



## **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

**Abstracts**

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# Preparing Europe for invasion by the beetles emerald ash borer and bronze birch borer, two major tree-killing pests

1-4 October 2018

Austrian Research Centre for Forests (BFW), Vienna, Austria

## Meeting Programme

### 1 October 2018

[page]

08:00 **Registration**

10:00 **Welcome to BFW Vienna and introductory remarks**

Peter Mayer and Gernot Hoch  
BFW, Austria

10:15 **Cooperative Research Programme (CRP)**

Gary Fitt  
OECD Theme Representative, CSIRO, Brisbane, Australia

10:35 **Conference purpose and link to the EU PREPSYS project**

Hugh Evans  
Forest Research, UK

### The threats: history and potential

[6]

10:50 **Evolution of the regulatory response to emerald ash borer infestation in the USA  
a history of adaptation across federal and state jurisdictions**

[8]

Scott Pfister  
USDA APHIS, Otis Laboratory, USA

11:20 **Break**

11:50 **A quarter-century of emerald ash borer in Europe**

[9]

Yuri Baranchikov  
Sukachev Institute of Forestry, Krasnoyarsk, Russia

12:20 **Interactions of bronze birch borer and emerald ash borer with novel and  
coevolved hosts**

[10]

Daniel Herms  
The Davey Tree Expert Company, Kent, USA

12:50 **Discussion from morning session**

13:20 **Lunch**

<b>European initial perspectives</b>	[page]
<b>14:20 The European starting point current perceptions and measures to prepare for emerald ash borer and bronze birch borer</b>	[11]
Hugh Evans Forest Research, UK	[12]
<b>14:50 How can we best prepare for and manage risks and impacts of EAB and BBB in Europe?</b>	[13]
Antoon Loomans NVWA, The Netherlands	
<b>15:20 Break</b>	
<b>15:50 EPPO perspective on emerald ash borer and bronze birch borer</b>	[15]
Françoise Petter EPPO, France	
<b>16:20 Initial impressions on the key concerns for Europe. What questions do we need to concentrate on?</b>	
Discussion session	
<b>17:30 Mixer and poster session</b>	

## 2 October 2018

<b>European initial perspectives (cont.)</b>	[17]
<b>09:00 Invasive alien pests threaten the carbon stored in Europe's forests</b>	[19]
Franz Essl University of Vienna, Austria	
<b>Monitoring and detection</b>	[21]
<b>09:30 Developing and improving detection tools for emerald ash borer and other buprestids</b>	[22]
Joe Francese USDA APHIS, Otis Laboratory, USA	
<b>10:00 Emerald ash borer detection and monitoring in Canada</b>	[23]
Christa Ryall and Peter Silk Canadian Forest Service, Sault Ste Marie, Canada	
<b>10:30 Host volatiles attractive to the bronze birch borer <i>Agrilus anxius</i> Gory (Coleoptera: Buprestidae)</b>	[24]
Peter Silk Canadian Forest Service, Fredericton, Canada	
<b>11:00 Break</b>	
<b>11:20 Trapping the bronze birch borer, <i>Agrilus anxius</i></b>	[25]
Claire Rutledge Connecticut Agricultural Experiment Station, USA	

<b>11:50 A review of trapping European buprestids with the goal of developing monitoring tools</b>	[page]
Zoltan Imrei Hungarian Forest Research Institute, Hungary	[26]
<b>12:20 Testing a compromise trapping design to capture non-native species of long-horned beetles and <i>Agrilus</i> spp</b>	[27]
Alain Roques INRA, France	
<b>12:50 Initial progress in use of detection dogs for EAB monitoring</b>	[28]
Ute Hoyer-Tomiczek BFW, Vienna, Austria	
<b>13:20 Keeping the pests out and maximising the likelihood of early detection of invasion. What is the best approach?</b>	
Discussion Session	
<b>13:40 Lunch</b>	

## Dispersal and range expansion [29]

<b>14:40 Emerald ash borer population dynamics and range expansion in Canada</b>	[30]
Christian MacQuarrie Canadian Forest Service, Sault Ste Marie, Canada	
<b>15:10 To EAB or not to EAB? It is doubtful that <i>Agrilus planipennis</i> will become a devastating forest pest in Europe in the nearest future</b>	[31]
Marina J. Orlova-Bienkowskaja A.N. Severtsov Institute of Ecology and Evolution, Moscow, Russia	
<b>15:40 Pathways for transfer of emerald ash borer and bronze birch borer to Europe</b>	[32]
Bjørn Økland Norwegian Institute of Bioeconomy Research (NIBIO), Norway	
<b>16:10 Break</b>	
<b>16:40 Quantification of pathways and optimal surveillance strategies of human-assisted introductions for emerald ash borer</b>	[33]
Denys Yemshanov Natural Resources Canada, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, ON, Canada	
<b>17:10 Managing resources to optimise prevention and to maximise detection and early deployment of management options. What is the best first response strategy?</b>	
Discussion Session	
<b>18:00 End</b>	

## Conference Dinner

**19:00 Parkhotel Schönbrunn**

---

## 3 October 2018

[page]

### Managing infestations of EAB and BBB

[35]

**09:00 Systemic insecticides and EAB: products, costs and benefits**

[36]

Deborah McCullough  
Michigan State University, USA

**09:30 Introduced parasitoids for biological control of emerald ash borer in North America**

[37]

Juli Gould  
USDA APHIS, Otis Laboratory, USA

**10:00 Beyond eradication: managing emerald ash borer to slow ash mortality**

[38]

Deborah McCullough  
Michigan State University, USA

**10:30 Break**

**11:00 A collaborative approach to preparing for and reacting to emerald ash borer: a Colorado example**

[39]

Kathleen Alexander  
Boulder Parks and Recreation, USA

**11:30 EFSA contribution to European Union preparedness for the invasion of the emerald ash borer and bronze birch borer: from media scanning to survey guidelines**

[40]

Giuseppe Stancanelli  
EFSA, Italy

**12:00 Managing invasive populations at the local and long distance scales. What is the best combination of containment and population reduction?**

Discussion Session

**13:00 Lunch**

### Economic and social dimensions of managing pest invasions

[41]

**14:00 Acceptance sampling for cost-effective surveillance of emerald ash borer in urban environment**

[42]

Denys Yemshanov  
Natural Resources Canada, Canadian Forest Service, Great Lakes Forestry Centre,  
Sault Ste. Marie, ON, Canada

**14:30 Getting plant health management wrong: what does it mean?**

[43]

Glyn Jones  
Fera Science Ltd, UK

**15:00 The social dimensions of managing emerald ash borer and bronze birch borer values, impacts and gaining a social licence to operate**

[44]

Mariella Marzano  
Forest Research, UK

**15:30 Break**

[page]

**16:00 Emerald ash borer impacts on visual preferences - results from urban forest recreation settings in Minnesota and Vienna**

[45]

Arne Arnberger  
BOKU, Vienna

**16:30 Lessons learned from managing citrus and Asian longhorn beetle in Italy developing best methods and engaging with stakeholders**

[46]

Mariangela Ciampitti  
ERSAF, Plant Health Service, Italy

**17:00 What have we learned so far about managing resources to minimise risk and maximise the likelihood of reducing the impacts of invasive buprestid beetles?**

Discussion Session

**18:00 End**

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## 4 October 2018

### The bigger picture taking stock of multiple factors and next steps

[47]

**09:00 Ash dieback and emerald ash borer ranges overlap despair or hope?**

[48]

Hans Peter Ravn,  
University of Copenhagen, Denmark

**09:30 Ash dieback and emerald ash borer the final straw for ash in Europe?**

[49]

Rimvydas Vasaitis  
SLU, Sweden

**10:00 Dramatic regional changes in ash demography resulting from emerald ash borer invasion of North America**

[50]

Andrew Liebhold  
USDA Forest Service, USA

**10:30 EFSA guidelines for EAB surveys in the EU**

[51]

Gritta Schrader  
JKI, Germany and EFSA, Italy

**11:00 Managing the complexities of multiple components of risk at a range of geographical and human scales. Where next for Europe? Pulling together what we have learned and planning how to disseminate the information for policy and other development.**

Discussion Session including video conference link to EU DG Santé

**12:00 Cooperative Research Programme (CRP): concluding remarks**

Gary Fitt  
OECD Theme Representative

**12:30 End of Conference**

## Posters

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	[page]
<b>Preparing for the early detection of EAB (<i>Agrilus planipennis</i>) to allow quick response by the NPPO in Hungary</b>	[54]
Zsuzsanna Dancsházy*, György Pataki *National Food Chain Safety Office (NÉBIH), Directorate of Plant Protection, Soil Conservation and Agri-environment	
<b>Emerald ash borer development rates and modelling for potentially invaded regions of Canada and Britain</b>	[55]
Kenneth W. Dearborn*, Sandy M. Smith, Chris J. K. MacQuarrie, Daegan J. G. Inward *University of Toronto, St. George, Faculty of Forestry, Toronto, Ontario, Canada M5S 3B3	
<b>The battle plan: defining a strategy to mitigate the emerald ash borer invasion in Kentucky forests</b>	[56]
Ignazio Graziosi*, Lynne K. Rieske *World Agroforestry Centre, Nairobi, Kenya & Department of Entomology, University of Kentucky, Lexington, USA	
<b>The "emerald ash borer discovery trail": a novel outreach approach to engage public in emerald ash borer research</b>	[57]
Ignazio Graziosi*, Lee Townsend, Lynne K. Rieske *World Agroforestry Centre, Nairobi, Kenya & Department of Entomology, University of Kentucky, Lexington, USA	
<b>Ash seedbank dynamics, recruitment, and regeneration in the wake of the emerald ash borer invasion</b>	[58]
Catherine P. Herms*, Wendy S. Klooster, John Cardina, Deborah G. McCullough, Daniel A. Herms *Department of Horticulture & Crop Science, Ohio Agricultural Research & Development Center, The Ohio State University, Wooster, OH 44691, USA	
<b>Assessment of the systems approach for the phytosanitary treatment of ash wood infested with emerald ash borer</b>	[59]
Chris J. K. MacQuarrie*, Robert Lavallée, Leland Humble *Natural Resources Canada Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen St East, Sault Ste. Marie, Ontario, Canada P6A 2E5	
<b>Modelling the potential spread of Emerald Ash Borer in the UK</b>	[60]
Cerian Webb* *University of Cambridge, UK	

