Euphresco

Final Report

Project title (Acronym)
Risk-based strategies to prepare for and manage invasive tree borers - Pest Risk Evaluation and Pest management SYStems (PREPSYS)

Project duration:

Start date:	2016-10-01
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Contents

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2. Short project report

2.1. Short executive summary

Extensive literature review and interactions with researchers and managers dealing with *Agrilus planipennis* (emerald ash borer, EAB) and *Agrilus anxius* (bronze birch borer, BBB) has assessed the 'state of the art' as a basis for potential invasion of Europe by these pests. Key references providing strategic summaries are cited in the special issue of Forestry: An International Journal of Forest Research (Appendix 1, including links to the articles), with additional relevant references and links in Appendix 2.

Although there is increasing information on the two pest species, further work especially from a European perspective is required to both anticipate and to react to incursions of the pests. The PREPSYS project addressed key questions and gaps in our knowledge on the pests' biology, control (including firewood risks and treatments and biological control agents), dispersal and economic/environmental impacts. PREPSYS has pulled together the accumulated knowledge on EAB and BBB to prepare a European Toolbox for their detection and management and this has been published in a recent special edition of Forestry: An International Journal of Forest Research. This can form the basis for a coordinated approach to deal with the very real threats from EAB and BBB.

It is known from North America and European Russia that there is usually a gap of several years between arrival and first detection of EAB. PREPSYS has assessed the range of options for survey and early detection of EAB or BBB and concluded that girdling of trees (stressing the trees) is the most effective for this purpose. However, there are logistic problems in using this technique and so use of traps with chemical lures is often more practical; a range is available with similar efficiencies in capturing adult beetles.

Management of infestations is usually through felling of infested or dead trees and this is an expensive and time-consuming procedure. Extensive research in North America indicates that slowing progress of infestations using trunk injections of the insecticide Emamectin benzoate is an effective process to 'buy time' for selective felling and other measures. It is recommended that registration of the insecticide for use in Europe should be carried out urgently.

In the longer term, introduction of parasitoids (natural enemies) from the native ranges of EAB is now becoming more effective after a slow initial period after releasing species from China and Russia. There is also detailed knowledge of the climatic requirements of these classical biological control agents and this has improved establishment and efficacy. Since there is a need for assessment of possible adverse impacts on non-target species, tests for potential use of these agents in Europe should be carried out urgently. Methods for mass production are, fortunately, already developed in the USA.

Outreach and information provision are an important part of detection and management of EAB and information should be made increasingly available in Europe to prepare for the likely arrival of EAB from European Russia, Ukraine or any of the infested regions of the world.

2.2. Project aims

PREPSYS has studied two buprestid beetle pests (*Agrilus* species) of trees that have potential to cause severe damage to trees in Europe. These are the emerald ash borer, *Agrilus planipennis* (EAB) which originates in South-East Asia and the bronze birch borer, *Agrilus anxius* (BBB) which originates in North America. EAB has established in North America and European Russia and outbreaks have recently been identified in Ukraine (2019); the pest is causing massive tree mortality in these new zones.

Although there is increasing information on the two species, further work especially from a European perspective is required to both anticipate and to react to incursions of the pests. PREPSYS has, therefore, addressed key questions and gaps in our knowledge on the pests' biology, control (including chemical treatments and biological control agents), dispersal and economic/environmental impacts.

The main goal of the project was to provide research outputs to underpin contingency planning, policy development and policy communication through assessment of the entry, establishment, spread, impact and management of the pests, with the main emphasis on reducing the likelihood of their establishment and, as a worst case, in coping should the pests succeed in establishing populations in Europe. The key overall question that the PREPSYS research activities have addressed is: 'How can we best prepare for and manage the risks and impacts of EAB and BBB?'

