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Viewpoint

Challenges and solutions in early detection, rapid response and communication about potential invasive alien species in forests

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Abstract

Invasive alien species (IAS) are an important threat to forests. One of the best ways to manage potential IAS is through early detection and rapid response (EDRR) strategies. However, when dealing with IAS in forests, EU regulations are divided between phytosanitary regulations and IAS regulations. A version of EDRR for the former has been in place in the EU for more than 15 years while the latter is still in the process of being implemented. During 2019, a workshop was held to gather international experts on different plant health pests and IAS. The purpose of this workshop was to identify the opportunities and difficulties in applying the EDRR system in the EU phytosanitary and IAS legislation to four species for providing suggestions to improve the EDRR system. The model species are well known and come from different trophic levels. These species were the American pokeweed (*Phytolacca americana*), the grey squirrel (*Sciurus carolinensis*); and the plant health pests *Geosmithia morbida* and Emerald ash borer (*Agrilus planipennis*). We identified the similarities in the challenges of early detection, rapid response and communication of these species. For all species, difficulties in species identification, knowledge gaps on the pathways of spread, a lack of resources and uncertainty over which national government service was the competent authority were identified as the main challenges. Other challenges like public perception for the grey squirrel or methodological problems were species-specific. Regarding the rapid response: public perception, determination of the eradication area, sufficient scientific capacity and the lack of resources were common challenges for all species. Therefore, collaboration between institutes dealing with plant health pests and IAS can lead to better control of both groups of unwanted organisms in forests.

Key words: early warning and rapid response system, plant health legislation, EU IAS legislation, alien species, *Geosmithia morbida*, Emerald ash borer, American pokeweed, Grey squirrel

Introduction

Forests are often complex systems with great importance for biodiversity, the economy and human health (Streck and Scholz 2006). They function as carbon sinks for the increasing levels of greenhouse gasses, which relates to climate change in the recent century (Aalde et al. 2006). However, in recent decades, forests are also under pressure from over-exploitation by humans and/or severely increased frequency of biotic (pathogens, insects, etc.) and abiotic disturbances (droughts, storms, fires, etc.) (La Porta et al. 2008; Klapwijk et al. 2013; Hirka et al. 2018; Kunca et al. 2019). Another important threat to forests is the increasing number of invasive alien species (IAS) (Liebhold et al. 1995; Roques 2015). IAS are alien species whose introduction or spread has been found to threaten or adversely impact biodiversity and related ecosystem services (EU Regulation 1143/2014). In the context of this article, we also consider plant pests (including pathogens) as IAS. A plant pest is any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products (FAO 2017). These IAS are brought by human-mediated translocation to new habitats where they lack natural enemies or encounter "naïve" hosts that have not developed resistance to them (Nunez-Mir et al. 2017; Csóka et al. 2017). In recent years, management practices to combat IAS have been developed, but these have had mixed results due to a variety of reasons (Pluess et al. 2012; Klapwijk et al. 2016). In many cases, efficient control is extremely difficult and expensive, particularly if there is a delay in recognizing the problem and applying the appropriate control measures.

The level of success of eradication campaigns for established IAS is higher when the populations are only locally established or have invaded confined areas such as islands (Genovesi 2011). However, eradication success often requires long-term financial support and dedicated management actions over many years (Kettenring and Adams 2011). Therefore, it is always easier to prevent potential IAS from entering a country, or to eradicate them when only locally established (Simberloff 2003).

Early detection and rapid response (EDRR) is a system to prevent the establishment of an IAS in a new country/area. An EDRR system combines different tools to detect IAS and eradicate them as early as possible (Yang et al. 2011). An effective EDRR system at national level uses verified data from surveillance programmes (including data from both professional and amateurs surveyors) to enable rapid assessment of the scale of the regulated organisms' distribution, followed by effective eradication measures by the official national responsible body (e.g. National Plant Protection Organisation in the case of plant pests) (Figure 1). Most of the EDRR systems focus on entry pathways like ports, airports, railways, roads, distribution centres (Carnegie and Nahrung 2019) or where IAS are likely to be detected such as urban areas with special regards to pet or plant trade (Kaiser and Burnet

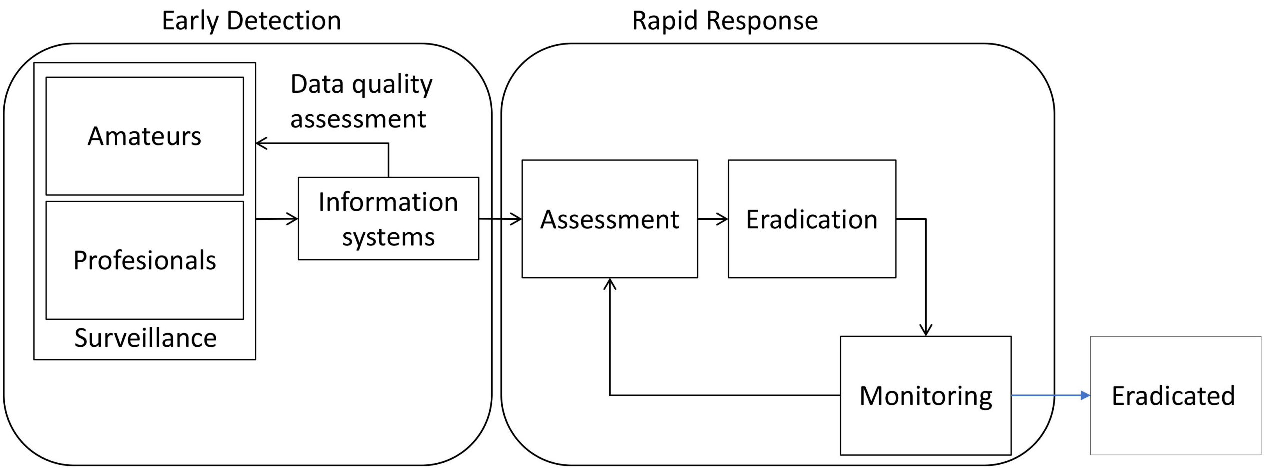

Figure 1. Flow chart representing the main stages of a system for the early detection and rapid response of regulated plant health pests or IAS in the EU.

2010). Worldwide, the evidence indicates that the implementation of an EDRR system has many challenges (Bulman 2008; Lovett et al. 2016; Carnegie and Nahrung 2019).

The European Union (EU) legislation on plant health focuses on pests that are affecting the health of plants (Regulation (EU) 2016/2031), while the EU regulation on IAS (EU Regulation 1143/2014) excludes pests of plants but includes other species which severely affect biodiversity and ecosystem services in the European Union. Plant health legislation has a long history, with the current legislation (Regulation (EU) 2016/2031) being the 3rd iteration specifically dealing with plant pests since the creation of the EU. It came into force in December 2019, replacing the previous legislation (Directive 2000/29/EC) which was active since 1993. The current legislation includes lists of pest species (priority, quarantine, and regulated non-quarantine pests), that can be subject to phytosanitary measures. The legislation lists high-risk hosts whose import into the EU is banned until a full commodity risk assessment is carried out to prove that they are not a risk to EU plant health.

A legal framework came into effect in January 2015 (EU Regulation 1143/2014), and provides a firm basis for addressing threats posed by IAS harmful to biodiversity in the EU. Species on the Union list require actions from EU Member states to prevent their spread, eradicate or manage them. So far 66 species are included on the list, including terrestrial and aquatic plants, mammals, fish, crayfish and invertebrates. The EU Regulation also provides a timeframe by which EU Member states are obliged to establish EDRR systems and introduce other measures to prevent introduction and spread. The experience gained by establishing an EDRR for plant health pests could guide and benefit the establishment of an EDRR for other IAS.

The current paper provides an overview of the challenges encountered when developing an EDRR system for IAS taxa of different taxonomic groups. The aim of this manuscript is to explore the differences, similarities and solutions in employing an EDRR systems for detecting four very different model IAS species:

- A plant – American pokeweed *Phytolacca americana* Linnaeus, 1753 (Caryophyllales: Phytolaccaceae) is a poisonous herbaceous plant native to North America that is being currently considered for regulation by the EU IAS legislation. However, it is spreading rapidly in central Europe, causing problems by densely overgrowing the understorey vegetation layer and outcompeting plant species living in the ground layer.
- A fungal pathogen – *Geosmithia morbida* Kolarík, Freeland, Utley & Tisserat, 2010 (Hypocreales: Incertae sedis) is the causal agent of a disease known as thousand canker disease (TCD) in walnut trees (Hishinuma et al. 2015). In Europe, it was first detected in Italy in 2013, and it is spreading (Montecchio and Faccoli 2014). It is a regulated species under the phytosanitary legislation. The disease is vectored by the walnut twig beetle (WTB), *Pityophthorus juglandis* Blackman, 1928 (Coleoptera: Curculionidae, Scolytinae) (Tisserat et al. 2009) and can kill walnut trees (*Juglans* spp.) in three years (Montecchio et al. 2016).
- An insect – emerald ash borer *Agrilus planipennis* Fairmaire, 1888 (Coleoptera: Buprestidae) (EAB) is a pest of ash trees (*Fraxinus* spp.), originating from Northeast Asia. It is highly invasive in North America, killing hundreds of millions of ash trees and causing severe ecological damage and economic loss (Cappaert et al. 2005; Kovacs et al. 2010). In 2003, the pest was documented in the European part of Russia (Haack et al. 2015), and in Ukraine in 2019 (EPPO 2019). This species is regulated under the EU plant health legislation.
- A mammal – grey squirrel *Sciurus carolinensis* Gemlin, 1788 (Rodentia: Sciuridae) is native to North America and has invaded the UK, Ireland and north-western Italy. In Europe, it outcompetes and transmits an infection that is epizootic in sympatric native red squirrel (*Sciurus vulgaris* Linnaeus, 1758), and causes damage to trees by bark stripping. Since 2016, the grey squirrel is listed as an IAS of Union concern by the EU Regulation.