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\*presenting author

## Abstracts

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# The threats: history and potential

# Evolution of the regulatory response to emerald ash borer infestation in the USA; a history of adaptation across federal and state jurisdictions

Scott Pfister

USDA APHIS PPO S&T, Otis Laboratory, Buzzards Bay, MA 02542, USA

Emerald ash borer (EAB), *Agrilus planipennis*, was first detected in the United States in 2002. Initially, our collective knowledge of EAB biology, dispersal, survey and detection, and management options were limited. However, in the ensuing sixteen years, the regulatory strategy has evolved in response to our increased knowledge of the pest and through trial and error. EAB is thought to have been introduced in solid wood packing material sometime around 1990 as determined by dendrochronological analysis. With the exception of perhaps blue ash (*Fraxinus quadrangulata*), all native North American species of ash are highly susceptible to EAB infestation. Since its initial discovery in Michigan, EAB has spread to thirty-five states (and four Canadian Provinces) resulting in the death of millions of ash trees. While some natural dispersal has occurred, EAB has primarily spread through human-mediated movement associated with nursery stock, wood packaging, and firewood. Over this period the US regulatory program has transitioned from an initial goal of eradication to containment, to suppression, and now to management. However, many of the basic components of the regulatory program have remained the same, including quarantine enforcement, survey and detection, outreach, research, host resistance, and biological control. Considering the magnitude of the expansion of EAB since 2002, USDA APHIS is now proposing the possible deregulation of the pest. The personnel and monetary resources devoted to the regulatory program would be shifted towards the agency's biological control and host resistance efforts.

# A quarter-century of emerald ash borer in Europe

Yuri Baranchikov<sup>1</sup>, Denis Demidko<sup>1</sup>, Lidiya Seraya<sup>2</sup>

<sup>1</sup>V.N.Sukachev Institute of Forest FRC KSC SB RASc., Krasnoyarsk 660036, Russia

<sup>2</sup>All-Russia Institute of Phytopathology, Bolshiye Vyazemy, Moscow District, 143050, Russia

Nowadays emerald ash borer *Agrilus planipennis* Fairmair (EAB), East-Asian invader, has spread in European part of Russia over 12 administrative districts («subjects of the Russian Federation»). Dendrochronological crossdating proved that EAB appeared simultaneously both in North America (Michigan, USA) and in Eastern Europe (Moscow, Russia) in early 1990-s. The beetle itself was noticed because of its damaging activity much later: in 2002 (USA) and in 2003 (Russia). For a moment its secondary range in European Russia occupies approximately 250 thousand km<sup>2</sup> (~ 1/2 of territory of France) and spreads from the city of Yaroslavl at the North (57°37' N) to the Southern border of Voronezh District at the South (50°12') and from the city of Talovaya, Voronezh District (40°43' E) at the East to the city of Smolensk (32°02') at the West. The most Western locations of EAB are at 70 km from the border with Belorussia and only in 25 km from the border with Ukraine, so there is a large possibility that EAB already crossed the Russian border and can be found in Lugansk District of Ukraine and in Vitebsk District of Belorussia.

During last 7 years our team had a unique possibility to study EAB populations both in an epicenter of its secondary range in Europe (Moscow District) and in moving frontlines of invasion in Western and Southern directions. In these regions we received data on factors of population dynamics of EAB, especially relations with different ash species, speed of EAB distribution, EAB/ash dieback (*Hymenoscythus fraxineus*) interactions on the newly discovered territory of their overlapping ranges, relations with predators and parasitoids.

Although at frontlines of invasion the rate of parasitizing is rather low, during last 5 years EAB nearly disappeared from Moscow District. Existing data demonstrated that EAB outbreak collapse was caused in major extent by local polytrophic parasitoid from genus *Spathius* Nees (Hymenoptera: Braconidae) who have switched to the new abundant host. This is a unique example when local biota only during a quarter of a century assimilated populations of the aggressive invader. It generates some optimistic expectations about the future of ash species in Europe. European part of Russia with overlapping secondary ranges of invasive pest and pathogen (EAB and ash dieback) is a unique and promising polygon for international cooperative effort of saving the world's ash forests. There is an evident need in international consortium to bring the best available solutions together.

The work was supported by the Russian Foundation for Fundamental Research (grant 17-04-01486).

## Interactions of bronze birch borer and emerald ash borer with novel and coevolved hosts

Daniel A. Herms

The Davey Tree Expert Company, 1500 N. Mantua St., Kent, OH 44240, USA

Emerald ash borer (*Agrilus planipennis*) has caused widespread mortality of ash (*Fraxinus*) in North America, and by 2010 mortality of green (*F. pennsylvanica*), white (*F. americana*), and black ash (*F. nigra*) exceeded 99% near the epicenter of the invasion in southeast Michigan. In Asia, emerald ash borer does not devastate its endemic hosts and primarily colonizes stressed trees, which suggests that Asian ashes are inherently resistant owing to their coevolutionary history, and that emerald ash borer acts as a secondary colonizer.

In common garden studies, Manchurian ash (*F. mandshurica*) had high survival and little canopy decline, becoming more susceptible when experimentally stressed by girdling or drought. Rapid oxidation of phloem phenolic compounds has been implicated as a mechanism of resistance. Conversely, evolutionarily naïve North American and European species experienced complete or nearly complete mortality with green, black, and Oregon ash (*F. latifolia*) declining more rapidly than white ash. Experimental drought and girdling stress had no effect on resistance of white and black ash, respectively, which were highly susceptible even when healthy. Blue ash (*F. quadrangulata*) survived at a higher rate than other North American species but had lower survival and greater canopy decline than Manchurian ash. The European taxa evaluated in a common garden also experienced high decline and mortality, including *F. ornus*, *F. excelsior* 'Aureaefolia', and *F. angustifolia* subsp. *oxycarpa* 'Raywood', which suggests that EAB has potential to cause widespread economic and ecological impacts as it continues to spread in Europe.

Similar patterns of interaction occur between the North American bronze birch borer (*Agrilus anxius*) and its coevolved and evolutionarily naïve hosts. Periodic expansive outbreaks of bronze birch borer in North America resulting in widespread birch (*Betula*) mortality have been associated with drought and defoliator outbreaks. Experimental girdling and drought stress decreased resistance of North American paper birch (*Betula papyrifera*), providing additional evidence that bronze birch borer acts as a secondary colonizer of stressed trees. A common garden study revealed that coevolved North American hosts (*B. nigra*, *B. papyrifera*, *B. populifolia*) are much more resistant to bronze birch borer than evolutionarily naïve Eurasian species (*B. pendula*, *B. pubescens*, *B. platyphylla*, and *B. maximowicziana*), which experienced 100% mortality. Experimental drought stress had no effect on resistance of *B. pendula*, which were highly susceptible even when healthy. If bronze birch borer were to establish and spread in Eurasia, it may cause birch mortality on continental scale much as emerald ash borer has in North America.

## Abstracts

### European initial perspectives

# The European starting point current perceptions and measures to prepare for emerald ash borer and bronze birch borer

Hugh Evans<sup>1</sup>, David Williams<sup>1</sup>, Mariella Marzano<sup>2</sup>

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<sup>2</sup>Forest Research, Northern Research Station, Roslin, Midlothian, Scotland EH25 9SY

There is no doubt that emerald ash borer, *Agrilus planipennis*, is a successful invasive species and continues to expand its range, with resultant extensive tree mortality in North America and, to a lesser extent, in European Russia. From a European perspective, it is essential that preparedness for this important pest takes account of all factors that affect its potential to affect ash woodlands here. There are also concerns about the bronze birch borer, *Agrilus anxius*, which appears to be aggressive on European birch.

The PREPSYS project is collating, through literature review, personal contacts and direct experiences the 'state of the art' for management of these important pests in their natural and invaded ranges. Pulling this knowledge together, a number of perspectives are apparent, but need to be transposed into a European context:

- Pathways by which EAB and BBB can reach Europe need to be identified along with the volumes moving along those pathways; are measures to manage them adequate?
- Unless an established invasive population is detected extremely early, eradication is unlikely.
- Surveillance and increasing the likelihood of early detection of invasion needs to be assessed and implemented; what are the best traps/lures, is tree girdling best?
- There is promise in use of classical biological control through introduction of parasitoids from the native ranges of the pests; how prepared is Europe to follow this if the pest(s) establish?
- What are the true relative susceptibilities of European ashes and birches to EAB/BBB?
- Outreach has played a big part in management in North America. Is Europe ready to assess methods and commit resources to raise awareness of the pests?
- Ash trees in Europe are already being devastated by ash dieback fungus, *Hymenoscyphus fraxineus*. Will this affect the dynamics of EAB when the two organisms meet in the same ecosystem?

These, and other, questions are being addressed and will help guide the European preparedness campaign in the future.

# How can we best prepare for and manage risks and impacts of EAB and BBB in Europe?

Antoon J.M. Loomans, Dirk Jan van der Gaag

Netherlands Food and Consumer Product Safety Authority (NVWA), Ministry of Agriculture,  
Nature and Food Quality, P.O. Box 43006, 3540 AA Utrecht, the Netherlands.

The emerald ash borer (EAB), *Agrilus planipennis*, and the bronze birch borer (BBB) *Agrilus anxius*, are a major threat to European forests. EAB is a buprestid native to East Asia and BBB is native to North America. EAB has invaded North America and European Russia and is causing massive tree mortality. Research on *Agrilus* species of phytosanitary importance is currently concentrated in a few regions and for a few pest species only: for *Agrilus planipennis* in its area of origin (East Asia), and in its outbreak areas in the USA / Canada and European part of Russia, for *Agrilus anxius* in North America. In order to be prepared for an incursion of any type in Europe, we drafted a contingency plan and elimination programs for different scenarios based on information what is published and on the experience of people in the field.