The specific questions that were considered by partners involved in PREPSYS included:

- What are the potential risks and impacts for the two pests both in their countries of origin and where they have established in new locations?
- What are the pathways for movement of the pests and how can we better protect against the risk of introduction?
- How can we improve early detection both on the pathways and at their end points?
- What are the rates of natural spread and can we improve prediction of spread, both natural and by human assistance?
- How can we develop or improve cost-effective management and control approaches and tools (including chemical and biological control)?
- How can we best communicate and implement policy and engage with stakeholders (including policy makers, woodland owners and managers, academia and the public, importers and the wider nursery industry)?

In each case, the starting point was to identify the state of knowledge internationally and with specific reference to European conditions and identify and prioritise knowledge gaps.

The project team drew on expertise in countries already dealing with either EAB or BBB. For EAB these are China (native zone for the pest), Russia and the United States of America (invaded zones for the pest). As part of this knowledge-gathering phase, the PREPSYS consortium analysed management approaches and their effectiveness and extrapolated to European conditions within a risk-based systems approach. The project outputs analysed all information sources to develop best practice in pathway management, early detection, contingency outcomes and longer-term sustainable management practices. This accumulated knowledge will inform policy-making at national and EU levels. Knowledge gathered and synthesised during the project was disseminated in both a major international conference and in scientific and non-specialist publications.

2.3. Description of the main activities

The main activities of the project were:

<u>Review evidence gaps relating to improved understanding of risks, impacts and how to mitigate them</u>

This study provided the basis for exploring the main components that could result in transfer and establishment of EAB or BBB in Europe. It included detailed review of the literature and establishment of direct contacts with research groups and managers dealing with EAB and BBB. Fact-finding visits

to North America in 2017 and 2018 were included in order to explore and learn from current research and management for both EAB as an exotic and BBB as a native pest.
Arising from work in year 1, analysis of knowledge gaps was carried out to focus research within the project and to encourage other research groups to collaborate/contribute to the work. This included direct experimental work with researchers in North America on prevention and detection.

Prevention and Detection
A key requirement in anticipating and dealing with incursions of both EAB and BBB is reliable and accurate early detection, especially if eradication is to be considered and, in any event, remains central to longer-term management under a containment regime. There is considerable evidence from experiences globally that initial detection of a new pest can lag many years behind initial establishment. This was certainly the case for EAB in the USA and Russia.
A review of the current detection techniques and assessment of the best options for further development to improve early and accurate detection was undertaken. Topics included use of attractant lures and use of trained sniffer dogs.

Natural and human-assisted spread
Current knowledge of natural and human-assisted spread of EAB and BBB was assessed in order to describe and quantify spread rates under different climate/region combinations applicable to European conditions. There was also limited analysis of trade routes, pathways, population centres, *etc*., as modifying variables driving longer-distance 'jump spread'. This preliminary work prompted a new project to develop the optimal surveillance modelling pioneered by Dr Denys Yemshanov (Canadian Forest Service) and colleagues[1].
By interaction with ongoing programmes in North America and Russia as invaded territories and China/North America as native territories, the project partners considered the range of management options and their cost-effectiveness. Emphasis was on lessons learned and how techniques can be improved, which underpinned the activities on pest management. Apart from a literature review, there was strong emphasis on direct interactions with scientists and practitioners in North America and Russia, with prospects for ongoing collaboration being developed to build on the current project.

Pest management
Using knowledge gathered and ongoing interactions within the project partners and with other scientists, the benefits and constraints of existing management regimes were assessed. This approach included a range of options:

- direct intervention (chemical insecticides, with emphasis on trunk injection);
- biological control (classical biocontrol by introduction, enhancement of native natural enemies);
- indirect strategies (selection of potentially tolerant or resistant hosts with particular linkage to phylogenomics of the genus *Fraxinus* (Dr Richard Buggs and NERC ash genome project, with other partners) and ongoing selection programmes regarding Chalara, use of host plant mixtures, site enhancement, etc.)

All measures, but particularly use of chemical insecticides, will require stakeholder communication and acceptance of the proposed technologies.