These four model species were chosen because there is already a large amount of experience accumulated globally regarding their detection, control and eradication.

During the LIFE ARTEMIS conference in 2019 (Zidar 2019), workshops were held with experts on different IAS groups from all over the world with presentations on EDRR systems and discussions regarding the challenges and possible solutions for the EDRR particularly towards the above-mentioned model species. We first categorized the different challenges

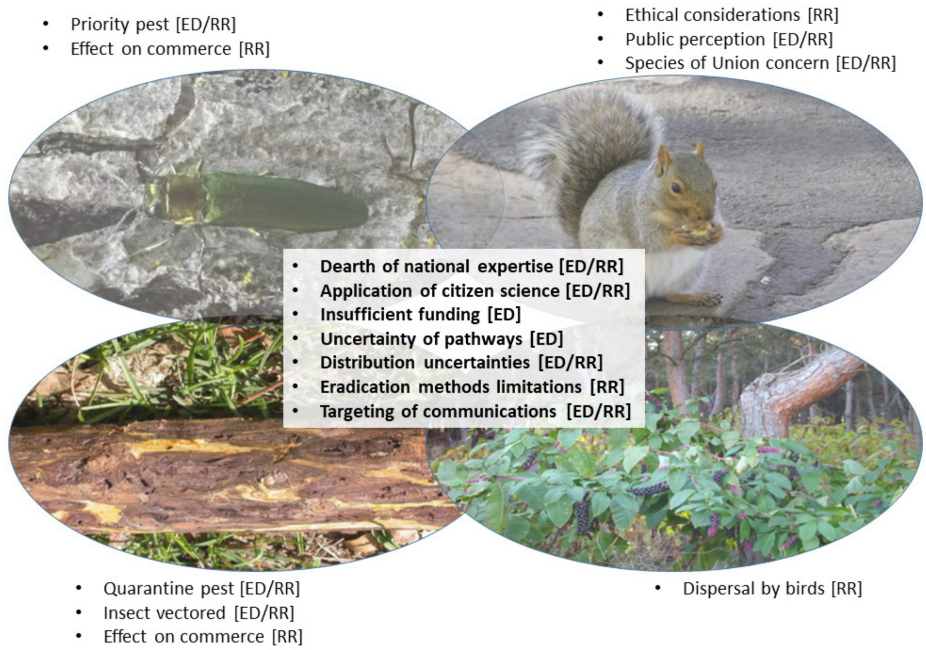

Figure 2. Venn diagram graphical representation of the four model species used in this study. Issues common to all species are listed in the centre box. Issues specific to a single species are listed in the box next to that species. The relevant EU regulations governing the different model species has been overlaid on the relevant species. Whether the problem is evident in the early detection [ED] or rapid response [RR] is listed in square brackets after the problem. Image credits: emerald ash borer – David Williams; grey squirrel – Merike Linnämagi, www.nobanis.org; thousand canker disease – Ned Tisserat, Colorado State University, www.Bugwood.org; American pokeweed – Ágnes Csiszár.

which are not yet resolved by the EU plant health or IAS legislation. Some solutions to these challenges are proposed and could be transferred between the different case study species. A particular focus is placed on effective communication with and among stakeholders, as it has been proven of pivotal importance for the successful implementation of an EDRR system against IAS.

Challenges and solutions for effective early detection

Following the workshop in 2019, a list of issues for each model species was developed by the workshop participants (Table S1). These issues were grouped according to whether they were common to the four model species, or specific to one/some of the model species (Figure 2).

The procedures and methods needed for the early detection of an IAS, where eradication is still possible, are herewith considered as part of the EDRR. Possible challenges and solutions for early detection are described below.

Common challenges

The following common problems were identified for the early detection of the four model species: species identification, insufficient resources for monitoring, insufficient information on how to contact the national competent authority to report a finding, a dearth of national available experts, and uncertainty on pathways of spread.

Species identification

Species identification was for all species an issue but depends on the context or the life history.

For the American pokeweed, identification of young plants is complicated because they are morphologically similar to some European native plants (e.g. deadly nightshade (*Atropa belladonna*)), while in contrast adult plants are relatively easily identified. Regarding the recognition of American pokeweed, guides (field guides, leaflets, educational material, etc.) must be prepared to help with identification of the plant. For the grey squirrel identification might also be an issue, because coat colour variation can confound differentiation from native red squirrels (Shuttleworth et al. 2016).

In the case of the two plant pests, there were challenges identified in the accurate identification of both TCD and EAB. *Geosmithia morbida* and its vector are species which are not conspicuous. Detection of the pathogen using molecular methods (e.g. Moore et al. 2019) is preferable to isolation, because of the high rates of non-recovery when isolating the pathogen from naturally infected material (Seabright et al. 2019). Early detection of the WTB is hampered because of its small size (1.5–1.9 mm in length) and the large potential for infection of the host without obvious symptoms (EPPO 2015). Wood boring insects are notoriously difficult to detect, and EAB is no exception. In the early stages, infested ash (*Fraxinus* spp.) trees are asymptomatic and the presence of EAB may go unnoticed until after adult beetles have emerged from the tree. The characteristic, D-shaped exit holes are rather small, up to 4 mm and may be difficult to spot in early stages of infestation because the beetle first attacks the tree in the upper canopy. Ash dieback (*Hymenoscyphus fraxineus*), which is widely present throughout Europe and causes the decline of ash trees could potentially mask the signs of EAB infestation. Nevertheless, closer examination of suspect trees, e.g. searching for exit holes of beetles on bark or serpentine galleries of larvae under the bark, confirm the presence of EAB. EAB can be confused with other jewel beetles (Buprestidae) or the galleries made by longhorn beetle larvae (Cerambycidae) (Volkovitsh et al. 2019), leading to false reporting by citizens. As a result, survey data obtained by citizen volunteers and data collected on the same trees/plots by an expert can be contradictory (Roman et al. 2017).

Official point of contact

Once detection and proper identification has occurred, a common problem to the four model species was a lack of knowledge of which official authority to report the finding. During the workshop several participants noted that they were unsure of the relevant competent authority responsible for the model species in their country. In many countries the Ministry of agriculture is the National Plant Protection Organisation (NPPO) (Eschen 2017), and is responsible for plant health pests. The competent authority for reporting IAS varies between the countries and can be a national Ministry, such as an environmental and/or a provincial governmental body. It is therefore important to communicate to the surveyors who use the information system whom they should contact to notify a finding of an important IAS.

Insufficient resources

Insufficient resources were identified as a problem in the early detection for all of the model species. This is particularly true when a species is not regulated, like in the case of American pokeweed. For a quarantine species under the plant health legislation, surveys are in part financed by the EU. To improve the national surveys with the highest chance of detecting the model species early in its invasion, a validated system of combining and collating survey records from both professional and amateur recorders is needed. Examples of validated systems for national amateur recorders are the Observatree system in the UK (https://www.observatree.org.uk) and the Invazivke information system in Slovenia (https://www.invazivke.si). Having effective surveillance and reporting mechanisms in place would lead to a more comprehensive understanding of the species spread, and accurate delimitation of the species' distribution area.

For the EAB and the grey squirrel, a lack of resources were also identified as most problematic in the rapid response phase.

A solution to the lack of resources (including experts) would be to invest in the training of people who already work in forests. For example, well-trained district foresters and national park rangers are important to inform and instruct forest owners, green area managers, riverbank managers, and citizens, in the identification of the IAS for early detection. In the case of American pokeweed, employees of electricity companies should be informed as American pokeweed mainly occurs in open areas in forests like electricity lines where it is brought by birds. EAB has been spreading westward from Russia towards Europe since its first detection in Moscow in 2003 (Baranchikov et al. 2008), and more recently in Ukraine (EPPO 2019). A comprehensive monitoring and surveillance programme will be required under the plant health regulation, as EAB has been listed as one of the 20 priority pests for the EU. This means that national annual risk based surveys, extensive public and industry awareness campaigns, and the development and testing of contingency plans is needed for this pest. Any such public awareness campaign could benefit from the experience of successful past projects such as that to limit the spread of the Asian longhorn beetle (*Anoplophora glabripennis*) and Citrus longhorn beetle (*A. chinensis*) in Italy (Ciampitti and Cavagna 2014). For the grey squirrel there was a successful establishment of citizen scientists monitoring and controlling grey squirrel in LIFE14 NAT/UK/000467 project (Shuttleworth et al. 2020).

Lack of knowledge of pathways of spread

To prepare a good ED system for IAS it is important to focus on the pathways of introduction. However, for the four model species the pathways were either difficult to identify or impractical in the field to monitor. The berries (i.e. seeds) of American pokeweed, which are poisonous for people and mammals, are consumed by birds (harmless for them), and seeds can be dispersed quickly over long distances (Li et al. 2017). The highest risk pathway for *G. morbida* and *P. juglandis* is unprocessed, fresh walnut logs and wood, whereas walnut plants-for-planting are not known to be an important pathway (EPPO 2015). There is also uncertainty about the natural spread potential of the insect vector. Laboratory flight mill experiments have shown that adults can fly 2 km in a day (Kees et al. 2017). The extent to which wind speed, humidity and air pressure affect natural spread of WTB is unclear (EPPO 2015), but the very small size of adult beetles suggests the possibility of a passive long-distance dispersal by wind. Adult EAB are also capable of flying over relatively long distances. Grey squirrels can also rapidly colonise forest landscapes via natural dispersal once they have been introduced (Teangana et al. 2000).