Evidence and expertise in risk assessment, biology, ecology, damage, detection, control options, risk management and risk communication is largely concentrated on EAB, which has rapidly extended its geographical range in North America and Russia. Current management approaches have been reviewed, based on literature, interviews with EAB/BBB experts and visits to outbreak and research sites in Russia (in 2014), Canada and USA (in 2017). This meeting is a next step in this process. The purpose is largely to learn from the current approaches and practices used in the various steps of the EAB invasion process, to better understand how to act pro-actively and take out the key elements in case of an invasion in Europe. This process includes pathway analysis (wood packaging material, hitchhiker potential); early detection (traps, lures, dogs), size of demarcation areas, short-term chemical control options for preservation of high valued trees in urban and conservation areas, risk mitigation including the pros and cons of doing nothing (as in Russia, and low target ash areas in North America), training people, communicating to the public and investigating the long-term potential of biological control. Gaps were allocated and analyzed to initiate new research including the following target points:

- Analysis of natural long distance pathways and the mechanical and physical effectivity of ISPM measures (such as chip size, temperature treatments, debarking);
- Early detection: latency time, the period between damage and the appearance of the first symptoms in the crown under European conditions (thinning/dying) at very low

density populations, efficacy lures and pheromones; positioning of traps, distance of effectivity; the use of dogs, scents and/or spectral images;

- Early establishment: determine the effectiveness of the control strategy to effectively reduce pioneer populations (combined effects of mechanical, chemical and biocontrol measures); the size of the required clear-cut zone and the buffer zone;
- The duration of the life cycle (longevity) and dispersal rate of EAB / BBB in Europe (EU); effect of (Atlantic) climate;
- Host selection behaviour: the importance and status of additional host plants other than *Fraxinus* (e.g. *Chionanthus virginicus*), infestation of superficial roots (EAB); vulnerability of various species of *Betula* (BBB);
- What are interactions between EAB/BBB and other pests (i.e. *Hymenoscyphus fraxineus*) on their hosts and what are the combined effects on the invasiveness of EAB?;
- Pro-active initialisation of biological control measures in Europe;
- Drafting a contingency plan for both species, incl. when to end the eradication scenario?

## EPPO perspective on emerald ash borer and bronze birch borer

Françoise Petter, Martin Ward

European and Mediterranean Plant Protection Organization, 21 Boulevard Richard Lenoir 75016, Paris, France

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Since 1951 the European and Mediterranean Plant Protection Organization (EPPO) has been helping its member Countries to strengthen plant protection activities and promote international cooperation.

The objectives of the Organization can be summarized as follows:

- To protect plant health in agriculture, forestry and the uncultivated environment.
- To develop an international strategy against the introduction and spread of pests (including invasive alien plants) that damage cultivated and wild plants, in agricultural and natural ecosystems and protecting biodiversity.
- To encourage harmonization of phytosanitary regulations and all other areas of official plant protection action.
- To promote the use of modern, safe, and effective pest control methods.
- To provide a documentation and information service on plant protection.

In order to achieve these objectives, the Organization has been given the task of identifying pests which may present a risk (early warning), identifying through Pest Risk Analysis their risk for the region and phytosanitary measures which can be taken against them. Once a pest has been identified as presenting a risk for the EPPO region, recommendation on how to eradicate and control this pest as well as recommendations on how to detect and identify the pest may be developed (e.g. phytosanitary procedures for inspection). Since a few years, the organization has also included in its work program activities on citizen science (development of guidelines on raising public awareness, production of toolkits to use in raising awareness campaigns, including a 'Don't' risk it! campaign for international travelers). The technical work of the Organization is carried out by Panels and Expert Working Groups under the supervision of two Working Parties (one on phytosanitary measures and another on plant protection products). The EPPO Secretariat has developed and maintains different databases including the EPPO Global Database as well as a monthly reporting service newsletter on events of phytosanitary concern.

*Agrilus planipennis* (EAB) was added to the EPPO Alert List in 2003. A communication from the National Plant Protection Organization of Sweden attracted the EPPO Secretariat's attention to this potential new pest which had been recently introduced into North

America. It was then added to the EPPO List of pests recommended for regulation in 2004 on the basis of a PRA prepared by the EPPO Panel on Quarantine Pests for Forestry. The PRA was then updated and extended by an Expert Working Group in 2013. A Standard on procedures for official control, including measures for eradication and containment, was adopted in 2013.

*Agrilus anxius* (BBB) was added to the EPPO Alert List in 2010 and a Pest Risk Analysis was performed by an Expert Working Group in the same year.

The PRAs, Standards and information related to these pests are freely available on the EPPO Website (<https://www.eppo.int>) and through the EPPO Global Database (<https://gd.eppo.int>).

The different activities relevant to EAB and BBB will be presented, and challenges posed by these pests highlighted.

# Abstracs

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## European initial perspectives (cont.)

# Invasive alien pests threaten the carbon stored in Europe's forests

Franz Essl<sup>1</sup>, Rupert Seidl<sup>2</sup>, Werner Rammer<sup>2</sup>, Günther Klöner<sup>1</sup>, Adam Moreno<sup>1,3</sup>, Stefan Neumann<sup>1</sup>, Stefan Dullinger<sup>1</sup>

<sup>1</sup>University of Vienna

<sup>2</sup>University of Natural Resources and Life Sciences (BOKU) Vienna

<sup>3</sup>NASA Ames Research Center

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Forests mitigate climate change by sequestering large amounts of carbon (C). However, forest C storage is not permanent, and large pulses of tree mortality can thwart climate mitigation efforts. Forest pests are increasingly redistributed around the globe. Yet, the potential future impact of invasive alien pests on the forest C cycle remains uncertain. In a recent study (Seidl et al. 2018), we used a combination of species distribution and carbon cycle modelling (i) to evaluate the potential consequences that invasion by five different non-native forest pest species may have on the carbon storage in Europe's forests; and (ii) to assess how different scenarios of climate warming (RCP2.6 and RCP8.5) may change pathogen invasion patterns and subsequently forest carbon storage capacity. Considering five alien pest species we show that large parts of Europe could be invaded already under current climate. Climate change increases the potential range of alien pests particularly in Northern and Eastern Europe. We estimate the live C at risk from a potential future invasion as 1,027 Tg C (10% of the European total), with a C recovery time of 34 years. We show that the impact of introduced pests could be as severe as the current natural disturbance regime in Europe. Furthermore, the potential negative effects of invaders on C storage are increasing under climate change, either because the pests' climatically suitable ranges increase, or because these suitable ranges overlap the distribution of their potential host tree species more strongly. Our results call for increased efforts to halt the introduction and spread of invasive alien forest pests.

Seidl R., Klöner G., Rammer W., Essl F., Moreno A., Neumann M., Dullinger S. (2018) Invasive alien pests threaten the carbon stored in Europe's forests. *Nature Communications*, 9, 1626.

# Abstracts

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## Monitoring and detection

## Developing and improving detection tools for emerald ash borer and other buprestids

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Prior to the introduction of emerald ash borer (EAB) to North America and its subsequent detection, very little was known about the beetle, its biology and behavior. In efforts to support the USDA's eradication effort work was conducted to develop new detection tools for this invasive pest. This work has led to the development of several traps now in use in the U.S. including the purple prism traps that have been used in U.S. survey efforts beginning in 2008. Since the development of the purple traps, EAB has also been found to be attracted to the color green; green multi-funnel traps, coated with fluon, a fluoropolymer, have been found to be comparable to or better than purple prism traps for both detection and trap catch of EAB. As part of an ongoing project to improve survey tools for EAB, we conducted a multi-state comparison of several commercially available traps on a variety of host and non-host trees. In addition this project also included a general woodborer survey of cerambycid and buprestid genera, where trap catch in each of the designs was compared with a similar study also conducted in Poland. Trapping in these locations shows that green multi-funnel traps may be effective at capturing other species of *Agrilus*.

## Emerald ash borer detection and monitoring in Canada

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The emerald ash borer (EAB), *Agrilus planipennis* is a serious non-indigenous pest in North America causing extremely high levels of mortality to ash trees (*Fraxinus* spp., Oleaceae) in the USA and Canada. Knowledge of buprestid chemical ecology is sparse but the appearance of EAB into North America and its devastating ecological and economic impacts has afforded an opportunity to study the semiochemistry, biology and ecology of this buprestid in detail (Silk & Ryall 2104). We have provided the first evidence of a pheromone in the Buprestidae for EAB as the female-produced lactone 3Z-dodecen-12-olide (3Z-lactone). Adding (3Z)-lactone to green sticky prism traps baited with (3Z)-hexenol (host volatile) consistently increases trap captures and highest captures when traps were placed in exposed positions on the south aspect of the tree canopy and had highest trap captures and detection rates at very low insect densities. We have also developed sampling techniques to estimate incidence and density of EAB from branches (Ryall et al. 2011; Turgeon et al. 2015). The CFIA recommends using these tools to detect, delimit and monitor EAB. Trapping could be used to detect an infestation whereas branch sampling could be used to delimit its extent.

Ryall, K.L., Fidge, J.G. and Turgeon, J.J. 2011. Detectability of the emerald ash borer (Coleoptera: Buprestidae) in asymptomatic urban trees by using branch samples. *Environmental Entomology* 40: 679-688.

Silk, P. and Ryall, K. 2014. The chemical ecology of the emerald ash borer, *Agrilus planipennis*. A review. *The Canadian Entomologist* 147: 277-289.

Turgeon, J.J., Fidge, J.G., Ryall, K.L., and Scarr, T.L. 2015. Estimates of emerald ash borer (Coleoptera: Buprestidae) larval galleries in branch samples from asymptomatic urban ash trees (Oleaceae). *The Canadian Entomologist* 148: 361-370.

## Host volatiles attractive to the bronze birch borer *Agrilus anxius* Gory (Coleoptera: Buprestidae)

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The bronze birch borer (BBB), *Agrilus anxius* Gory, (Coleoptera: Buprestidae) is a species native to North America that typically attacks weakened and stressed birch trees (*Betula* sp. (Betulaceae)). Although this species does not typically cause high levels of mortality in healthy trees in its native range, there is concern about its possible introduction into Europe, the U.K. and Asia (Muilenburg and Herms 2012) where it may behave as a more primary aggressive species with European *Betula* sp. Indeed, a congener, the emerald ash borer (EAB), *Agrilus planipennis* Fairmaire, is an invasive species, introduced from Asia to North America, which is causing extensive mortality to ash (*Fraxinus* sp. (Oleaceae)) in its current introduced range.