Engagement
The project explored policy communication and implementation methods and considered ways to best engage with stakeholders on policy options in advance of pest introductions and if the pests succeed

[1] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/806872/ash-research-strategy-2019a.pdf; Priority research action theme 3 – Develop an optimal early warning system for EAB led by Forest Research.

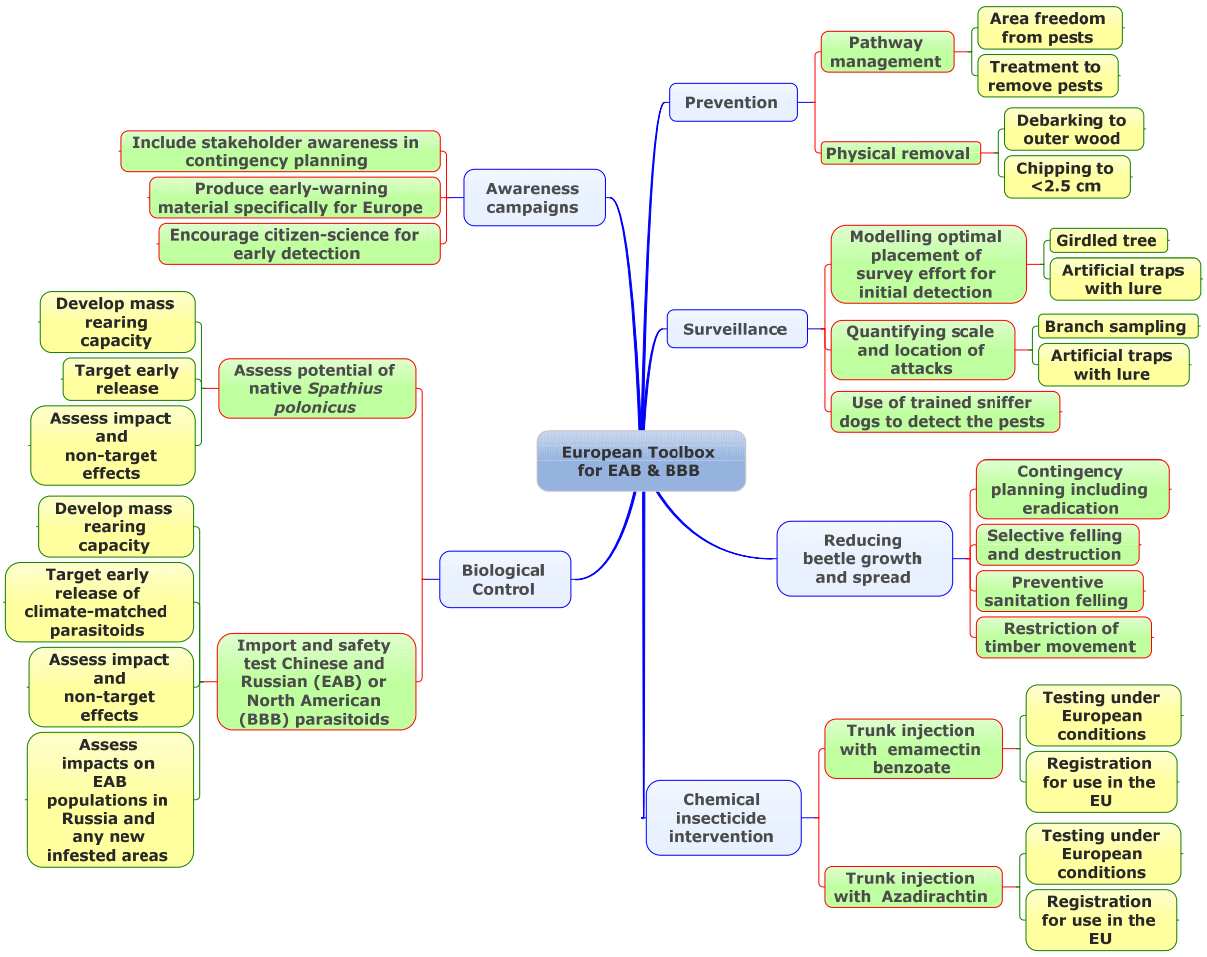
in establishing (including policy makers, woodland owners and managers, academia and the public, importers and the wider nursery industry).

