and Ireland.

Effort required:

See above for the most effective time to apply herbicides.

Resources required:

For the flailing, a hydraulically powered mechanical flail with either horizontal or vertical shaft heads is needed. For manual cutting, a chainsaw or bow-saws can be used, and a paint brush or spot gun is needed to apply herbicide to the cut stump. For stem injections, a drill and a spot gun along with the herbicide and water is required. If accessing plants in difficult terrain, appropriate safety equipment and expertise will be required.

Rhododendron ponticum (common rhododendron) © Rasbak CC 3.0

Solidago canadensis (goldenrods) © Donald Hobern CC by 2.0

Goldenrods, *Solidago canadensis*, *Solidago gigantea* and *Solidago altissima*

	Solidago canadensis	*Solidago gigantea*	*Solidago altissima*
Native range	North America		
Pathway(s) of introduction into the EU	Ornamental trade		
Distribution in the EU	Widespread across EU	Widespread across EU	Belgium
Native pollinators impacted	Bees, bumblebees, butterflies, hoverflies		
Impacts	Modify ecosystems by outcompeting native flora, leading to a decrease in pollinator food sources.		
Key species facts	Produce large numbers of seeds through wind dispersal and rhizome growth, and can reproduce in their first year. Rhizome (clonal) growth often results in dense monospecific stands.		

Available management measures

Prevention of new introductions

Measure
Engagement with horticulture sector to organise public awareness raising activities

Goal and description:

Where the import and sale of the species is not restricted, an alternative strategy is the engagement with the horticulture sector to raise awareness of the impacts of invasive alien species. The intended outcome would be a voluntary Code of Conduct on the sale of high risk species that importers, nurseries, retailers, and other horticulture professionals sign up to.

In addition to the above, raising public awareness of the impacts of IAS in general, and in particular in relation to the risks posed to the environment by ornamental plants, can be used to reduce intentional introductions. Such campaigns, often run by or with environmental groups with established access to the public and other stakeholders, can raise awareness of specific species that are a risk to certain Member States (or parts of), or can be more general and promote the purchasing of (alternative) native species, or 'gardening for wildlife'. The public can also be reached through labelling and awareness raising through the horticulture sector themselves (as part of the voluntary code of conduct).

Effectiveness:

Little is currently known on the effectiveness of such horticultural codes of conduct; however, to be effective, they require a well-developed implementation strategy and great deal of effort, in particular by the horticultural sector bodies, to ensure widespread adoption. The inclusion of monitoring and evaluation of their implementation and performance is also crucial, along with public disclosure, in order to provide the market incentive and social leverage for the adoption of the voluntary codes. In addition, they require evidence-based and independent advice (risk assessments) regarding which species need to be addressed.

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Effort required:

Such codes of conduct would need to be in place permanently.

Resources required:

Resources are needed to facilitate engagement between governments, the horticultural sector and other relevant stakeholders to develop the codes of conduct and their implementation strategy. There then needs to be sustained long term funding to undertake public and horticultural sector engagement activities, species risk assessments, monitoring and evaluation, and reviewing and updating the various measures developed under the codes of conduct.

Prevention of secondary spread

Measure

Restrictions on soil movement, and inspections and cleaning of machinery and equipment from infested areas

Goal and description:

The only measure to prevent natural spread by seed dispersal is to control or eradicate populations (see below). Short-distance human assisted dispersal is possible by rhizomes, stem fragments, and seeds in infested soil, or attached to machinery. To prevent secondary spread via movement of infected soil best practices should be adopted, and potentially supported by regulations and certification schemes which restrict the movement of soil from infested areas. In order to reduce the risk of seeds or rhizomes/stem fragments being transported attached to machinery, it is necessary to inspect and clean machinery used within or close to infested areas.

Effectiveness:

As *S. canadensis* and *S. gigantea* are widespread across the EU, these measures would need to be applied across a very large area, making their effectiveness rather low. However, these measures could be effective for *S. altissima*, which is currently only known from within the EU from Belgium, and also for the other Solidago species at a local (sub-national) scale where there are fewer infestations, and where areas of conservation value are at risk.

Effort required:

The measures would need to be in place until *Solidago* infestations have been eradicated.

Resources required:

In terms of biosecurity measures, operations within areas that are infested (or near infested areas) would need access to trained staff to undertake inspections and cleaning activities, cleaning equipment, and quarantine areas.