Our initial work on chemical ecology of BBB by GC/MS, GC/EAD, chemical synthesis and field trapping has identified potentially important host volatiles from *Betula papyrifera* Marshall which are antennally-active and may trap bronze birch borer adults. A better understanding of the behavior and chemical ecology of adult buprestids, in terms of host chemistry and pheromones (Silk and Ryall 2014), should provide early monitoring tools for these species.

Muilenburg, V.L. and Herms, D.A. 2012. A review of bronze Birch Borer (Coleoptera: Buprestidae) life history, ecology and management. *Environ. Entomol.* 41: 1372- 1385.

Silk, P. and Ryall, K. 2014. The chemical ecology of the emerald ash borer, *Agrilus planipennis*. A review. *Can. Entomol.* 147: 277-289.

## Trapping the bronze birch borer, *Agrilus anxius*

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Bronze Birch Borer (*Agrilus anxius* BBB) is known to be a primary pest of many European and Asian species of *Betula* when they are planted in North America as ornamentals. This includes European birch *Betula pendula* which is an abundant and ecologically and economically important tree, especially in Northern Europe. Concern about the potential for the BBB to invade Europe and decimate European Birch trees led to exploration of tools developed to detect and monitor Emerald Ash Borer (*Agrilus planipennis* EAB) for the detection and monitoring of BBB. The first year of the study, both Purple Prism Traps (PPT) and Green Multi-Funnel Traps (GMFT) were hung in birch trees and ash trees. As girdling has been shown to increase the attractiveness of both birch and ash to their respective beetles, half the traps were hung in girdled trees, and half were hung in intact trees. In the second year, PPT were hung in birch trees, using trees that had been girdled the year before to assess if trees became more attractive in the year after girdling.

Both trap types captured both species of beetles, however beetles were overwhelmingly caught in traps hung in their own host trees. Girdling ash did not impact the numbers of either sex of emerald ash borer captured. Girdling birch trees did increase the number of both male and female BBB caught in traps, and this was true across all sites despite a range of BBB population levels. Girdled birch trees were equally attractive the first and second year that they were girdled. This suggests that there is no need to wait for a year after girdling a tree to hang traps, and that girdled trees retain attractiveness in their second year. Neither species showed a preference between PPT and GMFT. In addition to trapping target species, over 1,000 non-target buprestids in 4 genera and at least 21 species were collected over the two years. Both PPT and GMFT hung in girdled birch trees show strong promise as a monitoring and detection tool for BBB. Further work is needed to determine optimal trap placement.

## A review of trapping European buprestids with the goal of developing monitoring tools

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The research initiated in the US on the orientation and communication related research on *A. planipennis* facilitated progress on monitoring buprestid species at far lower population densities in Europe. Field observations were made for the study of mating and host-finding behavioral responses of European oak buprestids based upon visual stimuli. By using pinned dead *A. planipennis* models visual mating approaches were observed by males of *Agrilus biguttatus*, *Agrilus sulcicollis*, and *Agrilus angustulus*, which behaviour was similar to that previously observed in males of *Agrilus planipennis*. A high degree of cross-species compatibility with respect to these visual cues were observed in the field when *A. biguttatus* were allowed to approach a number of different species of pinned, dead females. Small branch-traps with (4 cm × 8 cm) green plastic surfaces caught more *Agrilus* if visual decoys were included. The visual decoy was particularly important for the most serious pest, *A. biguttatus*.

Recent advances in material science allow high-fidelity replication of complex visual cues that trigger behavioral responses. Nanoscale replicas of the surface structure of *A. planipennis* were created. This high fidelity decoy offered the same distinctive light-scattering pattern as real resting females and elicited stereotypical male mating flights of *A. biguttatus* from up to 1 m away. Formulations of tree-produced volatiles such as manuka oil and Z3-hexen-1-ol had a slight tendency to increase *Agrilus* spp. trap catches, while Z9-tricosene, a chemically similar lure to the *A. planipennis* contact sex pheromone, resulted in a significant increase of trap catches for *Agrilus* spp. in general and for *A. angustulus* in particular.

Our results suggested that small sticky branch-traps can provide a useful tool for monitoring of buprestids, and of these the green plastic-covered branch-traps significantly out-performed other trap designs in the course of our experiments. In our most recent studies we aimed at developing non-sticky traps, which would be suitable to catch a wide range of buprestid species. These traps might be suitable both for monitoring invasive or indigenous species and have the potential to be further optimized with respect to visual and olfactory cues.

## Testing a compromise trapping design to capture non-native species of long-horned beetles and *Agrilus* spp.

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The accidental introduction of exotic xylophagous beetles represents an ever-increasing threat to forest biosecurity and the economies of many countries. Early detection of such species upon arrival at potential points-of-entry is challenging. Trappings using either black cross-vane or black multifunnel traps baited with a 8-component blend of cerambycid pheromones, to which were added host volatiles (ethanol and [-]- $\alpha$ -pinene), were carried out at both potential points-of-entry and in natural forests in France from 2016 on. The blend confirmed a generic attractiveness for long-horned beetles, with the trapping of 114 native species and three exotic Asian ones, together with a large number of scolytid species, including exotic ambrosia beetles (*Xylosandrus* spp. and *Euplatypus* spp.). However, these black traps caught only very few buprestid beetles. Therefore, the attractiveness of green multifunnel traps baited with the same 8-component blend was compared to the one of black traps in 6 forests and 1 airport during 2017. The green traps effectively captured 25 species of buprestids of which 15 *Agrilus* spp. (8 species at Charles-de Gaulle airport) but both the number of species and individuals of trapped cerambycids was significantly decreased with regard to the trappings by black traps, showing that green traps cannot be expected to help detecting simultaneously exotic species of both families at arrival. Because the number of traps to be deployed in ports-of-entry has to be minimized as much as possible, we tested during 2018 at the same sites the use of multifunnel and cross-vane traps combining black and green design (6 funnels or 1 side of each color, respectively) with regard to black and green traps baited with the same blend. The final results will be presented during the conference but preliminary analyses tend to show that such patchwork traps may not represent a good compromise for effective trapping of both cerambycids and buprestids.

## Initial progress in use of detection dogs for EAB monitoring

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Surveillance is a key element in management of invasive wood boring insects like *Anoplophora glabripennis* and *Anoplophora chinensis*. Detection of infested trees depends on effective visual inspection. As one complementary method, dogs have been trained at the Austrian Research Centre for Forests (BFW) since 2009 and employed for the detection of *A. glabripennis* and *A. chinensis* in several European countries. The likelihood of the early detection of trees infested by the emerald ash borer (EAB) *Agrilus planipennis* by visual inspection is very low due to minimized signs and symptoms of the infestation. Encouraged by the positive results of the evaluation of the dog detection method for *A. glabripennis* and the successful use of detection dogs in practice for the monitoring of this invasive pest, dog detection could be also a suitable complementary method for monitoring the Emerald Ash Borer. Therefore, the initial training of six dogs on *Agrilus planipennis* started in November 2017 at the BFW. All dogs were previously trained on the detection of *A. glabripennis* and *A. chinensis*. Scent material of EAB, such as living larvae, bark and wood pieces of infested ash trees with galleries, saw dust and frass of EAB originated from Connecticut, USA. Imprinting of the dogs was done with living EAB larvae, followed by the addition of saw dust with frass and galleries in bark and wood of ash trees to complete the scent pattern of EAB for the dogs. Training the dogs involved inspection of firewood and wood logs as typical pathways for introduction of EAB as well as young ash trees in a forestry nursery and old ash trees in an urban area.

In June 2018, the sensitivity of the dog detection method towards EAB was tentatively quantified during training units with five dogs. Three different experimental set ups with three repeats each were tested under single blind conditions: (1) ash wood/bark pieces with EAB galleries hidden in young ash trees in a forest nursery, (2) dead EAB beetle and saw dust hidden in firewood piles, (3) wood/bark pieces with EAB galleries hidden between wood logs on the ground. Set up (1) consisted of 2 positive and 28 negative samples, set ups (2) and (3) of 2 positive and 6 negative samples in random order. Young ash trees infested with *Hymenoscyphus fraxineus*, the causal agent of the ash dieback, served as negative samples in set up (1), non-infested ash wood pieces in the set ups (2) and (3). Additionally, the wind direction and strength, the temperature, air humidity and the duration of the search were recorded. The experiments ascertained an overall sensitivity of 83.3 to 100 % and a specificity of 88.9 to 99.8 %. Although the number of used dogs is limited, these results are very encouraging, and further training and experiments have to be carried out for confirmation. EAB inspections with detection dogs especially at import points could provide one promising method helping to prevent new introductions of EAB.

## Abstracts

### Dispersal and range expansion

## Emerald ash borer population dynamics and range expansion in Canada

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For invasive species how successful adult insects are in various life history processes influences how well invaders can colonize and reproduce. Emerald ash borer (EAB) is a significant invasive forest insect in North America that has killed millions of ash trees. We have previously shown that EAB population dynamics are influenced by the stage of the infestation and the location of the tree they insect develops in. This results in slow rates of population growth that result in populations that are difficult to detect. However, once these populations pass a 'tipping' point populations become large, easy to detect but difficult to manage. In Canada, how and when these populations transition from small to large has likely influenced rates of population spread and growth.

To determine what factors influence population growth rates we tested the effect of host condition insect performance. In this study healthy trees were girdled to simulate poor host condition and then both artificially and naturally infested by emerald ash borer. The ensuing adults that developed were then assessed for their success in terms of number, lifespan, size, mating success and fecundity. Girdling increased the number of insects that emerged from trees, but was associated with reduced lifespan, and had confounding effects on mating success and fecundity. Adult size was positively affected by girdling but negatively affected by crowding that larvae experienced during development. This suggests that it is not necessary to consider host condition when assessing the risk of emerald ash borer, as the dynamics of populations attacking poor-condition trees will be the same as the dynamics populations attacking good-condition trees.