Ongoing reviews were carried out of the procedures used in all countries where EAB and BBB are either present or pose a potential future risk. Particular attention was paid to interaction with stakeholders and the general public, accounting for the differing priorities and perceptions between urban and rural locations. A range of socio-economic techniques were employed to explore the initial policy environment and how that impacts on practitioners spanning the entire pathway from source to sink and the subsequent implications for stakeholders if the pests succeed in establishing. Interactions with policy and management regimes in North America were included in the WP.

2.4. Main results (knowledge, tools, etc.)

The results are best summarised under the key output which we have termed the European Toobox for EAB/BBB. This was developed though the extensive literature review process (see Appendix 1 and Appendix 2), fact-finding visits to Canada by partner UKFC (GB) and NVWA (NL) and to USA by partner UKFC (GB) and BFW (AT) in July 2017, to USA partner UKFC (GB) in 2018 and direct research interaction between partner UKFC (GB) and Connecticut Agricultural Experiment Station in both 2017 and 2018.

In summary the key points from the European Toolbox are shown in the schematic below and described in the following text. More details and literature references can be found in Evans et al. (2020) https://doi.org/10.1093/forestry/cpz074



1. Surveillance effort needs to be very high to have any chance of early detection of EAB invasion and establishment. A wide variety of trapping systems has been tested in North America to detect EAB at the earliest occurrence in any given area and as tools to delimit the boundaries

of known infestations. However, there is no one definitive trap that is regarded as being of optimum efficiency. In Canada, the preference is to use green sticky prism traps baited with the green leaf volatile (3Z)-hexenol and the female produced sex pheromone (3Z)-lactone, whilst in the USA the preference is for green, fluon-coated multi-funnel traps baited with (3Z)-hexenol or the purple sticky prism traps baited with (3Z)-hexenol. An alternative to artificial trapping systems is the use of girdled host trees, which are far more attractive to adult EAB or BBB because these trees release chemicals that signal they are stressed and susceptible to attack. This is the most effective method at very low pest densities. Branch sampling for presence of larvae is a more quantitative method at higher pest densities. The use of sniffer dogs trained to detect EAB has commenced in Austria (partner BFW) and offers promise for selective detection of infestations and inspection of transported wood.

2. Increase analysis of pathways (scale and end points) to develop risk-based optimal surveillance strategy for Europe using a similar modelling approach to that developed in North America. A new project has commenced to develop this further[1].
3. Slowing tree mortality by trunk injection of Emamectin benzoate is an effective underpinning strategy that, although it has limited impact on total pest populations, enables a more gradual use of resources for survey, selective felling and tree replacement.
4. Natural enemies are promising for biological control of the pests, but have a long development and build-up phase. In North America, after assessment of potential impacts on nontarget hosts, four species of parasitoid (parasitic wasps) have been licensed for release in the USA and Canada. Three species are larval parasitoids; *Spathius agrili* and *Tetrastichus planipennisi* (both Hymenoptera: Eulophidae) from China and *Spathius galinae* from Russia. The fourth, *Oobius agrili* (Hymenoptera: Encyrtidae), is an egg parasitoid from China. There are very encouraging signs that released parasitoids have established and are beginning to reduce EAB populations, although care has to be taken to ensure that the species are matched to the most suitable climatic zone.
5. Outreach should commence before the pests arrive in Europe. This should be done at many scales from national, regional to local. Resources of information should be compiled and made available for pre-emptive and ongoing awareness campaigns. Strong engagement is also needed to build trust and provide robust explanations for decision-making management approaches that are taken including their efficacy, longevity and costs.
6. Awareness campaigns should be informed by social studies that assess how different stakeholder groups will perceive the risks and benefits of EAB and BBB management approaches in order to improve likely social acceptability. Research suggests that while there is strong support for management of tree pests and disease, pre-emptive felling and insecticide use generally receive little public support. The risk of losing certain valuable ash trees if insecticide is not used may change opinions and more research is needed on who is likely to reject chemical use and in what contexts. There has also been little research on whether the method of application (e.g. stem injections rather than spraying) makes a difference. Based on evidence from the USA, opposition to felling of ash trees in urban residential areas was reduced when residents were offered replacement species.
7. The recent overlap in range between ash dieback and EAB in Russia presents a unique opportunity for study of the interaction before EAB reaches Europe.