The movement via human enterprise (e.g. trade, recreational activities) was identified for all of the model species. Movement of TCD on logs is one possible explanation for the large expansion (over 300 km) of the pests range between reports in 2016 (EPPO 2016) and 2019 (Guidotti et al. 2019). The EAB can also spread via movement of wood and wood packaging material (EPPO 2013a). In North America, the cultural practice of transporting firewood to campsites on recreational vehicles has led to the rapid spread of EAB across the continent (Koch et al. 2012). Globally there is a large international trade in wood commodities, and this is seen as a major pathway for many insect pests (Meurisse et al. 2019). Several researchers have identified the need for improvements in the phytosanitary surveillance of wood and wood packaging pathway (Haack et al. 2014; Eyre et al. 2018). This improved inspection should be backed up by reliable pathway analysis and identification of high-risk areas to anticipate points of EAB introduction direction of spread. The techniques for early detection of EAB also need to be improved and monitoring programs among countries need to be harmonized, based on perspective detection approaches and international policy standards (Semizer-Cuming et al. 2019). There have been examples of both the American pokeweed and the grey squirrel being introduced (accidentally and purposefully) to new areas (Signorile et al. 2016; Hoppenreijs et al. 2019).

Need for improvement in monitoring technologies

For all of the model species the technologies for monitoring would benefit from further improvement. Trapping systems for WTB monitoring, based on volatile organic compounds, have been developed and deployed effectively in surveying for this pest. For example, annual surveys of WTB populations in Italy using multi-funnel traps baited with specific aggregation pheromones have shown good efficacy (Faccoli et al. 2016). For EAB, EAB-green sticky prism traps or Fluon-treated multi-funnel traps placed in the upper canopy of ash trees and baited with a pheromone and green leaf volatile have proved to be useful (Francese et al. 2013; Silk et al. 2019), but they are less effective in some cities, likely due to limited attractive radius of the traps in these studies particularly when the pest is present at low densities. In addition, the placement of traps in towns and cities can be problematic due to the significant size of some of the traps designed for capturing buprestids. To increase the effectiveness of pest detection, girdled trap trees could also be used (Mercader et al. 2013) as a means to monitor EAB by citizens. A program like "adopt-a-tree" could be established on a large scale, recruiting citizens to carry out systematic and careful visual inspections of trees in their area and report symptoms of EAB. To accurately identify infested trees during ED, a method that can detect EAB-infested trees before the tree exhibits external signs of infestation, involves the careful peeling of the outer bark from the basal 50 cm of each of two mid-crown branches (Ryall et al. 2011). Legg et al. (2014) estimated that peeling branch samples from 148 trees would detect EAB with 90% probability in an area with as few as 3% of trees infested. This method has been used in Canada and provided the first detection of EAB in Quebec City – one small gallery and immature larva detected in a sample of 233 trees (466 branches) (Robert Lavalée *pers. comm.*). Sniffer dogs are capable of detecting trees infested with Asian long-horned beetle (Hoyer-Tomiczek et al. 2016), and preliminary studies testing their feasibility for detecting EAB-infested trees are underway (Hoyer-Tomiczek and Hoch 2020), so this method may be available for EAB detection in the future.

There is a knowledge gap in the efficacy of the use of sentinel trees in order to provide an ED system for TCD and EAB. These have been used in several regions and for several pests previously (Eschen et al. 2019a), and methods have been developed (Morales-Rodríguez et al. 2019; Eschen et al. 2019b) to improve their effectiveness. Monitoring of susceptible hosts in botanic gardens would further develop our knowledge of a pests host range and distribution (e.g. Csóka et al. 2020). Accurate mapping of all street trees within a city would help target risk-based surveillance in order to detect or delimit the spread of EAB and TCD. For example, the city of Belfast in Northern Ireland, UK has a comprehensive openly available database of all trees within the city limits (https://www.opendatani.gov.uk/showcase/the-public-trees-of-belfast-city). In Canada, the costs of obtaining an inventory of street tree species in Fredericton, New Brunswick, was greatly reduced by engaging the services of forestry students at the University of New Brunswick who made it a class project (Anon 2016). Although, camera traps are an effective non-invasive grey squirrel monitoring method, especially when deployed in remote areas (Goldstein et al. 2014), these rely on attracting animals to food baited locations at key geographical locations (Sapsford 2019) with associated inter-specific infection risks.

Ineffective or not available eradication methods

Ineffective or unavailable eradication methods were listed as a problem for all model species. For the American pokeweed, little research has been done on trying to find effective methods for its eradication. In Slovenia, local efforts to eradicate the species by cutting did not work efficiently, however, during the LIFE ARTEMIS project pulling of saplings and digging up of plants was tried and early evidence indicates that these methods are effective. To prevent infestation in forests, alternative forest management practices—for example selective cutting instead of clear-cutting, tending of young forests, and quick reforestation—would help reduce the suitable environments for the American pokeweed to establish. For the TCD, given the lack of effective treatment options, eradication programs rely on the removal and destruction of infested trees. This may help to slow the spread, but it is often hindered by incomplete host inventories and variation in susceptibility among host species (USDA 2009). In addition, current treatments applied to walnut to protect against common pests would have no effect on either the pathogen or the vector (EPPO 2015). Once the fungus has colonized the host tissues, it will continue to grow, thus systemic and contact insecticides targeting the beetle do not prevent the progress of the disease (Frank and Bambara 2019). The bark protects them from most chemical intervention and pruning of infected branches is ineffective as by the time symptoms develop the pathogen/vector will have spread systemically (EPPO 2015). Recent results have shown that methyl bromide fumigation, a product no longer registered in the EU, can be effective at killing the pathogen and vector in its the wood and wood packaging pathway (Seabright et al. 2019). Preventative measures for use in the field such as using the entomopathogen *Beauveria bassiana* and/or the insecticide permethrin to control the vector have shown promising results (Mayfield et al. 2019).

As the EAB is already invasive in the USA, there was already more research done for RR (Mercader et al. 2015). However, the limited control options to deal with EAB (emamectin benzoate which is extensively used in the US to deal with EAB is not widely approved for use within Europe) would seriously compromise any eradication or containment efforts. The insecticide TreeAzin, which protects ash trees from EAB for up to 2 years and has low toxicity to non-target species, may have more public acceptance (McKenzie et al. 2010; Mercader et al. 2015). Finally, research on alternative controls, such as breeding of EAB-resistant ash is being explored (Herms et al. 2015; Wu et al. 2019). Recent evidence in the US indicates a small percentage of North American ash have survived EAB invasion and will be tested for putative resistance in tree breeding programs (Tanis and McCullough 2015; Showalter et al. 2020).

For the eradication of the grey squirrel, live-trapping or shooting are effective removal tools (Gill et al. 2019). However, trapping can be labour intensive with frequent daily trap inspections needed where red squirrel is present, or where there is a significant risk of capturing non-target species (Shuttleworth et al. 2016).

Contingency planning

Contingency planning was identified as an important activity for all of the four model species. Contingency planning includes a number of parts, including identification of roles and responsibilities for government and stakeholders in emergency response to a detection of a regulated organism, information on operational activities to contain/eradicate the regulated organism, suitable communication activities to be conducted, and detail of the need for regular tests of the contingency plan (EPPO 2009). As stated earlier, EAB is a priority pest under the EU plant health regulation, therefore EU Member states will need to develop contingency plans for this pest. Several national and regional contingency plans already exist for EAB (Forestry Commission 2017; Anon 2018). There are also EAB-specific containment/eradication standards available to guide national responses to EAB detections (EPPO 2013b). Contingency plans are often situation specific. For example, the most likely scenario for EAB invasion into EU Member states was probably interceptions on traded wood products or plants for planting. However, given the current spread pattern of EAB westwards from Russia through Ukraine, the contingency plans may need to be organised under different invasion scenarios. To the best of the authors' knowledge, no contingency plans exist for TCD or grey squirrel. American pokeweed is not a regulated species therefore the establishment of a contingency plan at national level is probably of low priority. Due to the long history of contingency planning in plant health science, there may be much cross learning in the plant health sector for those in the IAS sector.

Species-specific problems

Legislation

The workshop participants also highlighted some issues that were unique to one of the model species. While EAB, TCD and the grey squirrel are all regulated under EU legislation, American pokeweed is not yet. Listing a species in legislation enables the strongest means of controlling its spread. Such legislation would ensure the development and implementation of an EDRR system for American pokeweed in the EU.

Public attitude

A problem specific to the grey squirrel is that surveillance reliant upon the general public may be hampered by citizens being unwilling to report sightings because of concerns about control using lethal means (Dunn et al. 2018). Any requests for information and sightings must therefore clearly communicate the risk posed to native red squirrels by grey squirrels. In particular, in the UK and Ireland, grey squirrels carry squirrel pox virus infection (Romeo et al. 2019) and therefore parallel disease surveillance of sympatric red squirrels is necessary in the vicinity of the congener (Everest et al. 2017).