In a related study we attempted to determine why population growth rates of new populations in the northern part of the distribution in Canada appear to be slower growing than those in the south. Our hypothesis is that a cooler climate at more northern sites has resulted in populations that are growing slower and thus subject to different dynamics than populations in the south. To test this we sampled populations along a latitudinal gradient and across infestations of different ages and assessed the frequency of one and two year life cycles. Support for our hypothesis would suggest that management of EAB in Canada would need to incorporate the frequency of one and two year life cycle in a targeted population.

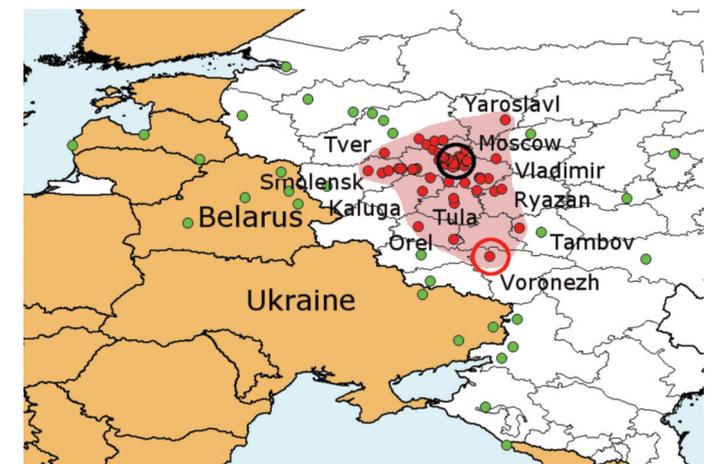
## To EAB or not to EAB? It is doubtful that *Agrilus planipennis* will become a devastating forest pest in Europe in the nearest future

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*Agrilus planipennis* was first recorded in European Russia and North America almost at the same time (2003 and 2002 correspondingly). EAB has become one of the most notorious forest pests in the USA and Canada. But the data obtained from regional forest services of different regions of European Russia in 2018 indicate that EAB has not become a serious forest pest there. *Agrilus planipennis* has significantly damage urban plantations of *Fraxinus pennsylvanica* (introduced from North America) in some cities, but infestations of the only native ash species *Fraxinus excelsior* are rare, even in the regions, where *F. excelsior* is common and EAB occurs more than 10 years there. Moreover, all these infestations have been observed near plantations of *Fraxinus pennsylvanica* severely damaged by EAB. Our survey in 18 districts of Moscow in 2016 and 2017 showed that *F. pennsylvanica* is still common all over the city in spite of severe outbreak of the pest in 2007-2013. The survived trees are recovering. The pest has become rare. In summer 2018 we collected just one beetle. No expansion of EAB range since 2013 has been recorded (Fig. 1). In summer 2018 we examined ash trees in the east of Belarus (Mogilev, Orsha, Vitebsk) and found no symptoms of EAB infestation. There is an outbreak of the pest in Voronezh now, but in general, the situation in Russia is much better than in the USA. It seems that EAB will not become a serious forest pest in EU countries at least in the next 10 years.

Fig. 1: Current range of EAB. Initial point of invasion (Moscow city and its vicinity) is circled black. The region of current severe outbreak (Voronezh) is circled red. Red dots: localities, where EAB has been detected. Green dots: localities, where surveys in 2016-2017 gave negative results.



# Pathways for transfer of emerald ash borer and bronze birch borer to Europe

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While continental range expansion for invasive beetle species on the European continent may be particularly hard to arrest, it should be possible to prevent overseas invasions of the bronze birch borer (BBB) and the emerald ash borer (EAB). Invasion of BBB will likely have dramatic impacts on both ecosystem processes and economy in many forest regions throughout Eurasia, where susceptible birches are found across 11 time zones. Considering the high mortality of European and Asian birches to BBB attacks, it is important to avoid overseas introduction of this species in Eurasia. Arrival of EAB in ash forests of the UK and the Scandinavian Peninsula will most likely also require transport overseas, since overland range expansion will be limited by the discontinuous distribution of ash in northern Europe. For the pathway wood with or without bark, the substrate may become safe to import from areas with BBB or EAB after removal of outer sapwood, heat treatment or irradiation, while import of plants for planting represents an unacceptable risk. EAB and BBB may also survive in wood chips of their host trees, but the lower limit of chip size for survival is uncertain and could potentially be relatively small. In addition, several cases show that imported wood chips may include large fragments, either because setting a maximum size by a chipping screen allows long fragments to pass through, or because leftover material after chipping has been included. Import control of BBB and EAB is not a feasible method for detecting and rejecting large contaminated wood chip consignments. A simulation study with an imported shipload of 100 million litres of chips showed that the probability of detecting BBB by the current sampling protocols used by port inspectors was extremely low ( $< 0.00005$ ). Obtaining a 90% chance of detection would require sampling an excessively large volume of wood chips (27 million litres). The use of pheromone traps or dogs in ports of entry may potentially increase the detection rate, but it still seems unrealistic to rely on import control to detect and return individual large consignments. This is due both to a potential high number of undetected beetles slipping through the control, and the fact that a long delay of unloading ships probably will not be accepted in practice. In line with the goals of increased use of biofuels in the EU, the last 10 years have seen a threefold increase in energy production from solid biofuels in EU. The import of deciduous wood chips to the EU increased strongly in the period 2004–2013. This increase has slowed down in the last years, while the import of wood pellets to EU has been steadily increasing. Import of wood chips made from tree species that are hosts of BBB and EAB is not accepted in UK and Norway. However, tree species composition in a shipload of wood chips imported to Norway was found to deviate from the declaration and included tree species that are illegal due to the risk of importing forest pests. We suggest that wood chips should be regulated as a commodity rather than by individual host tree species, due to the irregular species composition of wood chips and the practical difficulty of determining the tree species content of large consignments by import control. Because wood pellets and pulp are not pathways for BBB and EAB, such imports could potentially replace all overseas import of wood chips to Europe if wood chips were regulated.

# Quantification of pathways and optimal surveillance strategies of human-assisted introductions for emerald ash borer

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Decision makers tasked with planning the surveillance of invasive species often have to rely on uncertain knowledge about the long-distance introductions of an invader, and face the dilemma of scarce resources available to conduct surveys but the aspiration to cover all possible pathways of pest entry. Often, surveillance planning relies on the estimates of invader's propagule pressure (such as estimated rates or likelihoods of pest arrival or spread), however these estimates often appear to be highly uncertain when characterized by pathway-based, low-probability spread events. Also, these approaches may not be effective when the survey budget is limited.

We provide an overview of most common data sources that could help characterize the pathways of long-distance spread of Emerald Ash Borer (EAB, *Agrilus planipennis* Fairmaire), a major pest of ash in North America and Europe. We present a pathway-based surveillance planning methodology, which meets an important decision-making objective: it maximizes coverage of potential pathways of pest entries from already-infested areas, and, in turn, fully captures the high-threat infested sources (as opposed to common propagule pressure models, which focus on uninfested sites only). To monitor the infested source locations, we formulate a maximum expected coverage problem (MECP), which maximizes the expected number of sources that are covered by the survey system, where a source is covered if at least one of its transmission pathways connects to a surveyed destination. To monitor pest introductions, we present and compare two survey models based on propagule pressure (PP): maximizing the expected number of transmission pathways that are covered by survey locations and maximizing the expected number of survey locations that have one or more pest introductions. We demonstrate the models by assessing the potential spread of the emerald ash borer (EAB) by visitors to campgrounds in central Canada and the U.S. Midwest. The MECP and PP-based model solutions agreed for large surveillance budgets but exhibited differences when the budgets were small. Compared to the PP model, the MECP is more influenced by the degree of connectivity between the invaded and uninvaded sites and prioritizes the sites that may receive pest transmissions from many infested source locations. Overall, the approach helps incorporate the data on long-distance spread and can be adapted to survey the spread of EAB and other pest species via human-mediated vectors in other regions.

# Abstracts

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## Managing infestations of EAB and BBB

## Systemic insecticides and EAB: products, costs and benefits

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Emerald ash borer (EAB) has rapidly become the most destructive and costly invasive forest insect in the U.S. Much of the economic costs are borne by municipalities and private property owners who must either protect ash trees in landscapes with insecticides or remove the trees as they succumb to EAB. Systemic insecticides, applied by trunk injection, basal trunk sprays or soil drenches, are transported in xylem from the base of the tree to the canopy. These products have largely replaced cover sprays of conventional insecticides for pest control in landscapes. Our ability to use systemic insecticides to protect trees from EAB has substantially improved, due to new insecticide products and application methods, along with a better understanding of ash physiology and EAB biology. A brief summary of a recent six-year study to evaluate three systemic insecticides applied annual or at 2-year or 3-year intervals will be presented. Several studies have shown protecting ash trees with systemic insecticides is less costly than removing trees, and retains the ecological services provided by mature trees. Additional costs and benefits of removing versus protecting ash trees in landscapes will be addressed.

## Introduced parasitoids for biological control of emerald ash borer in North America

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In response to the invasion of the United States by the destructive emerald ash borer (EAB), *Agrilus planipennis*, scientists from the U.S. and China, Korea, and Russia collaborated to discover promising natural enemies that could be released in a classical biological control program. Potential biocontrol agents were imported into quarantine and host specificity testing was conducted. In 2007 permits were issued for the release of three of the agents: two larval parasitoids, *Spathius agrili* (Hymenoptera: Braconidae) and *Tetrastichus planipennisi* (Hymenoptera: Eulophidae), and the egg parasitoid *Oobius agrili* (Hymenoptera: Encyrtidae). Releases began in the mid-west and have expanded to 25 states as the EAB population has spread throughout the country. Follow-up monitoring of establishment and spread of the parasitoids shows that *T. planipennisi* is establishing and dispersing well in northern states, and although *O. agrili* is small and difficult to recover, it too seems to be establishing in some states. *Spathius agrili* populations have been recovered for a year or two after release, but populations do not persist in the north. A large parasitoid like *S. agrili* is needed, however, because *T. planipennisi* has a short ovipositor and can only parasitize EAB in branches less than 11 cm in diameter. Scientists have discovered a new EAB parasitoid in the genus *Spathius*, *S. galinae*, from Russia. Climate matching indicates a better fit for the northern U.S. and early results indicate that this parasitoid is establishing. Work is continuing to discover which parasitoids are best suited for the variety of climate conditions in the United States, to quantify the role that *O. agrili* is playing where it has established, and how to integrate the use of insecticides to save mature trees with releases of natural enemies in urban areas. Recent studies of the next generation of ash growing in sites where *T. planipennisi* has established indicate that this parasitoid, combined with predation by native woodpeckers, has the potential to maintain EAB at a low density following an EAB outbreak.