Taken together, the components of the Toolbox provide a range of measures that would employ the most effective and up to date methods to prepare for and manage the threats posed by EAB and BBB. Early detection is key to putting the management measures into action and research and development continues to this end.

The Consortium was also successful in obtaining funding from the Organisation for Economic Co-operation and Development (OECD) under its Co-operative Research Programme on Biological Resource Management for Sustainable Agricultural Systems to organise a major international conference ‘Preparing Europe for invasion by the beetles emerald ash borer and bronze birch borer, (Vienna, Austria, 1-4 October 2018). Part funding was also provided by Defra (GB). The Programme

and presentations from the conference are available on the BFW website https://bfw.ac.at/emeraldashborer
Arising from the conference, a special edition of Forestry: An International Journal of Forest Research was organised and published in April 2020, containing a wide range of papers on EAB and BBB (https://academic.oup.com/forestry/issue/93/2).

2.5. Conclusions and recommendations to policy makers

The European Toolbox also serves as a quick reference to the main conclusions from the project. In particular, some of the sub-topics require urgent consideration by policy makers both to encourage further knowledge gathering and, particularly, to address policy needs and encourage practical implementation of the recommendations.

1. Surveillance. Early detection is vital and close attention should be paid to placement of scarce survey resources in those areas of Europe that are most likely to receive invasion by the pests. Collaboration with researchers in Canada are underway in a new project[1] to attempt optimal surveillance modelling to pinpoint high risk pathway end points in Europe. It is recommended that liaison with the European Food Safety Authority (EFSA) should be further encouraged to link in to the BBB[2] and the EAB (in preparation) survey cards and use of Ribess+ modelling for surveys. Coordination of trapping effort, including selection of trap type and lures should also be given high priority by EU Member States, with coordination of the European Commission DG Santé.
2. Using outputs from optimal surveillance modelling, the aim would be to place scarce survey resources in the places regarded as presenting the highest risk of arrival of EAB. A risk-based approach to survey is essential to increase the likelihood of avoiding a long time period between arrival of a pest and its first detection.
3. Although there are potential non-target impacts from use of chemical insecticides, it is now clear from ongoing usage and research in North America that trunk injection of Emamectin benzoate is an effective tool to manage infestations of EAB and 'buy time' for those managing the pest. Urgent steps should be taken in the EU to test and register Emamectin benzoate for this purpose.
4. Biological control through deployment of a range of effective natural enemies against EAB is now proving increasingly effective in North America. There is also promise from effects of native natural enemies in the infested area of European Russia. Inclusion in EU and National contingency planning and policy development is essential and urgent. This would include fast-tracking of safety testing for release of parasitoids and capacity building for scale-up and release of the most promising candidate species.
5. Efforts to increase outreach and involvement of the local authorities and the public in detection and reporting of infestations should be increased. In particular, both hard-copy and on-line resources for Europe should build on the extensive knowledge base that has accumulated in North America. The scope for use of citizen science should also be investigated at local and national scales. Explanation of management measures (felling of infested trees, insecticide usage and release of natural enemies) should be enhanced to provide up to date information and encourage support by the public for such measures.
6. There is an increasing zone of overlap between EAB and ash dieback caused by the fungus *Hymenoscyphus fraxineus* in Western Russia. A key question is whether the interaction between the two organisms will affect total tree mortality. Support for joint research into this interaction should be provided urgently.