Surveillance measures to support early detection

Measure

Repeated monitoring of habitats at high risk of invasion by field surveys (with remote sensing) and supported by citizen science

Goal and description:

S. canadensis and *S. gigantea* are already widely established within the EU, therefore early detection for these species is not relevant at a national scale for most EU Member States. However, the detection of these alien goldenrods needs to be incorporated into existing invasive species and botanical monitoring schemes (or needs to be established if they do not exist) for habitats that are susceptible to *Solidago* invasion (e.g. grasslands, wetland edges, riparian habitats, forest edges) and sensitive to their impacts (e.g. areas of importance for biodiversity conservation). To support physical surveys, remote sensing technology can be used to map existing species ranges and support the identification of sites at risk of invasion. In addition, citizen science schemes that are already contributing to the monitoring of the spread of *Solidago* species inside and outside of Europe should be used to retrieve new records.

Effectiveness:

Active monitoring of high risk sites was successful in the early detection of *S. gigantea* in unmanaged grasslands in South Africa. For citizen science in particular, it is important to note that the alien *Solidago* species can be confused with the native *S. virgaurea*.

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Effort required:

These measures would need to be in place permanently.

Resources required:

These measures would require trained staff to undertake monitoring and access to specialist knowledge to confirm identification. If remote sensing is used, it is necessary to have access to relevant camera technology, associated skills for image analysis, along with access to an aeroplane/drone to collect the images. For citizen science initiatives, resources for the production of materials for awareness raising, website/database and a recording smart phone app are required.

Rapid eradication of new introductions

Measure

Physical removal (hand pulling and digging), or herbicide application

Goal and description:

Small new infestations of *Solidago* can be effectively eradicated by hand pulling and digging out the rhizomes, ideally before flowering. Pulling the stem alone will leave parts of the rhizome network in the ground, from which the plant will regenerate. Repeated mowing (twice a year) over several years can also be used to eradicate small populations using the same methods as detailed below.

Herbicides can also be used to eradicate small populations, and can be sprayed on the foliage or applied by dabbing on a cut stump (what remains of the stalk after being cut).

Effectiveness:

Physical removal is effective, as long as the entire rhizome system is removed, and repeated treatments are applied. Herbicide application only needs to be applied once.

Effort required:

The measures will need to be repeated over a number of years to ensure that the species has been eradicated, as *Solidago* can form a persistent seed bank.

Resources required:

Trained people to effectively undertake pulling/digging/mowing or to apply herbicides, equipment (gloves, spades etc.), access to mowing equipment (tractor etc.), herbicides and safety and spraying equipment are needed.

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Management of established populations

Measure

Physical/mechanical control (cutting/mowing), or herbicide application

Goal and description:

Cutting twice a year (May and August, in Europe), with removal of the litter layer, followed by the sowing of native grass/forb mixture over several years, can be effective to control large infestations of *S. canadensis*, *S. gigantea* and *S. altissima*, resulting in a strong reduction of shoot density/coverage. For agricultural areas, tilling can be used to control the species.

Control can also be achieved through herbicide application, which should be applied when carbohydrates are moving from developed shoots back to the rhizomes. Germinating seedlings are also sensitive to herbicides.

Effectiveness:

Mowing or cutting twice a year, or the application of herbicides, have been shown to be effective at reducing goldenrod infestations.

Effort required:

Mowing with a machine or cutting need to be applied over multiple years for effective control. Herbicide application will need to be applied until the seed bank is exhausted.

Resources required:

Expertise, tools and machinery for cutting/mowing, and transport for removal of the litter layer are needed. Herbicides, trained staff, safety and spraying equipment are required, in case of herbicide application.

Invasive Alien Species and Pollinators – Annex I

IUCN guide to the EU Regulation on Invasive Alien Species 1143/2014

Regulation applies to:

All invasive alien species (IAS)*
- Introduced outside natural range
- Live specimens that may reproduce
- Adversely impact biodiversity and related ecosystem services

Listing criteria:

- Alien to the Union (exc. outer regions)
- Capable of establishing & spreading in >2 Member States or 1 marine region
- Adverse impacts to biodiversity & ecosystem services
- Risk Assessment shows concerted action at Union level required
- Inclusion on the *Union List* will effectively prevent, minimise or mitigate impacts

List of IAS of Union concern

Prevention measures

Emergency measures

- For IAS of imminent risk of introduction not on *Union List*
- IAS need to likely meet *criteria* for inclusion on *Union list*
- Member States (MS) may apply temporary *Restrictions*
- MS must notify Commission - to decide if apply EU wide
- MS must carry out Risk Assessment and submit for inclusion on *Union List*