## Beyond eradication: managing emerald ash borer to slow ash mortality

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Substantial knowledge of emerald ash borer (EAB) (*Agrilus planipennis* Fairmaire) has been acquired since this invasive pest was first identified in 2002 in southeastern Michigan. This knowledge can be useful in developing strategies to mitigate EAB damage in a given area. Much of the difficulty of EAB management results from EAB adult dispersal behavior and our relatively poor ability to detect new, low density infestations. Host preference behavior of EAB adults can help guide detection and monitoring activities. Girdled ash trees are highly attractive to EAB adults and can be used for detection and as trap trees in recently infested areas. Highly effective systemic insecticides, particularly emamectin benzoate products, can be integrated with girdled trees to slow EAB population growth and the rate of ash mortality. An overview of results from a large scale pilot project encompassing 390 km<sup>2</sup> will be presented. Systemic insecticides and biological control are also compatible. Preliminary results from a current study indicate treating a small portion of the ash resource with emamectin benzoate can reduce EAB populations without interfering with parasitism or woodpecker predation.

## A collaborative approach to preparing for and reacting to emerald ash borer: a Colorado example

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For urban forest management in Colorado, collaboration has been the key to success; not only collaboration among agencies at all levels of government, but also in engaging industry allies, coordinating extensive education and outreach efforts, and in fostering community support.

A unique interagency team, the Emerging Pests in Colorado (EPIC) Workgroup, was formed in Colorado in 2009 to respond to the immediate threat from thousand cankers disease of black walnut and to plan for the arrival of other invasive urban forest pests to Colorado. When the invasive emerald ash borer (*Agrilus planipennis* Fairmaire) (EAB) was detected in Boulder, Colorado in 2013, it marked the westernmost occurrence of EAB in the United States, threatening millions of planted and naturalized ash trees representing over 25% of the tree canopy throughout Colorado's urban and riparian forests. The detection in Boulder prompted the development of a second multi-agency group, the Colorado EAB Response Team. The two teams have worked closely since 2013 on a delimitation survey, quarantine, diagnosis workshops, media requests, assisting smaller communities with EAB plans, extensive education and regional outreach.

The presentation focuses on 1) how the interagency collaborative pre-planning and post-EAB response has supported community forestry programs throughout the state; 2) methodology to solicit public support for management of invasive species; 3) the development of the post-detection EAB management plan and economics behind the strategy in the city of Boulder; and 4) extensive outreach and pre-detection efforts underway in other major Colorado communities.

# EFSA contribution to European Union preparedness for the invasion of the emerald ash borer and bronze birch borer: from media scanning to survey guidelines

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The European Food Safety Authority (EFSA) and its Scientific Panel on Plant Health (PLH) provides independent scientific advice for the European Commission (EC), the European Union Member States and the European Parliament on the risk posed by plant pests which can cause harm to plants, plant products or biodiversity in the EU. This is done by continuing to provide support to the new EU plant health law (pest categorisations, pest risk assessments, commodity risk assessments, peer review of risk assessment and scientific documents prepared by third parties, impact assessments for pests prioritisation) and by an increasing support in the recent years to the EU plant health crisis preparedness (by: 1) horizon scanning for identification of new and emerging plant health threats via automated and manned media and literature monitoring; 2) development of risk based plant health surveillance guidelines and factsheets; 3) establishment of cooperation projects. In collaboration between EFSA and the European Commission Directorate-General Joint Research Centre (JRC), a media monitoring system for the surveillance of plant pests has been set up. The system is based upon the fully automatic event-based surveillance system MEDISYS (Medical Information System). MEDISYS is part of the Europe Media Monitor (EMM) system and is a fully automatic public health surveillance system to monitor reporting on human and animal communicable diseases, chemical, biological, radiological and nuclear threats, and food & feed contaminations. The EMM system retrieves news items from official and unofficial media sites, general news media and selected blogs. Generally, news items are either retrieved from RSS feeds or by crawling HTML sites. Over 22,000 feeds of general news sites from over 107 countries are currently monitored including news websites at national, regional and local level, as well as feeds from specialist plant health sources were added in the directory of monitored sources. A Plant Health Threat Ontology with pest and disease names coming from multilingual sources such as UniProt Taxon, EPPO and Wikipedia has been built with multilingual keywords definitions for 560 categories for plant health threats, covering more than 350 quarantine plant pests and the outbreaks of new plant pests or diseases. Media monitoring related data can support risk managers in the establishment of control measures and can help better understand the impacts of plant pests and their control and the societal response to plant health threats. This system is now being extended to the automated monitoring of scientific literature. In this presentation the monitoring results for the emerald ash borer and bronze birch borer are reported.

## Abstracts

### Economic and social dimensions of managing pest invasions

## Acceptance sampling for cost-effective surveillance of emerald ash borer in urban environment

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Surveillance of forest pests has been long recognized as a critical component of cost-effective control of new invasions. We develop acceptance sampling strategies for surveillance of emerald ash borer (EAB) in Winnipeg, Manitoba, Canada. The landscape in Winnipeg is divided into sites for which we know the density of ash trees, the likelihood of infestation, and the detection rates for two EAB inspection methods – branch sampling and trapping. With acceptance sampling, a sample of trees is inspected in each site and if one or more trees is found to be infested, then the site is declared as infested. The manager's problem is to determine the optimal number of trees to inspect with each inspection method in each site subject to a survey budget constraint. We compare acceptance sampling strategies computed with two different management objectives. The first objective maximizes the expected number of sites (or area) with detected infestations. The second objective minimizes the expected number of undetected infested trees in sites that were not surveyed or where the surveys did not find the signs of infestation. The choice of the management objective influences the survey strategy: Achieving the first objective prescribes the selection of sites with highest infestation rates in close proximity to the infested area, whereas second management objective would require inspecting the sites with both high infestation rates and high host densities. We also incorporate the uncertainty about the EAB invasion likelihoods with a large set of scenarios of site infestation rates. We explore the impact of the uncertainty about site infestation rates and detection probability on the surveillance strategies. Adding uncertainty prescribes inspecting a larger area footprint with lower sampling rates and extending the surveys to further distances from the infested locations. When the decision-maker is risk-averse and strives to avoid the worst-case outcomes of the survey (such as damages from failed detections), the optimal strategy is to survey additional sites with high host densities at further distances from the infested area where the arrival of EAB, if undetected, could cause significant damages. Accounting for the uncertainty addresses possible temporal and spatial variation in infestation rates and helps develop a more diversified survey strategy. The approach is generalizable and can support delimiting survey and control programs for new pest incursions.

## Getting plant health management wrong: what does it mean?

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The risks posed by pests and disease of trees, woodlands and forests are difficult to assess and any analysis invariably comes wrapped in varying degrees of uncertainty. They are also difficult to communicate to stakeholders since successful biosecurity (or simple luck) means that the negative impacts do not materialise. In this light, what does "wrong" mean? Plant health is just one consideration of many for decision makers who must allocate funds for the tasks. Such allocations may be insufficient to match the risks. Further, once allocated to the area of plant health, such funds may be mis-directed toward less effective parts of the pathway or less damaging pests for example. This can include continuing eradication efforts when a more effective response is adaptation.

There is a strong economic argument for the public support of plant health policies and this is now generally accepted at national level decision making. However, the degree to which it influences the efficient allocation of resources for plant health (or indeed the allocation of resources within the total plant health budget) is open to debate. It has been argued that the response to plant health risks is typically reactive rather than pro-active, that there is a temporal lag from the pest entering and spreading through the landscape to stakeholder awareness and willingness to respond to manage the outbreak. This has consequences for the cost-effectiveness of the available management options and therefore the potential for economic savings by investing in early action. This further implies that prevention pre-border is most effective but also that there is a threshold for the spread beyond which management responses should cease and that adaptation measures ("learning to live with") are most appropriate.

# The social dimensions of managing emerald ash borer: values, impacts and gaining a social licence to operate

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The Emerald Ash Borer (*Agrilus planipennis*) or EAB has caused extensive damage and high mortality to native ash (*Fraxinus* spp.) in North America. As the United Kingdom and other European countries battle with the deadly pathogen *Hymenoscyphus fraxineus* (ash dieback) affecting native European ash (*Fraxinus excelsior*), there is a huge concern that the arrival of EAB will signal the demise of this much loved tree. While Europe prepares for EAB both in terms of scientific studies and policy development, it is vital that we understand the social and economic dimensions that will influence preparedness and acceptability of potential management measures. In this paper we will assess the range of socio-economic constraints and opportunities that managers and decision-makers will have to operate within to prevent the arrival and establishment of EAB in Europe - or failing that, to underpin early detection, mitigation and/or adaptation. Success in reducing the impact of EAB will be dependent on close engagement and partnership with key individuals and organisations along the most likely pathways of spread and whom affect the implementation of management responses. This involves mapping the underlying values, attitudes and behaviours of multiple stakeholders at different spatial scales. Social license to operate and pathways of spread will vary across cultures, local economies and political jurisdictions. Therefore to explore the constraints on management actions and assess likely stakeholder responses, we combine insights from case studies of EAB management in the USA with recent social research on tree health management – particularly ash dieback - from the UK and Europe generally.