The tools for the toolbox are becoming more effective and sophisticated. However, there needs to be greater coordination and 'ownership' of the toolbox. EU DG Santé and EFSA, along with EPPO, are ideally placed to guide action plans and to provide financial and logistic support. National Plant

[2] https://efsa.onlinelibrary.wiley.com/doi/pdf/10.2903/sp.efsa.2020.EN-1777

Protection Organizations (NPPOs) can influence this process. Outcomes from PREPSYS have provided the key topics that could provide a management strategy for Europe and there is already follow-on research into some of the main topics, notably optimal surveillance, pathway analysis and development of effective monitoring tools. However, ownership of a future strategy in Europe remains at National levels and requires close coordination.

2.6. Benefits from trans-national cooperation

The PREPSYS project has been fully international in both its partnership and also in development of links to relevant researchers, NPPOs and pest managers and administrators. This has resulted in excellent collaboration throughout the project, especially in fact-finding visits to North America during 2017 and 2018.

A very significant event was the international conference, partly funded by OECD and by Defra, in October 2018. The event brought together 83 scientists, policy makers and representatives of regional and national plant protection organisations. Participants came from 27 countries (Australia, Austria, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Hungary, Ireland, Italy, Latvia, Luxembourg, Netherlands, Norway, Russia, Slovenia, Spain, Sweden, Switzerland, United Kingdom, United States) including those where invasion by emerald ash borer has had major impact on tree survival. Discussions and development of new collaborations were excellent and demonstrated further benefits of a trans-national approach.

Direct collaborative joint research was also initiated with researchers in both Canada and USA. Dr Williams from Forest Research carried out research on new lures and trapping systems for BBB with Dr Rutledge of Connecticut Agricultural Experiment Station (visits and joint work in 2017 and 2018). He also has ongoing collaboration with Dr Francese of USDA Forest Service at Otis. Dr Hoch and Ms Hoyer-Tomiczek from the Federal Research and Training Centre for Forests have commenced training of sniffer dogs to detect EAB life stages, in collaboration with scientists in the USA (Connecticut and USDA).

Arising from the project work, collaboration with Dr Yemshanov (Canadian Forest Service) has commenced to develop optimal surveillance modelling for early detection of EAB and BBB. Although the work commenced during PREPSYS, it has now been extended through a new collaborative project funded by Defra in the UK.

Presentations about the project were given at the USDA Interagency Forum in January 2017, at the Canadian Forest Service Sault Ste Marie laboratory and at various small meetings in the USA during fact-finding visits in 2017 and 2018. Several presentations from the project team were given at the PREPSYS International Conference in Vienna in October 2018 (see programme https://bfw.ac.at/emeraldashborer).

3. Publications

3.1. Article(s) for publication in the EPPO Bulletin

None.

3.2. Article for publication in the EPPO Reporting Service

None.

3.3. Article(s) for publication in other journals

A number of articles arising from the project either directly or indirectly through international collaboration have been published.

- Special issue of Forestry: An International Journal of Forest Research published in April 2020. The articles from this issue are listed in Appendix 1. https://academic.oup.com/forestry/issue/93/2