Implications of pathogen-insect relationships

Many plant pathogens need a vector—very often an insect—for their dispersal in new habitats. The low frequency of occurrence of *G. morbida* on generic vectors such as *Stenomimus pallidus* (Coleoptera: Curculionidae) suggests a very casual relationship between the fungus and this beetle, a hypothesis supported also by the low population density of *S. pallidus* indicating that it may not be capable of vectoring enough of the pathogen to adversely affect tree health (Ginzel and Juzwik 2014). Instead, the strong interactions occurring between *G. morbida* and *P. juglandis* must be considered as one of the major components of a highly specific insect-pathogen complex, where the containment of the vector may have significant effects on the dispersal potential of the pathogen. Unfortunately, in the rapid response against the TCD invasion, the capacity to manage the insect-pathogen complex is usually limited, with efforts to promptly control the vector considered ineffective in the reduction of the TCD spread in the USA (Cranshaw and Tisserat 2009). Nevertheless, in some cases the TCD early detection is also possible in the absence of specific disease symptoms. In 2013, adults of *P. juglandis* were caught in traps in Maryland, but *G. morbida* had not been identified through search for visual symptoms and random sampling of branches. In 2014, adults were trapped again in that same traps, and *G. morbida* was also identified from a log baited with *P. juglandis* pheromone (Maryland Department of Agriculture 2014). A similar trend was recorded also in Italy where the *P. juglandis* populations are monitored with pheromone traps since 2014—leading to the first record of the species in Europe (Montecchio and Faccoli 2014)—in the main walnut plantations of the Northern regions. The presence of TCD infection symptoms are also investigated visually on the plantation trees, and very often evidence of the pathogen presence is recorded only the year following the first insect discovery in the plantation (Faccoli *pers. observation*). In this respect, fungus-vector relationships have strong implications in the early-detection mechanisms, because the development of the disease “thousand cankers” needs the combined presence of both *P. juglandis* and *G. morbida*, making the early interception of the vector a prerequisite for the occurrence of the pathogen.

Effects on commerce

Especially when the IAS are associated with plants, an economical aspect will follow (Born et al. 2005). This might have implications for the willingness of people to submit their record of the tree pest. On one hand it might be that the neighbouring forest owner realises the consequences of the submission of the record of a priority species, which can lead to all the host plants are being destroyed (Mackenzie and Larson 2010). However, in Slovenia it was shown that forest owners are in favour of cutting the trees in order to eradicate a particular species (Japelj et al. 2019). It is important that awareness is raised regarding the problems of the particular species.

In the cases of two of the model species a significant potential effect on commerce in outbreak areas was identified. In the vicinity of an outbreak of either EAB or TCD the NPPO would most likely impose extensive phytosanitary control mechanisms. For example, a ban on trade of susceptible host plants, and the untreated wood of host plants would most likely be enacted in the area surrounding the outbreak. Furthermore, eradication treatments applied to susceptible host plants could negatively affect trade and tourism in the infested area. In the case of EAB, the PRA for the EU area listed the potential negative economic, environmental and social impacts of an EAB outbreak as being high (EPPO 2013a). For TCD, the EPPO PRA (EPPO 2015) indicated that negative effects would be seen in the EU in terms of economic, environmental and social aspects. The negative social effects were rated as locally high in areas where walnuts are common and provide an important source of income.

Communication as an integrated part of the EDRR system

Having communication plans in place is important for prevention and early detection of IAS (Liebhold and Kean 2019). The design of communication strategies depend on many factors, including the visibility or the damage caused by the species, the previous knowledge of the target groups, and what the intended outcome is (e.g. improving identification skills, increase reporting rates, or enhance public support for eradication). In addition, communication should focus on positive messaging to avoid potential disengagement due to overly negative messaging. Here we will provide some examples for prevention, early detection and rapid response.

For the grey squirrel, effective early detection via members of the public can be achieved successfully through social media campaigns that aim to empower people with field identification skills and knowledge of species threat (Bryce and Tonkin 2019). The creation of new, or support to existing, community-based squirrel monitoring groups has been invaluable in the United Kingdom and is a sustainable and cost-effective approach (see Shuttleworth et al. 2015).

Dissemination of knowledge and raising awareness among stakeholders, is important to stop additional plantings of American Pokeweed. There should be an increase of coordination to take responsibility for different parts of the invasion pathway, create regulatory rules if necessary, and to coordinate information for increased effectiveness.

Tree diseases are cases where there is relatively more experience with communication and the mobilisation of citizens for early detection. As with other plant health threats, training and awareness-raising among stakeholders (including the public) can aid in early detection of the disease. In the UK, training through the Observatree network has led to a number of new disease reports and reports of detection of threatening plant health pests (Anon 2017). Efforts to facilitate reporting could include provision of a dedicated phone number for reporting plant health and biosecurity concerns, as is the case in New Zealand (MPI 2019). The project Sentinel Plant Network for the detection and diagnosis of significant plant pests and diseases (including WTB and TCD) is focused on citizen science and funded in USA through the USDA's APHIS, Animal and Plant Health Inspection Service.

For managers and officials making decisions about funding programs to mitigate EAB impacts, a positive framing of the message (i.e. "we can reduce costs and keep more of our ash trees alive by actively managing EAB") is more effective than a negative framing (i.e. "EAB is going to kill all of your ash trees"). Studies in the US have shown that protecting a portion of urban ash trees with insecticides keeps more trees alive and costs less than removing heavily infested trees or doing nothing (McCullough and Mercader 2012; Vannatta et al. 2012). Similarly, positive messaging to reduce the human-assisted spread of EAB, such as "use local firewood" rather than "don't move firewood!" may resonate better with the public. Using television and social media to increase public awareness on EAB and encouraging citizens to report sightings of ash trees that display signs of infestation will help managers identify suspect trees for removal or protection with insecticides.

In addition, municipalities, public institutions or non-governmental organizations could initiate citizen science projects to raise awareness and encourage the recording of IAS as is done in the Green Pioneers project at Meise Botanic Garden (Bogaerts et al. 2019). As mentioned before, the message should be positive, stressing the importance of the ability of natural forest rejuvenation and the ways pokeweed may affect such processes.

Similarly, messages about the importance of preserving the red squirrel and reporting alien sciurid species should be promoted and disseminated through social and printed media as well as workshops and professional channels: this type of approach has been used for the UK LIFE NAT/UK/000467 project (http://www.redsquirrelsunited.org.uk) and has led to positive outcomes.

In cases when rapid response actions are taken following a detection, it is of utmost importance to inform the public and landowners about the specific actions that are going to be taken and to explain why this is necessary.

People who are negatively affected by EAB or TCD may disagree with the decisions taken, especially when such actions involve cutting trees on privately owned lands (Mackenzie and Larson 2010). Showing the evidence of infested trees and explaining that the removal of trees will save many other trees is then a strong message to convey. In order to encourage worried landowners to report suspicious cases, reconstitution funding could be made available to cover the cost of treatment and repurposing of the affected land. Such a reconstitution fund was made available to landowners in Ireland affected by ash dieback (*Hymenoscyphus fraxineus*) to reduce the resulting financial hardship.

Communication is even more important to raise public awareness of grey squirrel's impacts and detection via press and social media coverage and to coordinate with woodland owners and regional conservation agencies (Bryce and Tonkin 2019). Indeed, the public are often unaware of the impacts caused by grey squirrel and its presence is often considered desirable by some citizens (e.g. in UK: Dunn et al. 2018). Thus, it can be difficult to communicate lethal management actions on mammals as they are sentient, perceived to be "cute" species and elicit a diffused empathy (Verbrugge et al. 2013). This can negatively impact species control activities in some areas. Depending on cultural differences between countries, citizens can impede or even sabotage lethal management activities (e.g. in Italy in the past), and control programs have not included such methods (e.g. in Netherlands) reverting to non-lethal means of control. A recent study published in Italy, using media reporting as an indicator for public perception of management activities to control grey squirrel populations (Lioy et al. 2019) showed that communication efforts decreased the amount of negative news coverage on control activities in certain parts of Italy, highlighting the potential of communication campaigns. A similar result was reported by Verbrugge et al. (2017) for Netherlands, where communication was important for the effective eradication of Pallas squirrel (*Callosciurus erythraeus*). In this case, introduced squirrels were live-trapped on privately owned lands, after public support was created through personalized communication efforts (Verbrugge et al. 2017), sterilised and housed in captivity. Communication campaigns should be directed towards professionals and citizens for increasing their awareness and involving them in the early detection and monitoring of squirrels. This is particularly crucial when species density decreases after a control activity or is low at the beginning of a new invasion, and it is difficult to detect few specimens. For example, in Scotland a Community Hub information management system for staff and volunteers is under development to better retrieve and integrate data from all sources and thus improve feedback and actions (Bryce and Tonkin 2019).

General discussion

A number of challenges have been identified for the EDRR for each of the four model IAS species. Interestingly, many of the issues were common for these four organisms, including the identification, funding, knowledge of institutional frameworks, available resources and capacity, and a lack of understanding of the pathways regarding early detection (Figure 2). However, considering the dissimilarities, the problems were rather species-specific or were due to the selection of the species. For the RR many issues overlapped with ED.

The overlap in challenges between early detection and rapid response is not so surprising. Rapid response activities are divided into (i) the need to delimit the infested range of the species, and (ii) eradication actions. Delimiting the range involves surveying the area and identifying other individuals of the regulated species in a certain radius around the first observation.

Identification of the species depends on the variability within and between species in areas such as life history, identification methods, and on the trophic level. For all the selected species, identification was mentioned as a challenge which could be solved with education and training for surveyors. Non-experts have more problems identifying species of insects and pathogens than they do species of plants. (Japelj et al. 2019). More media attention on insect pests and pathogens was shown to improve the accuracy of species identification by the general public (Japelj et al. 2019), as these pests can often cause types of damage which can be confused. This would make the possibility of citizen science for the detection of IAS more useful for early detection (Roy et al. 2018). In all of the countries represented at the workshop we noted a limited resource for surveillance. In many countries, there are only a few taxonomic experts on each taxonomic group to support surveillance (e.g. fungal taxonomy in Europe; Dahlberg et al. 2010), while the use of public would give more eyes in the field. Another problem is the lack of identification material like guide books available to compare IAS with the local flora and fauna, although this is slowly being developed for both the general public (Kus Veenvliet et al. 2019) and the experts (e.g. for EAB see Parsons 2008; Volkovitsh et al. 2019). To reach this goal it would be good to educate people by preparing identification materials for both experts and the general public, where the emphasis should be on the more difficult to identify species.