# Emerald ash borer impacts on visual preferences - results from urban forest recreation settings in Minnesota and Vienna

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Extensive outbreaks of invasive forest insects such as the emerald ash borer (*Agrilus planipennis*; EAB) are having serious impacts on the cultural ecosystem services of forests in the United States and Europe. Limited experience with how such outbreaks might affect urban recreational opportunities prompted this investigation of visitors to a state park in St. Paul/Minneapolis, Minnesota, USA, where EAB damage is occurring and in Vienna, Austria, where no EAB-impact is yet observed. A photo-questionnaire solicited recreational areas visitors' visual preferences for trail environments in a discrete choice experiment. Systematically manipulated digital images simulated different levels of EAB impact in combination with other physical, managerial and social attributes including trail-proximate EAB-related forest management responses, land use context of the viewscape beyond the trail environment, visitor types and behaviour, and visitor densities. Both physical and social attributes of EAB-impacted forests influenced urban visitors' trail preferences. Results indicated that EAB impacts were significant but of lesser importance than surrounding viewscape development and visitor numbers. Specifically, respondents preferred dense trailside shrub vegetation and low trail user numbers and disliked viewscales showing city buildings close to the trail and removal of most ash trees. Results suggest that trail planning should not only consider near-view landscape impacts but also the visual quality of more distant viewscales, and that urban forest managers need to be aware of how EAB impacts and subsequent management responses affect recreation setting preferences.

# Lessons learned from managing Citrus and Asian longhorn beetle in Lombardy (Italy); developing best methods and engaging with stakeholders

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*Anoplophora chinensis* (Citrus longhorn beetle) and *Anoplophora glabripennis* (Asian longhorn beetle) are two species of invasive organisms originating from Asia, accidentally introduced into Lombardy. These insects damage the plant by boring galleries inside the wood, which weakens the plant and provides access ways for other pathogens (e.g. fungi, bacteria). The serious infestations in urban forestry can result in a reduction in biodiversity. In addition these two species are quarantine pests and, to fulfill the phytosanitary law, all infested plants must be destroyed with heavy economic and social consequences. These beetles are three centimeters long, but it is not easy to identify them among the vegetation. The life cycle takes one or two years and the infestation can remain undiscovered for years. When an infestation is discovered may be several plants already infested. Therefore, early detection is essential. Ornamental trees for the first species and wood packaging material for the second one were been the most likely pathways. In Lombardy there are many sites at risk of introduction of these pests. Because it is impossible for the Plant Protection Service to check all host plants, it is very important to inform subjects directly involved with the problem, such as officials, parks and municipal staff, but also residents, urging them to report any suspected presence of these insects.

Since 2004 the Lombardy Plant Protection Service launched a campaign through communication media designed to provide residents with information about the problem. The communication campaign is repeated every year and the message is: "This pest is not a threat to humans, but it is a serious threat to plants and the environment. So if you see an adult or a sign of the presence of this insect, you should call the Plant Protection Service". Leaflets and posters were distributed, and voice-mail and e-mail boxes were also activated. Meetings with municipal technicians and residents were organized and articles were

published in newspapers, magazines and scientific journals. For the first time a TV advert was created on this topic and broadcast. A brief documentary has been posted on YouTube to inform viewers about the threat posed by this insect. In addition, since 2008, a unique awareness campaign was launched in the stations of the Milan underground.

The surveillance carried out by residents has been very effective. Thanks to an increasing level of awareness among citizens, new infestations of *Anoplophora* spp. were detected in Lombardy. This experience shows that an active role of residents is crucial to preserve green areas and biodiversity and to prevent environmental and economic damage caused by pests.

With the same purpose in 2018 has been developed a mobile application for tablets and smartphones.

## Abstracts

### The bigger picture taking stock of multiple factors and next steps

## Ash dieback and emerald ash borer ranges overlap despair or hope?

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The devastating ash dieback caused by *H. fraxineus* damage most *Fraxinus excelsior* trees, but leave some trees almost unaffected. Some of these trees possess heritable resistance against ash die back, and selection and testing activities have been initiated in several European countries in order to identify trees for future seed collection. But how will a combination of EAB and *H. fraxineus* affect the remaining ash trees? Will trees with low susceptibility to *H. fraxineus* prove robust against EAB damage? Or may such trees oppositely reveal higher susceptible to EAB due to trade-off between insect and pathogen resistance? Studies to answer these questions can be done in the areas where both the pathogen and the pest are present. This contribution will discuss the ideas for collaborative research in such an area and present objectives, perspectives and challenges.

## Ash dieback and emerald ash borer the final straw for ash in Europe?

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Currently, dieback of *Fraxinus* spp. (Ash DieBack, ADB) occurs in Europe on a massive scale (1). This is an emerging disease, threatening the existence of ash over the continent, caused by *Hymenoscyphus fraxineus*, alien and invasive fungus, origin of which is Far East Asia. This presentation will illustrate patterns of ADB spread throughout Europe, symptoms, and options for its management. One option to be discussed is creating databases of ADB-resistant/tolerant ash genotypes subjecting those for further propagation. Aims of our EU LIFE+ project on "Saving NATURA 2000 habitats on Gotland Island, Baltic Sea" were: i) search for visually healthy trees in Natura 2000 damaged ash sites; ii) select and GPS record those; iii) collect seeds from and sow; iv) search for vigorous 2-3 years-old saplings of ash under canopy of disease-affected stands; v) planting out those; vi) monitor health status of "mother", sawn and planted trees. Results of the work will be presented.

Another presented Scandinavian project will be "Emerald Ash Borer (EAB), invasive deadly pest approaching eastern EU border: preparing for the worst case scenario". The aim is to conduct a pilot study and to elaborate the basis for the future work to mitigate the effects of eventual invasion of EAB to EU. The objectives: i) in European Russia, monitor spread of EAB; ii) study population genetics of EAB; iii) search for the potential biological control agents and options for their rearing; iv) map viable trees in Russia; v) collect plant material from those to study biochemical traits potentially contributing for EAB-resistance mechanisms for eventual propagation. The goal is to clarify the current north-west range limit of EAB. To do this, ash trees are surveyed along the highway M10, between Moscow and St.Petersburg (2). IMPORTANT: During last 4 years EAB nearly disappeared from the city and from Moscow suburbs and many of damaged ash are still alive and are regenerating successfully (3).

(1) Vasaitis R., Enderle R. (eds) 2017: Dieback of European Ash (*Fraxinus* spp.) - Consequences and Guidelines for Sustainable Management. Swedish University of Agricultural Sciences, Uppsala, 320 pp. <http://www.slu.se/globalassets/ew/org/inst/mykopat/forskning/stenlid/dieback-of-european-ash.pdf>

(2) Selikhovkin A.V., Popovichev B.G., Mandelshtam M.Y., Vasaitis R., Musolin D.L. 2017: The frontline of invasion: the current northern limit of the invasive range of Emerald Ash Borer, in European Russia. *Baltic Forestry* 23:309-315. [https://www.balticforestry.mi.lt/bf/index.php?option=com\\_content&view=article&catid=14&id=482](https://www.balticforestry.mi.lt/bf/index.php?option=com_content&view=article&catid=14&id=482)

(3) Seraya L., Yatsenko I., Demidko D., Baranchikov Y. 2018: Susceptibility of different ash species to Emerald Ash Borer in ash collection of the Main Botanical Garden in Moscow. In: Proceedings of LIFE+ ELMIAS Ash and Elm Conference, 26 August – 1 September, Uppsala – Visby, Sweden (ed. R. Vasaitis). Swedish University of Agricultural Sciences, Uppsala p. 75. <https://www.slu.se/iufro-rots2018>

# Dramatic regional changes in ash demography resulting from emerald ash borer invasion of North America

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Subsequent to its introduction near Detroit, the emerald ash borer (*Agrilus planipennis* Fairmaire) has caused extensive mortality of ash tree species (*Fraxinus* spp.) in the eastern United States. As of 2018, the pest was documented in 967 counties within the natural range of ash in the eastern United States. Regional forest inventory data from the U.S. Forest Service Forest Inventory and Analysis program were used to quantify trends in ash mortality rate and volume per hectare relative to the year of initial emerald ash borer detection. Results indicate that the annual ash mortality rate increases by as much as 2.7 % per year after initial detection of the pest in a county. Corresponding decreases in ash volume (as much as 1.8 m<sup>3</sup> per hectare per year) continue for several more years until most live ash is killed. Though this insect is killing the vast majority of overstorey Ash in eastern N. America, large numbers of seedlings and saplings exist in the understorey. Analysis of overstorey ash mortality and seedling / sapling dynamics provides some information from which the future dynamics of ash in N. America can be inferred.

# EFSA guidelines for EAB surveys in the EU

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The European Commission requested EFSA to facilitate the Member States (MS) in the planning and implementation of their survey activities. In this context, EFSA develops pest survey cards for pests of EU relevance (Regulation (EU) No 652/2014) within the European Commission co-financing programme of the annual Member State survey activities. Each survey pest card summarizes the biological, epidemiological and diagnostic key information relevant for the detection and identification of the pests by inspectors and laboratory technicians in the MSs. Moreover, guidelines for 3 pilot pests are being prepared for the survey planners and designers in the MSs (EFSA, 2018). *Agrilus planipennis* is one of the pilot pests, and for *A. anxius*, a pest survey card will be developed. The guidelines will provide

1. support on the underpinning statistical methods, and use of the EFSA WEB-based tools RiBESS+ and SAMPELATOR to inform survey design, including sample size calculations and
2. the relevant practical information for the implementation of surveys.

In the development of these deliverables, interaction with experts on these organisms and the Member States is needed before and after implementation of the surveys following the guidelines for ensuring they are fit for purpose and can be harmonized across the EU.

An important feature of the survey cards is the identification of risk factors, to focus the surveys on those areas, where the highest probabilities exist to find the pest in case it is already present. A risk factor is defined as a biotic or abiotic factor that enhances the probability of infestation in the epidemiological unit by the pest. The risk factors that are relevant for the surveillance are those that have more than one level of risk for the target population. EAB is unlikely to enter the EU via trade of host plant commodities from third countries where the pest occurs because the trade is subjected to the special requirements laid down in 2000/29/EC, and human assisted spread via movement of infested material or cultural practises is also unlikely due to the absence of the pest in the EU so far. However, the beetle could hitchhike to the EU by means of transport. Therefore, it is necessary to identify higher risk areas in the EU. This is the case for sites such as sawmills, nurseries, and garden centres and for forest areas along the terrestrial transport network. Also around harbours and airports with international transports the risk of finding the pest could be higher. In this presentation, the guidelines for EAB will be shown and open issues will be discussed.