IAS of Member State/regional concern

- MS may establish a national list of IAS and apply *Restrictions* and other measures at national level
- For IAS that require enhanced regional co-operation MS may request Commission to require MS concerned to apply the following measures: Action plans, Surveillance, Early detection, Rapid eradication, Management, and Restoration

* Regulation 1143/2014 scope excludes:
- Species that expand range without human intervention
- Non-native species covered by other EU legislation

'Union List' = 66 species

2016 = 37 species listed (23 animals and 14 plants)
2017 = 12 species listed (3 animals and 9 plants)
2019 = 17 species listed (4 animals and 13 plants)

Prevention measures

Restrictions

- IAS of Union concern shall not intentionally be; brought into the Union, kept, bred, transported, sold, used or exchanged, permitted to reproduce, grown or cultivated, released into the environment

Permits

- Permits issued by MS allowing for research or ex-situ conservation activities

Action plans

- Pathways analysis of unintentional introduction for IAS of Union concern
- Pathway action plans implemented for priority pathways (within 3 years of adoption)

Authorisations

- In exceptional cases for reasons of compelling public interest (incl. social or economic) MS may permit activities
- Authorisation required from Commission

Management of widespread IAS

Management

- MS have in place effective management measures for IAS of Union concern that are widespread in their territory (18 mo. of adoption)
- Based on cost-benefit analysis

Restoration

- MS carry out restoration to assist ecosystem recovery degraded by IAS of Union concern
- Based on cost-benefit analysis

Early detection and rapid eradication

Surveillance

- MS establish a surveillance system for IAS of Union concern
- Needs to able to rapidly detect new introductions

Controls

- MS have in place risk-based controls to goods imported to verify they are not on the Union List or are covered by a valid Permit

Early detection notification to EC

Rapid eradication

- MS undertake eradication (complete & permanent) within 3 months of notification
- Methods used with due regard to human health, environment and animal welfare

Derogations

- Within 2 months of detection, MS may not eradicate if one of the following apply:
  - Technically unfeasible
  - Cost-benefit analysis show costs disproportionate to benefits
  - Eradication methods not available or have serious impacts to human health or environment
- Can be rejected by Commission within 2 months

Invasive Alien Species and Pollinators – Annex II

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Additional resources

Megachile sculpturalis **(and** ***Megachile disjunctiformis*****), giant resin bees**

- Discover Life. *Megachile sculpuralis* https://www.discoverlife.org/mp/20q?guide=Megachile_female
- Le Monde des insectes Forum communautaire francophone des insectes et autres arthropods.

Megachile sculpuralis validated photos https://www.galerie-insecte.org/galerie/esp-page.php?gen=Megachile&esp=sculpturalis

- BugGuide. *Megachile sculpuralis* https://bugguide.net/node/view/15541
- BugGuide. *Megachile disjunctiformis* https://www.discoverlife.org/mp/20q?search=Megachile+disjunctiformis&mobile=close&wep=0
- Exotic bee ID *Megachile* http://idtools.org/id/bees/exotic/factsheet.php?name=16425

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- European Code of Conduct on horticulture and invasive alien plants. Convention on the Conservation of European Wildlife and Natural Habitats, Standing Committee. Council of Europe, T-PVS/Inf (2008) 2. (Illustrated version (2011) - https://www.coe.int/en/web/bern-convention/on-invasive-alien-species

***Vespa velutina nigrithorax*, Asian hornet**

- GB Non-native Species Secretariat Asian Hornet factsheet http://www.nationalbeeunit.com/downloadDocument.cfm?id=698
- UK National Bee Unit page on Asian hornet, incl. information on trap construction http://www.nationalbeeunit.com/index.cfm?sectionid=117
- EU Life funded 'Stop Vespa' project https://www.vespavelutina.eu/en-us/vespa-velutina
- iNaturalist Vespa watch https://www.inaturalist.org/projects/vespa-watch
- EC European Alien Species Information Network citizen science smartphone app https://easin.jrc.ec.europa.eu/easin/CitizenScience/About
- UK 'Asian hornet watch' smartphone app http://www.nonnativespecies.org/alerts/index.cfm?id=4

***Lasius neglectus*, invasive garden ant and *Linepithema humile*, Argentine ant**

- AntWeb https://www.antweb.org/
- Bay Area citizen science Ant survey http://www.birds.cornell.edu/citscitoolkit/projects/calacademy/antsurvey
- GB Non-native Species Secretariat factsheet on Argentine ant http://www.nonnativespecies.org/factsheet/factsheet.cfm?speciesId=2020
- Pacific Invasive Ant Toolkit - http://www.piat.org.nz/story-map
- Argentine Ants in New Zealand - https://argentineants.landcareresearch.co.nz/index.asp
- *Lasius neglectus*, CREAF - http://www.creaf.uab.es/xeg/lasius/index.htm
- AntWiki - http://www.antwiki.org/wiki/Welcome_to_AntWiki