We found that the pathways of movement of the four model species were very species-specific, varying from wood trade to animal trade and horticulture. Focusing the early detection methods for each of the model species on their most likely pathways is crucial. Important high-risk areas like ports are key points for introduction of IAS and therefore setting multilure traps or sentinel trees, would help to detect the species early (Rassati et al. 2014). However, detection outside of the point of entry might already be too late, therefore thorough checking consignments with detection dogs and other types of inspection technologies are more likely to detect and prevent the species from establishing and spreading. For the American pokeweed, the primary introduction route is mainly horticulture, while the immediate spread strategy in the area takes place via birds. Given this secondary pathway, a surveillance programme should use a risk based and bioclimatic sampling strategy to systematically survey the region, rather than focussing primarily on the points of entry. Whether an early detection strategy should focus heavily on the pathway depends on the way the IAS are spreading and should be decided for each species individually.

For communication, the general approaches towards the general public would be (1) avoiding the catastrophist attitude (that usually leads to fear, sense of impotence and blocks any actions); (2) not denying the problem of the IAS, but (3) sending realistic and positive messages to favour proactive, responsible and conscientious behaviours (Tricarico et al. 2018). To this end, citizens should be involved in management of IAS (e.g. through citizen science, adoption of codes of conduct and good practices, such as "use local firewood", "adopt a tree", and management actions when possible) and positive stories should be reported (e.g. not only successful EDRR by technicians, but also how with citizens' help a new invasion was blocked or mitigated) in order to receive their support. A recent study conducted by Japelj et al. (2019) about social perception on the most detrimental IAS to Slovenia's forests showed that almost all respondents (97%) support an EDRR system, with the non-lethal measures more preferred than lethal ones. However, lethal measures could be the only option in certain cases. People opposing such management actions, especially for mammals, will always be present in the community and it is important to be conscious of this. However, it is also fundamental to make those people aware that "doing nothing" is always a management choice, and that this choice comes with certain consequences (on biodiversity, human health and activities) (Japelj et al. 2019). Eriksson et al. (2019) analysed the public's awareness of invasive forest pathogens and the acceptability of policies aiming to combat them in nine European countries. Once again, they found that media exposure was positively associated with awareness of these pathogens and strengthened the link between problem awareness and policy acceptability.

In this study we intentionally focused on four very different species, with different legal status and biology. It was therefore expected that we would get exaggerated differences in early detection, rapid response and communication problems. By using these species we discussed the core issues and sought to identify common solutions. One of the main problems of IAS management is that many are not regulated, and contingency plans are not yet developed, as the species have not yet been identified as a serious threat. A relatively low number of IAS are listed in the EU IAS regulation. For plant health pests, it is well known that the regulatory aspects can take many years to be implemented, and that many pests are missed by the phytosanitary framework and go on to cause disease epidemics (Brasier 2008; Liebhold et al. 2012). Horizon scanning exercises, the use of sentinel plants and intensive collaboration with countries with potential IAS are therefore very important tools to select potential species to be included for regulation (Roy et al. 2018; Eschen et al. 2019b).

There are many differences between the plant health and IAS legislation in the EU. The plant health legislation has been in force for many years and deals with IAS causing disease in plants and affecting the environment and economy, and this receives strong attention from stakeholders. The EU IAS regulation is still in the early stages of implementation and focuses on IAS causing a threat to biodiversity. The implementation of the IAS regulation can benefit from the extensive experience built with the implementation of the plant health legislation.

After the categorization of the different challenges we found that many challenges are cross cutting over the four model species. Having these issues solved in a general EDRR framework would make detection of plant pests and other IAS more efficient. Therefore, we recommend the following actions: 1) diagnostic protocols developed for amateurs should be prepared for every species using either morphological and molecular approaches especially for species on the list of Union concern; 2) there should be increased consideration of IAS issues in research calls, and an increased focus on developing and sustaining national experts in areas such as plant pathology and taxonomy (EPPO 2004); 3) information on how to contact the national competent authority to report a finding should be easily accessible nationally; 4) there is a need for more experts or increase the knowledge among professionals or amateurs; 5) frequent pathways of spread nationally should be investigated so targeted surveillance can be planned; 6) research should focus on effective methods for surveillance and eradication; and 7) contingency plans or rapid response plans are needed urgently at the national level.

Governments should especially focus on these challenges in order to provide a robust EDRR system that is effective against IAS (i.e. both plant health pests and other IAS). However, it is also important to give due consideration to the species-specific issues that may arise, therefore additional resources needs to be devoted to solving these challenges.

Current EDRR activities tend to focus on a part of a pathway rather than formulating a comprehensive EDRR approach across the entire invasion pathway (i.e. covering the country of origin of the IAS, the port of entry of the IAS and the range into which the IAS has invaded). Taking such a comprehensive approach into account would mean coordination among regulatory authorities and levels of government, as well as using strong international trans-jurisdictional collaboration. For this, clear roles, data sharing agreements, detection/response plans, evaluation/update cycles of the EDRR system, and communication plans, are needed. In order to keep the EDRR system efficient, the system measuring the effectiveness should be established by linking risk maps, data collection and post survey evaluation of the detection of non-native species. Whenever this does not seem to be the case the EDRR system should be adapted and updated when new information is known.

In conclusion, we investigated the EDRR system with case studies of four different IAS. Although these species have different trophic levels and are covered by different types of legislation, there are many similar problems which need similar solutions. Although the plant health regulation and the EU IAS regulation have differing terminology and contents, we suggest there can be a large amount of learning from each other regarding the solutions in the fight against IAS in forests.

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References

Aalde H, Gonzalez P, Gytarscky M, Krug T, Kurz W, Ogle S, Raison J, Schoene D, Ravindranath NH, Elhassan NG, Heath L, Higuchi N, Kainja S, Matsumoto M, Sanz Sanchez MJ, Somogyi Z, Carle JB, Murthy IK (2006) Forest land. In: Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K (eds), IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme Volume 4, Chapter 4. IGES, Japan, pp 1-83

Anon (2016) Fredericton's Street Tree Management Plan - Phase 2. University of New Brunswick - Faculty of Forestry and Environmental Management 2015-2016 Graduating Class, 114 pp

Anon (2017) Pioneering tree health partnership to continue thanks to funding boost. https://www.observatree.org.uk/media/pioneering-tree-health-partnership-continue-thanks-funding-boost/ (accessed August 2020)

Anon (2018) Oregon Emerald Ash Borer Readiness & Response Plan. https://static1.squarespace.com/static/58740d57579fb3b4fa5ce66f/t/5b1ad1896d2a73a4cffcdad1/1528484258046/EAB+Plan+2018.pdf (accessed August 2020)

Baranchikov Y, Mozolevskaya E, Yurchenko G, Kenis M (2008) Occurrence of the emerald ash borer, *Agrilus planipennis* in Russia and its potential impact on European forestry. *EPPO Bulletin* 38: 233–238, https://doi.org/10.1111/j.1365-2338.2008.01210.x

Bogaerts A, De Smedt S, Meeus S, Groom Q (2019) Green Pioneers: Raising awareness of invasive plants for all ages. *Biodiversity Information Science and Standards* 3: e37258, https://doi.org/10.3897/biss.3.37258

Born W, Rauschmayer F, Bräuer I (2005) Economic evaluation of biological invasions - a survey. *Ecological Economics* 55: 321–336, https://doi.org/10.1016/j.ecolecon.2005.08.014

Brasier CM (2008) The biosecurity threat to the UK and global environment from international trade in plants. *Plant Pathology* 57: 792–808, https://doi.org/10.1111/j.1365-3059.2008.01886.x

Bryce J, Tonkin M (2019) Containment of invasive grey squirrels in Scotland: In: Veitch CR, Clout MN, Martin AR, Russell JC, West CJ (eds), Island invasives: scaling up to meet the challenge. Occasional Paper SSC no. 62. Gland, Switzerland, IUCN, pp 180–186

Bulman LS (2008) Pest detection surveys on high-risk sites in New Zealand. *Australian Forestry* 71: 242–244, https://doi.org/10.1080/00049158.2008.10675042

Cappaert D, McCullough DG, Poland TM, Siegert NW (2005) Emerald ash borer in North America: a research and regulatory challenge. *American Entomologist* 51: 152–163, https://doi.org/10.1093/ae/51.3.152

Carnegie AJ, Nahrung HF (2019) Post-Border Forest Biosecurity in Australia: Response to Recent Exotic Detections, Current Surveillance and Ongoing Needs. *Forests* 10: 336, https://doi.org/10.3390/f10040336

Ciampitti M, Cavagna B (2014) Public awareness: a useful tool for the early detection and a successful eradication of the longhorned beetles *Anoplophora chinensis* and *A. glabripennis*. *EPPO Bulletin* 44: 248–250, https://doi.org/10.1111/epp.12116

Cranshaw W, Tisserat N (2009) Questions and answers about thousand cankers disease of walnut. Department of Bioagricultural Sciences and Pest Management, Colorado State University, November 8, 2009. Leaflet

Csóka G, Stone GN, Melika G (2017) Non-native gall-inducing insects on forest trees: a global review. *Biological Invasions* 19: 3161–3181, https://doi.org/10.1007/s10530-017-1466-5