EFSA (European Food Safety Authority), Ciubotaru RM, Cortiñas Abrahantes J, Oyedele J, Parnell S, Schrader G, Zancanaro G and Vos S, 2018. Technical report of the methodology and work-plan for developing plant pest survey guidelines. EFSA supporting publication 2018: EN-1399. 36 pp. doi:10.2903/sp.efsa.2018.EN-1399

# Posters

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## Preparing for the early detection of EAB (*Agrilus planipennis*) to allow quick response by the NPPO in Hungary

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The poster presents Hungary's reaction to the appearance of emerald ash borer (*Agrilus planipennis*) in the European part of Russia and its spreading to southwest. Preparing for the early detection of the pest began in 2011 with putting in place a survey programme. The National Plant Protection Organisation (NPPO) shared responsibility with the Forestry Agency by including non-native pests in their country-wide monitoring programme, covering, among them, EAB. As a second step, the NPPO of Hungary, a country neighbouring with Ukraine, in 2014 began to monitor firewood imports at the entry points (BIPs) to the EU. Wood from European non-EU countries is not subject to phytosanitary inspection before entering the EU.

The risk of introducing EAB with firewood from Ukraine to EU via the Hungarian border depends on various factors, such as:

Research-related:

- occurrence of EAB in Ukraine - key information

Inspection-related:

- source of the wood consignment – location in Ukraine
- EAB status of the area at the source of the wood – if EAB is present or not
- volume of trade and share of the host (ash) in the consignments
- quality of firewood consignments

In order to evaluate the magnitude of the risk of introducing EAB with firewood from Ukraine, checking of the non-regulated firewood consignments was launched, based on a good cooperation with the customs office. Weekly records of firewood lots per genus have been collected at the BIP and analysed by the headquarters of the NPPO. According to the monitoring experience, the risk on this pathway is quite low at the moment, wood consignments arrive from the southwestern part of Ukraine where EAB has not been recorded so far and the share of ash wood is below 1 %. The efforts of internal surveys for EAB and depth of checking firewood at the border will be increased when the above factors – in particular the status of the pest in Ukraine – change to increase the risk. Sharing information about EAB occurrence and developing feasible detection methods by researchers, together with risk-based checking of non-regulated imports by the NPPO could result in early detection to allow quick response to threats by *Agrilus planipennis*.

## Emerald ash borer development rates and modelling for potentially invaded regions of Canada and Britain

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The emerald ash borer (EAB), *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), is expanding its invasive range within North America and Europe. EAB easily overwhelms North American ash (*Fraxinus*) species, quickly killing trees in urban environments in the Northern Hemisphere and the deciduous forests of North America. Capable of developing in a broad range of climates, EAB will likely continue to expand westward through Europe from Russia, where there is a more continental climate like North America. However, in the more moderate climates of the UK compared to North America, EAB populations may increase the frequency of two-year life cycles. For instance, a longer duration of time as larvae may change how fast populations grow and kill trees. A longer life cycle also would influence the timing and application of control tactics, like biological control species releases. In order to understand the risk that EAB poses to the Britain and the rest of the UK it is imperative to be able to predict the potential range of EAB.

This study has two goals: 1) Determine the developmental rates of EAB life stages feeding in and on green and European ash across a range of biologically relevant temperatures (e.g., 7 – 30 °C), and 2) use these data to build predictive models for EAB development rates in Britain and the rest of the UK under a present and future climate. To accomplish these goals the various life-stages of EAB will be exposed to the range of temperatures in the controlled setting of growth chambers, where we will measure time of egg hatch and larval growth rates via head-capsule width to track instar specific development. The models will determine 1) how areas outside of the current invasive range of EAB will influence the growth rates, voltinism, and invasion abilities with a cooler climate creating a shorter thermal window for development; and 2) how cooler summer temperatures of the UK and the diet of another non-coevolved host, European ash, will influence the growth rates, voltinism, and invasion potential of EAB.

Our intent is that these results will be part of a framework for risk assessment of continued spread of current invasive ranges. These data will also be used to assess the risk of entry and spread of EAB within the UK. The models produced will enable a better allocation of time and resources towards monitoring and management efforts to mitigate ecological and economical losses to EAB.

## The battle plan: defining a strategy to mitigate the emerald ash borer invasion in Kentucky forests

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We are defining a novel integrated strategy to sustainably manage the non-native emerald ash borer (EAB) in Kentucky forests. Management of the EAB has been very challenging, due to high susceptibility of America *Fraxinus* species and the fast spread of beetle populations, this limiting success of biological control. We set 2 objectives: 1) slowing ash decline and EAB development by applying a low-dose of systemic insecticide while simultaneously mass-releasing parasitoids. This could facilitate the establishment and proliferation of biological control at various scale, thus providing long-term regulation of EAB populations and mitigating ash mortality, 2) defining how resident parasites and predators interact with EAB and with mass-released parasitoids. We identified native parasitic wasps associated with EAB. Collectively these efforts are contributing to a sustainable management approach against this highly invasive tree-killing pest.

## The „emerald ash borer discovery trail“: a novel outreach approach to engage public in emerald ash borer research

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The development of an novel integrated management approach for the emerald ash borer (EAB) in Southeastern US led us to design an outreach to communicate the threats posed by EAB, the mitigation efforts under evaluation, and the costs associated with the loss of ecosystem services provided by ash trees in our forests. We invited our audience into a research site, Raven Run Nature Sanctuary, a 300 ha park covered by mixed woodlands and meadows in central Kentucky. We established six educational stops along the most popular trail at the facility to communicate our research efforts and outcomes, and named the activity “EAB discovery trail”. Our four priorities were: 1) Engage a wide audience targeting users with diverse experiences, education, and age; 2) Focus learning objectives to provide knowledge on EAB identification and management, research tools, and forest health; 3) Employ a variety of teaching approaches, including visual tools, hands-on demonstrations, research gear; 4) Provide an engaging experience coupling a nature hike with a learning opportunity, also generating opportunity for exercise and/or mindful communing with nature.

# Ash seedbank dynamics, recruitment, and regeneration in the wake of the emerald ash borer invasion

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The long-term persistence of ash (*Fraxinus*) in forests invaded by emerald ash borer (*Agrilus planipennis*) will depend on the potential for seedling recruitment and regeneration. We quantified demography and regeneration of white ash (*F. americana*), green ash (*F. pennsylvanica*), and black ash (*F. nigra*) in 96 monitoring plots established across a gradient of ash density and soil moisture in forests near the epicenter of the EAB invasion in southeastern Michigan. As ash mortality increased, the number of viable ash seeds in soil samples decreased sharply, and no viable seeds were collected in 2007 or 2008. By 2009, mortality of ash with stem diameters > 2.5 cm exceeded 99% and no newly germinated ash seedlings were observed, leaving only an orphaned cohort of established seedlings and saplings. Trapping revealed that EAB was still present at low densities in 2012. The future of ash at these sites will depend on the outcome of the interactions between the orphaned cohort of previously established ash seedlings and saplings and low density EAB populations, as well as native and introduced natural enemies.

# Assessment of the systems approach for the phytosanitary treatment of ash wood infested with emerald ash borer

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Systems approaches are beginning to be adopted for the phytosanitary treatment of export lumber. Use of systems approaches requires extensive knowledge of the levels of reduction of pests of concern at each stage in the production pathway for the exported lumber. It is generally not possible to obtain statistically validated levels of reduction for most woodboring pests (e.g., *Monochamus* larvae) in milled lumber because of relatively low densities of these organisms. We used emerald ash borer (EAB) in ash as a model for evaluating the systems approach as it provides a unique opportunity to generate statistically valid datasets of the risk reduction at each stage in the production process (i.e., harvest, milling and heat treatment). EAB is usually present in infested ash at high densities a few years after a stand is attacked, and large volumes of infested ash are relatively easy to obtain in regions in North America where the insect is established.

Previous studies have assessed the effect of heat treatment on survival and subsequent emergence of EAB. The results of these studies suggests that present treatment guidelines (56 °C core temperature for 30 minutes ISPM 15 Option G) that meet these minimum standards will likely sanitize EAB infested wood, though these temperatures have not been optimized for EAB in production systems. Moreover, it is possible that some EAB may survive phytosanitary treatment temperatures due to insufficient heating. Though, if the resulting adults are non-viable (e.g., they cannot mate, disperse or lay eggs), then the risk posed by the material is mitigated. No study has examined the effect on EAB of sub-lethal exposure to phytosanitary treatment. We tested these assumptions by creating 7.5 cm thick ash slabs from EAB-infested trees and then treating these slabs to a range of temperatures (48-71°C). All EAB were then allowed to emerge from these slabs whereupon they were reared until death. We recorded emergence, lifespan, fecundity and fertility as measures of success and sublethal effects.

We found that there were no sublethal effects of heat treatment on EAB in infested ash slabs. However, we determined that there was no emergence from infested slabs treated to a target core temperature of 52 °C (realized temperature of 53.3 °C). Subsequent dissection of all treated slabs showed that all insects that did not emerge were either arrested in the adult stage for treatment temperatures < 52 °C. Above 52 °C unemerged emerald ash borer were arrested in the prepupal stage.

# Modelling the potential spread of Emerald Ash Borer in the UK

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An important factor in the establishment of EAB in both European Russia and North America was that the insect remained undetected for several years. This enabled spatial dispersal of the insect away from the point of entry, rendering national eradication of the insect impracticable. Although the UK is on high alert for EAB, it is still possible that the beetle will have started to spread away from any primary infestation prior to detection.

As part of the UK contingency plan for the potential arrival of Emerald Ash Borer (EAB) we are developing a stochastic model for the spatial spread of the insect. The model will be used to inform a targeted surveillance strategy and to investigate the likely efficacy of a range of control measures including felling and chemical control for a range of delayed detection scenarios.

Existing models and epidemiological studies relating to the spatial spread of Emerald Ash Borer in North America, European Russia and Canada provide insight into the key factors affecting within host dynamics, local and long-distance spread. In our presentation we consider how the UK host landscape, natural predators, climate and ash dieback may affect model assumptions for within-host dynamics, local dispersion of adults, and human-mediated dispersal compared to the existing outbreak zones.