***Rhododendron ponticum*, common rhododendron**

- Forestry Commission Practice Guide – Managing and controlling invasive rhododendron https://www.forestry.gov.uk/pdf/fcpg017.pdf/$FILE/fcpg017.pdf
- Irish Wildlife Manual. *Rhododendron ponticum*: A guide to management on nature conservation sites. https://www.npws.ie/sites/default/files/publications/pdf/IWM33.pdf
- The Control of Rhododendron in Native Woodlands. Native Woodland Scheme Information Note No. 3. Woodlands of Ireland. https://www.woodlandsofireland.com/sites/default/files/No.%203%20-%20Rhododendron%20Control.pdf
- Cleaning heavy equipment used on land to minimize the introduction and spread of invasive species. http://files.dnr.state.mn.us/natural_resources/invasives/terrestrialplants/equipment_cleaning_to_minimize.pdf

- ISMP 41 International movement of used vehicles, machinery and equipment. https://www.ippc.int/static/media/files/publication/en/2017/05/ISPM_41_2017_En_2017-05-15.pdf
- GB Non-native Species Secretariat Rhododendron ID sheet http://www.nonnativespecies.org/downloadDocument.cfm?id=71
- UK Environmental Observation Framework. Understanding citizen science and environmental monitoring https://www.ceh.ac.uk/sites/default/files/citizensciencereview.pdf
- EC European Alien Species Information Network citizen science smartphone app https://easin.jrc.ec.europa.eu/easin/CitizenScience/About

***Solidago canadensis, Solidago gigantea* and *Solidago altissima*, goldenrods**

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- European Code of conduct on horticulture and invasive alien plants. Convention on the Conservation of European Wildlife and Natural Habitats, Standing Committee. Council of Europe, T-PVS/Inf (2008) 2. (Illustrated version (2011) - https://www.coe.int/en/web/bern-convention/on-invasive-alien-species

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- GB - http://www.nonnativespecies.org/index.cfm?pageid=299
- Ireland - http://invasivespeciesireland.com/wp-content/uploads/2010/07/Horticulture-Code-Final.pdf
- Belgium - https://www.health.belgium.be/en/code-conduct-invasive-plants
- Netherlands - https://www.nvwa.nl/documenten/nvwa/organisatie/convenanten/publicaties/convenant-waterplanten
- Cleaning heavy equipment used on land to minimize the introduction and spread of invasive species. http://files.dnr.state.mn.us/natural_resources/invasives/terrestrialplants/equipment_cleaning_to_minimize.pdf
- ISMP 41 International movement of used vehicles, machinery and equipment. https://www.ippc.int/static/media/files/publication/en/2017/05/ISPM_41_2017_En_2017-05-15.pdf
- GB Non-native Species Secretariat *Solidago canadensis* factsheet (incl. native *S. virgaurea*). http://www.nonnativespecies.org/factsheet/factsheet.cfm?speciesId=3323
- NOBANIS *Solidago canadensis* factsheet https://www.nobanis.org/globalassets/speciesinfo/s/solidago-canadensis/solidago-canadensis.pdf
- Manual of the alien plants of Belgium *Solidago altissima* http://alienplantsbelgium.be/content/solidago-altissima
- Life Project CSMON - *Solidago gigantea*, Verga d'oro maggiore http://www.csmon-life.eu/pagina/dettaglio_specie/193
- Bund (Friends of the Earth Germany) Citizen science for young researchers for young researchers http://www.bonn.bund.net/uploads/media/BUND_Neophyten_Broschuere_2015_Vers_2.pdf & http://www.bonn.bund.net/uploads/media/Solidago_canadensis.pdf
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Switzerland:

- Raccomandazioni dell'AGIN B: *Solidago canadensis/gigantea* Versione 1.0 https://extranet.kvu.ch/files/documentdownload/150218093126_04_R_Verga_d_oro.pdf
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Hungary:

- Hungarian Little Plain project (EU Life) http://www.kisalfoldilife.hu/en/content/conservation-action

France:

- Fédération des Conservatoires botaniques nationaux
http://www.fcbn.fr/sites/fcbn.fr/files/ressource_telechargeable/fiche_solidago_canadensis_sr.pdf &
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