Csóka G, Hirka A, Mutun S, Glavendekić M, Mikó Á, Szőcs L, Paulin M, Eötvös CB, Gáspár C, Csepelényi M, Szénási Á, Franjević M, Gninenko Y, Dautbašić M, Muzejinović O, Zúbrik M, Netoiu C, Buzatu A, Bălăcenoiu F, Jurc M, Jurc D, Bernardinelli I, Streito J-C, Avtzis D, Hrašovec B (2020) Spread and potential host range of the invasive oak lace bug [*Corythucha arcuata* (Say, 1832) - Heteroptera: Tingidae] in Eurasia. *Agricultural and Forest Entomology* (*in press*)

Dahlberg A, Genney DR, Heilmann-Clausen J (2010) Developing a comprehensive strategy for fungal conservation in Europe: current status and future needs. *Fungal Ecology* 3: 50–64, https://doi.org/10.1016/j.funeco.2009.10.004

Dunn M, Marzano M, Forster J, Gill RMA (2018) Public attitudes towards “pest” management: perceptions on squirrel management strategies in the UK. *Biological Conservation* 222: 52–63, https://doi.org/10.1016/j.biocon.2018.03.020

EPPO (2004) Plant Health Endangered - State of Emergency. https://www.eppo.int/RESOURCES/position_papers/council_madeira_declaration ((accessed August 2020))

EPPO (2009) PM 9/10 (1) Generic elements for contingency plans. *EPPO Bulletin* 39: 471–474, https://doi.org/10.1111/j.1365-2338.2009.02332.x

EPPO (2013a) Pest Risk Analysis for *Agrilus planipennis*. https://pra.eppo.int/getfile/ea649f30-ca3d-4620-b62b-127e0777f187 (accessed August 2020)

EPPO (2013b) PM 9/14 (1) *Agrilus planipennis*: procedures for official control. *EPPO Bulletin* 43: 499–509, https://doi.org/10.1111/epp.12063

EPPO (2015) Pest Risk Analysis for Thousand cankers disease (*Geosmithia morbida* and *Pityophthorus juglandis*). 15-21058 https://gd.eppo.int/download/doc/337_pra_exp_GEOHMO.pdf (accessed 3 August 2020)

EPPO (2016) Update on the situation of thousand cankers disease in Italy. *EPPO Reporting Service* no. 08. article: 2016/153

EPPO (2019) Presence of *Agrilus planipennis* confirmed in Ukraine. https://gd.eppo.int/reporting/article-6632 (accessed 3 August 2020)

Eriksson L, Boberg J, Cech TL, Corcobado T, Desprez-Loustau M-L, Hietala AM, Jung MH, Jung T, Lehtijarvi HTD, Oskay F, Slavov S, Solheim H, Stenlid J, Oliva J (2019) Invasive forest pathogens in Europe: Cross-country variation in public awareness but consistency in policy acceptability. *Ambio* 48: 1–12, https://doi.org/10.1007/s13280-018-1046-7

Eschen R (2017) Informing authorities about new pest records on woody plants. In: Roques A, Cleary M, Matsiakh I, Eschen R (eds), Field guide for the identification of damage on woody sentinel plants. CABI, Delemont, 281 pp

Eschen R, O’Hanlon R, Santini A, Vannini A, Roques A, Kirichenko N, Kenis M (2019a) Safeguarding global plant health: the rise of sentinels. *Journal of Pest Science* 92: 29–36, https://doi.org/10.1007/s10340-018-1041-6

Eschen R, De Groot M, Glavendekić M, Lacković N, Matosević D, Morales-Rodríguez C, O’Hanlon R, Oskay F, Papazova I, Prospero S, Franić I (2019b) Spotting the pests of tomorrow - Sampling designs for detection of species associations with woody plants. *Journal of Biogeography* 46: 2159–2173, https://doi.org/10.1111/jbi.13670

Everest DJ, Floyd T, Donnacie B, Irvine RM, Holmes JP, Shuttleworth CM (2017) Confirmation of squirrelpox in Welsh red squirrel. *Veterinary Record* 181: 514–515, https://doi.org/10.1136/vr.j5132

Eyre D, Macarthur R, Haack RA, Lu Y, Krehan H (2018) Variation in inspection efficacy by member states of wood packaging material entering the European Union. *Journal of Economic Entomology* 111: 707–715, https://doi.org/10.1093/jee/tox357

Faccoli M, Simonato M, Rassati D (2016) Life history and geographical distribution of the walnut twig beetle, *Pityophthorus juglandis* (Coleoptera: Scolytinae), in southern Europe. *Journal of Applied Entomology* 140: 697–705, https://doi.org/10.1111/jen.12299

FAO (2017) ISPM 5 Glossary of phytosanitary terms. http://www.fao.org/fileadmin/user_upload/faoterm/PDF/ISPM_05_2016_En_2017-05-25_PostCPM12_InkAm.pdf

Forestry Commission (2017) Updated Contingency Plan for Emerald Ash Borer (*Agrilus planipennis*). https://www.forestresearch.gov.uk/documents/5253/EABContingencyPlanUpdated26-09-2017.pdf

Francese JA, Rietz ML, Mastro VC (2013) Optimization of multifunnel traps for emerald ash borer (Coleoptera: Buprestidae): Influence of size, trap coating, and color. *Journal of Economic Entomology* 106: 2415–2423, https://doi.org/10.1603/EC13014

Frank S, Bambara S (2019) Walnut twig beetle and Thousand cankers disease in NC. North Carolina Cooperative Extension, https://content.ces.ncsu.edu/walnut-twig-beetle-and-thousand-cankers-disease-in-north-carolina (accessed 10 August 2020)

Genovesi P (2011) Are we turning the tide? Eradications in times of crisis: how the global community is responding to biological invasions. In: Veitch CR, Clout MN, Towns DR (eds), Island invasives: eradication and management. IUCN, Gland, Switzerland, pp 5–8

Ginzel M, Juzwik J (2014) *Geosmithia morbida*, the Causal Agent of the Thousand Cankers Disease, Found in Indiana. Purdue University. http://www.thousandcankers.com/media/docs/HN-89%20Ginzel%20and%20Juzwik.pdf

Gill R, Ferryman M, Shuttleworth C, Lurz P, Mill A Robertson P, Dutton D (2019) Controlling grey squirrel populations in woodlands in Britain. Forest Research, UK Forestry Standard Technical Note Forest Research, 16 pp

Goldstein EA, Lawton C, Sheehy E, Butler F (2014) Locating species range frontiers: a cost and efficiency comparison of citizen science and hair-tube survey methods for use in tracking an invasive squirrel. *Wildlife Research* 41: 64–75, https://doi.org/10.1071/WR13197

Guidotti A, Scarpelli I, Rizzo D (2019) First finding of *Geosmithia morbida* and *Pityophthorus juglandis* in Tuscany. Regional Forest Service of Tuscany, 4 pp [In Italian]

Haack RA, Britton KO, Brockerhoff EG, Cavey JF, Garrett LJ, Kimberley M, Lowenstein F, Nuding A, Olson LJ, Turner J, Vasilaky KN (2014) Effectiveness of the International Phytosanitary Standard ISPM No. 15 on reducing wood borer infestation rates in wood packaging material entering the United States. *PLoS ONE* 9: e96611, https://doi.org/10.1371/journal.pone.0096611

Haack RA, Baranchikov Y, Bauer LS, Poland TM (2015) Emerald ash borer biology and invasion history. In: Van Driesche R, Duan J, Abell K, Bauer L, Gould J (eds), Biology and control of emerald ash borer. FHTET-2014-09, USDA Forest Service, Forest Health Technology Enterprise Team: Morgantown, pp 1-13

Herms DA, Cipollini D, Knight KS, Koch JL, Poland TM, Rigsby CM, Whitehill JG, Bonello P (2015) The Quest for Ash Resistance to EAB: Towards a Mechanistic Understanding. 26th USDA Interagency REsearch Forum on Invasive Species, 47–49, https://corescholar.libraries.wright.edu/biology/554 (accessed August 2020)

Hirka A, Pödör Z, Garamszegi B, Csóka G (2018) A magyarországi erdei aszálykárok félévszázados trendjei [(50 years trends of the forest drought damage in Hungary (1962-2010)]. *Erdészettudományi Közlemények* 8: 11–25, https://doi.org/10.17164/EK.2018.001

Hishinuma SM, Dallara PL, Yaghmour MA, Zerillo MM, Parker CM, Roubtsova TV, Nguyen TL, Tisserat NA, Bostock RM, Flint ML, Seybold SJ (2015) Wingnut (*Pterocarya* sp.) as a new generic host for *Pityophthorus juglandis* (Coleoptera: Scolytidae). *The Canadian Entomologist* 148: 83–91, https://doi.org/10.4039/tce.2015.37

Hoppenreijs JHT, Beringen R, Collas FPL, Eeuwes DDM, Odé B, van Valkenburg JLCH, Leuven RSEW (2019) Risicobeoordeling van voedselbossen als introductieroute voor invasieve plantensoorten. Radboud University, Nijmegen [in Dutch; English summary]

Hoyer-Tomiczek U, Hoch G (2020) Initial progress in the use of detection dogs for emerald ash borer monitoring. *Forestry: An International Journal of Forest Research* (*in press*), https://doi.org/10.1093/forestry/cpaa001

Hoyer-Tomiczek, U, Sauseng, G, Hoch G (2016) Scent detection dogs for the Asian longhorn beetle, *Anoplophora glabripennis*. *EPPO Bulletin* 46: 148–155, https://doi.org/10.1111/epp.12282