Additional papers

- Evans HF & Williams D (2017) Preparing for an Invasion. *Chartered Forester* Autumn 2017, 23-25
- Marzano M, Hall C, Dandy N, LeBlanc Fisher C, Diss-Torrance A & Haight RG (2020). Lessons from the Frontline: Exploring How Stakeholders May Respond to Emerald Ash Borer Management in Europe. *Forests*, **11,** 617-632.
- Hoch G, Evans H (2019). Internationale Konferenz 'Preparing Europe for invasion by the beetles emerald ash borer and bronze birch borer', Wien, 1.-4. Oktober 2018. Forstschutz Aktuell 65 (2019): 38-44. https://bfw.ac.at/rz/bfwcms.web?dok=10373
- Hoch G (2017)/ Neues Ungemach für die Esche: der Eschenprachtkäfer vor den Toren der EU. BFW Praxisinfo 43, 13-16. https://www.waldwissen.net/waldwirtschaft/schaden/insekten/eschenprachtkaefer/index_DE
- Hoch G, Krehan H (2017). Invasive Forstschadorganismen in Europa. AFZ-Der Wald 9/2017, 26-28.

Book of Abstracts

- Evans H, Marzano M, Hoch G (2018). Abstracts of the Conference: Preparing Europe for invasion by the beetles emerald ash borer and bronze birch borer, two major tree-killing pests October 1-4, 2018 Vienna, Austria. BFW, Vienna. https://bfw.ac.at/cms_stamm/050/PDF/prepsys_abstracts.pdf

Presentations

- Evans HF (2017). The new EU PREPSYS project: working to understand and manage the risks of exotic buprestid beetles. *28th USDA Interagency Research Forum on Invasive Species*, 10-13 January 2017, Annapolis, USA
- Evans HF, Williams D, Loomans A (2017) Preparing Europe for emerald ash borer and bronze birch borer: filling the knowledge gaps to prepare for the worst. Presentation to Canadian Forest Service at Sault Ste Marie Laboratory, 12 July 2017
- Loomans A (2017) PREPSYS – 'How can we best prepare for and manage risks and impacts of EAB and BBB?' Presentation to Canadian Forest Service at Sault Ste Marie Laboratory, 12 July 2017

- Williams DT, Straw N, Kulinich O, Gninenko YI (2017) Distribution and impact of emerald ash borer *Agrilus planipennis* (Coleoptera:Buprestidae) in the Moscow region of Russia. Presentation to Canadian Forest Service at Sault Ste Marie Laboratory, 12 July 2017
- Evans HF (2019). EAB threats and challenges for the EU. *Cooperation in crisis preparedness for Emerald Ash Borer in the European Union – Workshop 1: EAB Surveillance*. 23-25 January, 2019. Tallinn, Estonia.
- Hoyer-Tomiczek U, Sauseng G, Hoch G (2019). Detection dogs for the surveillance of invasive bark and wood boring insects. Oral presentation at the International conference "Detection and control of forest invasive alien species in a dynamic world" organised by the project LIFE ARTEMIS, 25-28 September 2019, Ljubljana, Slovenia.
- Hoch G (2017). Emerald ash borer, *Agrilus planipennis*. Talk at the Coordination Meeting of the Austrian Plant Protection Service, 19-20 October, Eisenstadt, Austria.
- Loomans AJM, Van der Gaag DJ (2018) How can we best prepare for and manage risks and impacts of EAB and BBB in Europe? Presentation *Agrilus* workshop Vienna, October 2, 2018
- Loomans AJM, Van der Gaag DJ (2018) Wat kunnen we leren van ervaringen elders (VS, Canada, Rusland) m.b.t. essenprachtkever. Ervaringen OECD PREPSYS voor Nederland. Presentatie Essenprachtkeverdag BTL Bomendienst October 31, 2018; March 28, 2019
- Loomans AJM, Van der Gaag DJ (2018) Inventarisatie Kennis *Agrilus*. Presentatie Essenprachtkeverdag BTL Bomendienst October 31, 2018; March 28, 2019
- Loomans AJM, Van der Gaag DJ (2018) Zijn we in Nederland en Europa voorbereid op een uitbraak van de essenprachtkever (*Agrilus planipennis*). Presentatie Essenprachtkeverdag BTL Bomendienst October 31, 2018; March 28, 2019