Japelj A, Kus Veenvliet J, Malovrh J, Verlič A, de Groot M (2019) Public preferences for the management of different invasive alien forest taxa. *Biological Invasions* 21: 3349–3382, https://doi.org/10.1007/s10530-019-02052-3

Kaiser BA, Burnett KM (2010) Spatial economic analysis of early detection and rapid response strategies for an invasive species. *Resource and Energy Economics* 32: 566–585, https://doi.org/10.1016/j.reseneeco.2010.04.007

Kees AM, Hefty AR, Venette RC, Seybold SJ, Aukema BH (2017) Flight Capacity of the Walnut Twig Beetle (Coleoptera: Scolytidae) on a Laboratory Flight Mill. *Environmental Entomology* 46: 633–641, https://doi.org/10.1093/ee/nvx055

Kettenring KM, Adams CR (2011) Lessons learned from invasive plant control experiments: a systematic review and meta-analysis. *Journal of Applied Ecology* 48: 970–979, https://doi.org/10.1111/j.1365-2664.2011.01979.x

Klapwijk MJ, Csóka Gy, Hirka A, Björkman C (2013) Forest insects and climate change: long-term trends in herbivore damage. *Ecology and Evolution* 3: 4183–4196, https://doi.org/10.1002/ece3.717

Klapwijk MJ, Hopkins AJM, Eriksson L, Pettersson M, Schroeder M, Lindelow A, Ronnberg J, Keskitalo ECH, Kenis M (2016) Reducing the risk of invasive forest pests and pathogens: combining legislation, targeted management and public awareness. *Ambio* 45: 223, https://doi.org/10.1007/s13280-015-0748-3

Koch FH, Yemshanov D, Magarey RD Smith WD (2012) Dispersal of invasive forest insects via recreational firewood: A quantitative analysis. *Journal of Economic Entomology* 105: 438–450, https://doi.org/10.1603/EC11270

Kovacs K, Haight R, Mccullough D, Mercader R, Siegert N, Liebhold A (2010) Cost of potential emerald ash borer damage in US communities, 2009-2019. *Ecological Economics* 69: 569–578, https://doi.org/10.1016/j.ecolecon.2009.09.004

Kunca A, Zúbrik M, Galko J, Vakula J, Leontovyč R, Konôpka B, Nikolov C, Gubka A, Longauerová V, Maľová M, Rell S, Lalík M (2019) Salvage felling in the Slovak Republic's forests during the last twenty years (1998-2017). *Central European Forestry Journal* 65: 3–11

Kus Veenvliet J, Veenvliet P, de Groot M, Kutnar L (2019) A field guide to invasive alien species in European forests. Institute Symbiosis, so. e. & The Silva Slovenica Publishing Centre, Slovenian Forestry Institute, Ljubljana, 217 pp

La Porta N, Capretti P, Thomsen IM, Kasanen R, Hietala AM, Von Weissenberg K (2008) Forest pathogens with higher damage potential due to climate change in Europe. *Canadian Journal of Plant Pathology* 30: 177–195, https://doi.org/10.1080/07060661.2008.10540534

Legg DE, Fidgen JG, Ryall KL (2014) Resampling simulator for the probability of detecting invasive species in large populations. *Journal of Software Engineering and Applications* 7: 498–505, https://doi.org/10.4236/jsea.2014.76046

Li N, Yang W, Fang S, Li X, Liu Z, Leng X, An S (2017) Dispersal of invasive *Phytolacca americana* seeds by birds in an urban garden in China. *Integrative Zoology* 12: 26–31, https://doi.org/10.1111/1749-4877.12214

Liebhold AM, Kean JM (2019) Eradication and containment of non-native forest insects: successes and failures. *Journal of Pest Science* 92: 83–91, https://doi.org/10.1007/s10340-018-1056-z

Liebhold AM, MacDonald WL, Bergdahl D, Mastro VC (1995) Invasion by exotic forest pests: a threat to forest ecosystems. *Forest Science* 41: a0001–z0001, https://doi.org/10.1093/forestscience/41.s1.a0001

Liebhold AM, Brockerhoff EG, Garrett LJ, Parke JL, Britton KO (2012) Live plant imports: the major pathway for forest insect and pathogen invasions of the US. *Frontiers in Ecology and the Environment* 10: 135–143, https://doi.org/10.1890/110198

Lioy S, Marsan A, Balduzzi A, Wauters LA, Martinoli A, Bertolino S (2019). The management of the introduced grey squirrel seen through the eyes of the media. *Biological Invasions* 21: 3723–3733, https://doi.org/10.1007/s10530-019-02084-9

Lovett GM, Weiss M, Liebhold AM, Holmes TP, Leung B, Lambert KF, Orwig DA, Campbell FT, Rosenthal J, McCullough DG, Wildova R (2016) Nonnative forest insects and pathogens in the United States: Impacts and policy options. *Ecological Applications* 26: 1437–1455, https://doi.org/10.1890/15-1176

Mackenzie BF, Larson BMH (2010) Participation under time constraints: landowner perceptions of rapid response to the Emerald Ash Borer. *Society & Natural Resources* 23: 1013–1022, https://doi.org/10.1080/08941920903339707

Maryland Department of Agriculture (2014) Walnut Twig Beetle and Thousand Cankers Disease. http://mda.maryland.gov/plantspests/Pages/TCD.aspx (accessed August 2020)

Mayfield AE, Juzwik J, Scholer J, Vandenberg JD, Taylor A (2019) Effect of Bark Application With *Beauveria bassiana* and Permethrin Insecticide on the Walnut Twig Beetle (Coleoptera: Curculionidae) in Black Walnut Bolts. *Journal of Economic Entomology* 112: 2493–2496, https://doi.org/10.1093/jee/toz150

McCullough DG, Mercader RJ (2012) SLAM in an urban forest: evaluation of potential strategies to slow ash mortality caused by emerald ash borer (*Agrilus planipennis*). *International Journal of Pest Management* 58: 9–23, https://doi.org/10.1080/09670874.2011.637138

McKenzie N, Helson B, Thompson D, Otis G, McFarlane J, Buscarini T, Meating J (2010) Azadiractin: An effective systematic insecticide for control of *Agrilus planipennis* (Coleoptera: Buprestidae). *Journal of Economic Entomology* 103: 708–717, https://doi.org/10.1603/EC09305

Mercader RJ, McCullough DG, Bedford JM (2013) A Comparison of Girdled Ash Detection Trees and Baited Artificial Traps for *Agrilus planipennis* (Coleoptera: Buprestidae) Detection. *Environmental Entomology* 42: 1027–1039, https://doi.org/10.1603/EN12334

Mercader RJ, McCullough DG, Storer AJ, Bedford JM, Heyd R, Poland TM, Katovich S (2015) Evaluation of the potential use of a systemic insecticide and girdled trees in area wide management of the emerald ash borer. *Forest Ecology and Management* 350: 70–80, https://doi.org/10.1016/j.foreco.2015.04.020

Meurisse N, Rassati D, Hurley BP, Brockerhoff EG, Haack RA (2019) Common pathways by which non-native forest insects move internationally and domestically. *Journal of Pest Science* 92: 13–27, https://doi.org/10.1007/s10340-018-0990-0

Montecchio L, Faccoli M (2014) First Record of Thousand Cankers Disease *Geosmithia morbida* and Walnut Twig Beetle *Pityophthorus juglandis* on Juglans nigra in Europe. *Plant Disease* 98: 696, https://doi.org/10.1094/PDIS-10-13-1027-PDN

Montecchio L, Vettorazzo M, Faccoli M (2016) Thousand cankers disease in Europe: an overview. *EPPO Bulletin* 46: 335–340, https://doi.org/10.1111/epp.12301

Moore M, Juzwik J, Miller F, Roberts L, Ginzel MD (2019) Detection of *Geosmithia morbida* on Numerous Insect Species in Four Eastern States. *Plant Health Progress* 20: 133–139, https://doi.org/10.1094/PHP-02-19-0016-RS

Morales-Rodríguez C, Anslan S, Auger-Rozenberg M-A, Augustin S, Baranchikov Y, Bellahirech A, Burokienė D, Čepukoit D, Çota E, Davydenko K, Doğmuş Lehtijärvi HT, Drenkhan R, Drenkhan T, Eschen R, Franić I, Glavendekić M, de Groot M, Kacprzyk M, Kenis M, Kirichenko N, Matsiakh I, Musolin DL, Nowakowska JA, O'Hanlon R, Prospero S, Roques A, Santini A, Talgø V, Tedersoo L, Uimari A, Vannini A, Witzell J, Woodward S, Zambounis A, Cleary M (2019) Forewarned is forearmed: harmonized approaches for early detection of potentially invasive pests and pathogens in sentinel plantings. *NeoBiota* 47: 95–123, https://doi.org/10.3897/neobiota.47.34276

MPI (2019) Report a pest or disease that's new to New Zealand. https://www.biosecurity.govt.nz/protection-and-response/finding-and-reporting-pests-and-diseases/report-a-pest-or-disease/ (accessed August 2020)

Nunez-Mir GC, Liebhold AM, Guo Q, Brockerhoff EG, Jo I, Ordonez K, Fei S (2017) Biotic resistance to exotic invasions: its role in forest ecosystems, confounding artifacts, and future directions. *Biological Invasions* 19: 3287–3299, https://doi.org/10.1007/s10530-017-1413-5

Parsons GL (2008) Emerald Ash Borer *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae) A guide to identification and comparison to similar species. Department of Entomology, Michigan State University, 56 pp