4. Open Euphresco data

All information from the project is in the public domain, particularly the:

1) Programme and presentations of the conference 'Preparing Europe for invasion by the beetles emerald ash borer and bronze birch borer', Vienna, Austria, 1-4 October 2018 https://bfw.ac.at/emeraldashborer
2) and a wide range of scientific articles on EAB and BBB published on the special edition of Forestry: An International Journal of Forest Research (93, 2 April 2020), https://academic.oup.com/forestry/issue/93/2 (the content of the special issue is presented in Appendix 1)
3) Some of the deliverables produced in the framework of the PREPSYS project are available from the project website https://www.forestresearch.gov.uk/research/prepsys/

Appendix 1: Contents of Forestry Special Issue

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Appendix 2: Additional selected literature

Selected literature on emerald ash borer and bronze birch birch borer (in addition to the key references in the special edition of Forestry: An International Journal of Forest Research.

Emerald ash borer

- de Andrade RB, Abell K, Duan JJ, Shrewsbury P & Gruner DS (2020). Protective neighboring effect from ash trees treated with systemic insecticide against emerald ash borer. *Pest Management Science*, pre print https://onlinelibrary.wiley.com/doi/abs/10.1002/ps.6041
- Duan J, Bauer L, Van Driesche R & Gould R (2018). Progress and Challenges of Protecting North American Ash Trees from the Emerald Ash Borer Using Biological Control. *Forests*, 9: 142-159 http://www.mdpi.com/1999-4907/9/3/142/pdf
- Herms DA & McCullough DG (2014). Emerald Ash Borer Invasion of North America: History, Biology, Ecology, Impacts, and Management. *Annual Review of Entomology*, 59: 13-30 https://www.annualreviews.org/doi/abs/10.1146/annurev-ento-011613-162051
- Klooster WS, Gandhi KJK, Long LC, Perry KI, Rice KB, Herms DA (2018). Ecological Impacts of Emerald Ash Borer in Forests at the Epicenter of the Invasion in North America. *Forests*, 9: 250-264 https://www.mdpi.com/1999-4907/9/5/250
- McCullough DG, Poland TM & Lewis PA (2016). Lethal trap trees: a potential option for emerald ash borer (Agrilus planipennis Fairmaire) management. *Pest Management Science*, 72 : 1023-1030 https://onlinelibrary.wiley.com/doi/abs/10.1002/ps.4083
- Orlova-Bienkowskaja MJ & Volkovitsh MG (2018). Are native ranges of the most destructive invasive pests well known? A case study of the native range of the emerald ash borer, *Agrilus planipennis* (Coleoptera: Buprestidae). *Biological Invasions*, 20: 1275-1286 https://link.springer.com/article/10.1007/s10530-017-1626-7
- Poland TM & Rassati D (2019). Improved biosecurity surveillance of non-native forest insects: a review of current methods. *Journal of Pest Science*, 92: 37-49 https://link.springer.com/article/10.1007/s10340-018-1004-y
- Sancisi-Frey S (2016). Observatree field identification guide – emerald ash borer. https://www.observatree.org.uk/wp-content/uploads/2018/01/16_0049_One-off-literature-Observatree-Guide-Emerald-ash-borer_wip14.pdf
- Siegert NW, McCullough DG, Poland TM & Heyd RL (2017). Optimizing Use of Girdled Ash Trees for Management of Low-Density Emerald Ash Borer (Coleoptera: Buprestidae) Populations. *Journal of Economic Entomology*, 110: 1096-1106 https://academic.oup.com/jee/article-abstract/110/3/1096/3094609?redirectedFrom=fulltext
- Silk P, Mayo P, Ryall K, Roscoe L (2019). Semiochemical and Communication Ecology of the Emerald Ash Borer, *Agrilus planipennis* (Coleoptera: Buprestidae). *Insects*, 10: 323l https://www.mdpi.com/2075-4450/10/10/323
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