Pluess T, Cannon R, Jarošík V, Pergl J, Pyšek P, Bacher S (2012) When are eradication campaigns successful? A test of common assumptions. *Biological Invasions* 14: 1365–1378, https://doi.org/10.1007/s10530-011-0160-2

Rassati D, Toffola EP, Roques A, Battisti A, Faccoli A (2014) Trapping wood boring beetles in Italian ports: a pilot study. *Journal of Pest Science* 87: 61–69, https://doi.org/10.1007/s10340-013-0499-5

Roman LA, Scharenbroch BC, Östberg JPA, Mueller LS, Henning JG, Koeser AK, Sanders JR, Betz DR, Jordan RC (2017) Data quality in citizen science urban tree inventories. *Urban Forestry & Urban Greening* 22: 124–135, https://doi.org/10.1016/j.ufug.2017.02.001

Romeo C, McInnes C, Dale T, Shuttleworth CM. Bertolino S, Wauters L, Ferrari N (2019) Disease, invasions and conservation: no evidence of squirrelpox virus in grey squirrels introduced to Italy. *Animal Conservation* 22: 14–23, https://doi.org/10.1111/acv.12433

Roques A (2015) Drivers and pathways of forest insect invasions in Europe, can we predict the next arrivals? *Atti Accademia Nazionale Italiana di Entomologia* 63: 145–150

Roy HE, Groom Q, Adriaens T, Agnello G, Antic M, Archambeau A-S, Bacher S, Bonn A, Brown P, Brundu G, López BC, Cleary M, Cogălniceanu D, de Groot M, De Sousa T, Deidun A, Essl F, Fišer Pečnikar Ž, Gazda A, Gervasini E, Glavendekic MM, Gigot G, Jelaska SD, Jeschke JM, Kaminski D, Karachle PK, Komives T, Lapin K, Lucy F, Marchante E, Marisavljevic D, Marja R, Martín Torrijos L, Martinou A, Matosevic D, Mifsud CM, Motiejūnaitė J, Ojaveer H, Pasalic N, Pekárik L, Per E, Pergl J, Pesic V, Pocock M, Reino L, Ries C, Rozylowicz L, Schade S, Sigurdsson S, Steinitz O, Stern N, Teofilovski A, Thorsson J, Tomov R, Tricarico E, Trichkova T, Tsiamis K, van Valkenburg J, Vella N, Verbrugge L, Vétek G, Villaverde C, Witzell J, Zenetos A, Cardoso AC (2018) Increasing understanding of alien species through citizen science (Alien-CSI). *Research Ideas and Outcomes* 4: e31412, https://doi.org/10.3897/rio.4.e31412

Ryall KL, Fidgen JG, Turgeon JJ (2011) Detectability of the emerald ash borer (Coleoptera: Buprestidae) in asymptomatic urban trees by using branch samples. *Environmental Entomology* 40: 679–688, https://doi.org/10.1603/EN10310

Sapsford B (2019) Red Squirrels Northern England 2019. Annual Squirrel Monitoring Programme Results. https://www.rsne.org.uk/sites/default/files/2019-09/Annual%20Monitoring%20Report%202019.pdf

Seabright KW, Myers SW, Fraedrich SW, Mayfield AE, Warden ML Taylor A (2019) Methyl Bromide Fumigation to Eliminate Thousand Cankers Disease Causal Agents from Black Walnut. *Forest Science* 65: 452–459, https://doi.org/10.1093/forsci/fxz001

Semizer-Cuming D, Krutovsky KV, Baranchikov YN, Kjær ED, Williams CG (2019) Saving the world's ash forests calls for international cooperation now. *Nature Ecology & Evolution* 3: 141–144, https://doi.org/10.1038/s41559-018-0761-6

Showalter DN, Saville RJ, Orton ES, Buggs RJ, Bonello P, Brown JK (2020) Resistance of European ash (*Fraxinus excelsior*) saplings to larval feeding by the emerald ash borer (*Agrilus planipennis*). *Plants, People, Planet* 2: 41–46, https://doi.org/10.1002/ppp3.10077

Shuttleworth CM, Lurz PWW, Halliwell EC (2015) Shared Experience of red squirrel conservation practice. ESI, 212 pp

Shuttleworth CM, Halliwell EC, Robertson PA (2016) Identifying incursion pathways, early detection responses and management actions to prevent grey squirrel range expansion: an island case study in Wales. In: Shuttleworth CM, Lurz PWW, Gurnell J (eds), The grey squirrel: Ecology & management of an invasive species in Europe. ESI, 475–494

Shuttleworth CM, Robinson N, Halliwell EC, Clews-Roberts R, Peek H, Podgornik G, Stinson M, Rice S, Finlay C, McKinney C, Everest DJ, Karl W, Larsen KW (2020) Evolving grey squirrel management techniques in Europe. *Management of Biological Invasions* 11: 747–761, https://doi.org/10.3391/mbi.2020.11.4.09

Signorile AL, Lurz PW, Wang J, Reuman DC, Carbone C (2016) Mixture or mosaic? Genetic patterns in UK grey squirrels support a human-mediated 'long-jump' invasion mechanism. *Diversity and Distributions* 22: 566–577, https://doi.org/10.1111/ddi.12424

Silk P, Mayo P, Ryall K, Roscoe L (2019) Semiochemical and communication ecology of the emerald ash borer, *Agrilus planipennis* (Coleoptera: Buprestidae). *Insects* 10: 323, https://doi.org/10.3390/insects10100323

Simberloff D (2003) Eradication-preventing invasions at the outset. *Weed Science* 51: 247–253, https://doi.org/10.1614/0043-1745(2003)051[0247:EPIATO]2.0.CO;2

Streck C, Scholz SM (2006) The role of forests in global climate change: whence we come and where we go. *International Affairs* 82: 861–879, https://doi.org/10.1111/j.1468-2346.2006.00575.x

Tanis SR, McCullough DG (2015) Host resistance of five *Fraxinus* species to *Agrilus planipennis* (Coleoptera: Burprestidae) and effects of Paclobutrazol and fertilization. *Environmetnal Entomology* 44: 287–299, https://doi.org/10.1093/ee/nvu005

Teangana, DÓ, Reilly S, Montgomery WI, Rochford J (2000), Distribution and status of the Red Squirrel (*Sciurus vulgaris*) and Grey Squirrel (*Sciurus carolinensis*) in Ireland. *Mammal Review* 30: 45–56, https://doi.org/10.1046/j.1365-2907.2000.00054.x

Tisserat N, Cranshaw W, Leatherman D, Utley C, Alexander K (2009) Black walnut mortality in Colorado caused by the walnut twig beetle and thousand cankers disease. *Plant Health Progress* 10: 10, https://doi.org/10.1094/PHP-2009-0811-01-RS

Tricarico E, Inghilesi AF, Brundu G, Iiriti G, Loi MC, Caddeo A, Carnevali L, Genovesi P, Carotenuto L, Monaco A (2018) Le specie aliene invasive: cosa e come comunicare al grande pubblico. Guida tecnica per operatori didattici di orti botanici, zoo, musei scientifici, acquari e aree protette. LIFE ASAP, 94 pp. https://lifeasap.eu/images/prodotti/6.1.4.1_Technical%20guide%20for%20multipliers.pdf

USDA (2009) Pathway Assessment: *Geosmithia* sp. and *Pityophthorus juglandis* Blackman movement from the western into the eastern United States. United States Department of Agriculture, Animal and Plant Health Inspection Agency, 50 pp

Vannatta AR, Hauer RH, Schuettpelz NM (2012) Economic analysis of emerald ash borer (Coleoptera: Buprestidae) management options. *Journal of Economic Entomology* 105: 196–206, https://doi.org/10.1603/EC11130

Verbrugge LNH, van den Born RJG, Lenders HJR (2013) Exploring public perception of non-native species from a visions of nature perspective. *Environmental Management* 52: 1562–1573, https://doi.org/10.1007/s00267-013-0170-1

Verbrugge LNH, van Delft JJCW, Crombaghs BHJM, Bouwens SJ, Bosman W (2017) Belang van publiekscommunicatie voor succesvolle bestrijding van invasieve exoten. [Communicating about invasive species control: Lessons learned from three examples from the Netherlands]. *De Levende Natuur* 118: 222–226 [in Dutch]

Volkovitsh MG, Orlova-Bienkowskaja MJ, Kovalev AV, Bienkowski AO (2019) An illustrated guide to distinguish emerald ash borer (*Agrilus planipennis*) from its congeners in Europe. *Forestry: An International Journal of Forest Research* 93: 316–325, https://doi.org/10.1093/forestry/cpz024

Wu D, Koch J, Coggeshall M, Carlson J (2019) The first genetic linkage map for *Fraxinus pennsylvanica* and syntenic relationships with four related species. *Plan Molecular Biology* 99: 251–264, https://doi.org/10.1007/s11103-018-0815-9

Yang W, Li Z, Lan Y, Wang J, Ma J, Jin L, Sun Q, Lv W, Lai S, Liao Y, Hu W (2011) A nationwide web-based automated system for outbreak early detection and rapid response in China. *WPSAR* 2: 1–6, https://doi.org/10.5365/wpsar.2010.1.1.009

Zidar S (ed) (2019) Detection and control of forest invasive alien species in a dynamic world, Book of abstracts of the international conference of the LIFE ARTEMIS project, 25-28 September, Ljubljana: The Silva Slovenica Publishing Centre, Slovenian Forestry Institute, 80 pp

Supplementary material

The following supplementary material is available for this article:

Table S1. Identified problems for the selected species in early detection and rapid response in forests.

This material is available as part of online article from:
http://www.reabic.net/journals/mbi/2020/Supplements/MBI_2020_deGroot_etal_SupplementaryTable.xlsx