Emerald ash borer

– our 'most unwanted', Toronto's experience

Emerald ash borer (EAB) is the most significant forest health challenge facing North America, with tens of millions of trees dead and dying as the beetle continues its spread to new areas. Edward Wilson and Sandy Smith report from Toronto, Canada, one of the hardest-hit urban centres, but where best practice has been demonstrated and lessons learned.

INTRODUCTION

Since 2012, the most significant forest health issue in the UK has been the introduction and spread of Chalara dieback of ash, caused by the fungus *Hymenoscyphus fraxineus*. Meanwhile, on the other side of the Atlantic, another invasive species, the emerald ash borer, is having a widespread and devastating impact on ash trees and woodlands.

The emerald ash borer (EAB) is a native of eastern Asia, and was first detected in Detroit, Michigan and Windsor, Ontario in 2002. It is now thought to have been accidentally imported inside packaging or shipping crates during the 1990s. Since its arrival, it has spread rapidly throughout the eastern United States and Canada, with many economic, ecological and social impacts. Ash is an important timber species and occupies a critical niche in many woodland ecosystems. It is also used as an amenity tree in towns and cities. To date, tens of millions of trees have been killed and EAB continues to spread into new areas. The cost of managing EAB is now counted in the billions of dollars.

The city of Toronto has long been known for its impressive 'green canopy' and its pioneering work in urban forestry. Besides heritage trees lining the avenues in older neighbourhoods, there are large areas of woodland in protected areas that criss-cross the city in a network of wooded ravines. Given its proximity to Detroit, Toronto was one of the first major centres to be faced with an EAB invasion. Toronto's controlled approach to managing what has been called an ecological tsunami serves as an important case study in planning and preparing for any accidental introduction of EAB to the UK.

EAB is not presently in the UK but sits at the top of the 'most unwanted' list of threats to forest health. Many experts talk in terms not of if, but when, it will arrive here. Given that our ash population is already under significant strain due to Chalara dieback, EAB will likely have a devastating impact should it become established. Apart from the cost of managing an EAB infestation, there are concerns for public safety due to the rapid death of large numbers of trees during the initial wave of EAB colonisation.

This article describes the key features of the emerald ash borer, essential for early detection, and provides a summary of measures adopted to manage the EAB invasion. Learning from the experience of cities such as Toronto will help us keep EAB out of the UK and minimise its impact if (or when) it appears.

BIOLOGY AND DISTRIBUTION OF EAB

The emerald ash borer *(Agrilus planipennis)* is a member of the beetle family Buprestidae. It is a specialist wood borer of ash trees (genus Fraxinus) and is known to colonise other tree species in the Oleaceae family. In its native range, across eastern Asia, the EAB colonises Manchurian ash (*F. mandshurica*) and Chinese ash (*F. chinensis*) but is not considered to be a major forest pest. However, in North America the emerald ash borer has few natural checks and colonises all 20 native species of ash. These include five ash species in Ontario: green ash (*F. pennsylvanica*), white ash (*F. americana*), black ash (*F. nigra*), blue ash (*F. quadrangulata*) and pumpkin ash (*F. profunda*). Most species have little or no resistance to attack and usually die following an infestation. Only blue ash has demonstrated some resistance. EAB also kills introduced species of ash from Europe planted for amenity purposes, including our common ash (*F. excelsior*).

When first detected in 2002, EAB was found across seven counties in southern Michigan. Within 15 years it has spread to 34 US states and four Canadian provinces, and continues to spread wherever ash trees grow. EAB typically kills trees within one to four years of initial attack; over 99% of all ash trees in a stand will likely be dead within six years. In Russia, a population of EAB has also become established in the Moscow region and is expanding rapidly to the west and south at a rate of approximately 25 miles each year.

One major reason for the rapid spread of EAB has been an inability to control the transport of ash firewood from regulated (infested) areas. New infestations have arisen far ahead of the frontal wave of the natural spread of EAB, mostly attributable to the transport of timber and firewood containing EAB larvae. Federal agencies have developed regulations to restrict transport of ash materials, but these have had limited success.

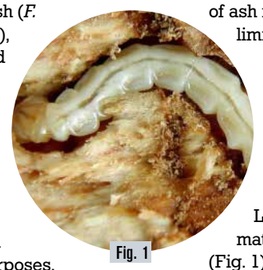
Fig. 1

SPECIES IDENTIFICATION AND LIFE CYCLE

EAB has three distinct forms: larvae, pupae and adults. Larvae are 25–32 mm long at maturity, creamy white in colour (Fig. 1). The head is flat and brown, while the abdomen has ten segments and a fork-like appendage at the tip. Pupae are 10–15 mm long and creamy in colour. They take on adult colouration as they mature. The larvae and pupae are rarely visible, as they develop in or under the bark of the host tree. Adults are bright metallic green in colour, 8–14 mm long and 3–3.5 mm wide (Fig. 2). They have an elongated body and flattened head, with large, black compound eyes and short antennae. The surface of the abdomen under the wings is usually a bright red colour.


Fig. 2


Fig. 3


Fig. 4

Adult beetles emerge from D-shaped holes, 4–5 mm across, between May and July (Fig. 3). These D-shaped holes are a feature of Buprestid beetles and are not exclusive to EAB. The females live for approximately 22 days, the males slightly less, feeding on ash foliage. Each female lays 60–90 eggs that hatch in 7–10 days in bark crevices. The larvae bore into the sapwood, phloem or cambium where they feed by chewing S-shaped tunnels. They continue feeding through four larval stages until temperatures drop in the autumn. Feeding tunnels can be 20–30 cm long and fill with excreted material (frass). When EAB populations become large enough, larval feeding causes girdling of the host tree and leads to tree mortality (Fig. 4). The larvae remain under the bark throughout the winter. They pupate in April or May and emerge as adults approximately two weeks later. Generally, a beetle will complete its life cycle in one year; in colder and more northern areas the life cycle can extend over two years.

SIGNS AND SYMPTOMS

There are several signs and symptoms of EAB in ash trees and woodlands. These include: crown dieback and individual dying branches, usually from the top down; a general yellowing and thinning of foliage; bark deformities and vertical fissures due to callus tissue produced in response to larval feeding; bark-stripping and holes in the trunk due to woodpecker activity; and epicormic shoots growing from the lower trunk and branches (Fig. 5). Other important features to observe include the D-shaped exit holes of emerging adults, and the characteristic insect galleries filled with frass that are exposed when bark peels back, 1–2 years after infestation.

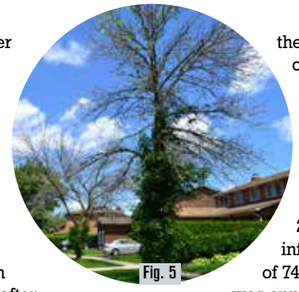
Fig. 5

An EAB infestation is difficult to detect until symptoms are severe, by which time the population has increased and had an opportunity to spread. The challenge with early detection is that many of the symptoms are similar to other conditions affecting ash trees. For example, a variety of root and butt rots can cause late flushing, thinning foliage and decline leading to eventual death. There can be confusion with Chalara dieback, where we see gradual death of scattered twigs and branches. Given the importance of early detection, it is recommended that suspect cases are referred to plant health experts at the earliest opportunity.


Fig. 6

TORONTO'S EXPERIENCE WITH EAB

The EAB invasion has presented a significant challenge for the city of Toronto and surrounding municipalities. Toronto is a highly forested urban area with over 28% woodland cover. The long-term goal is to increase woodland cover to 40%, which is being delivered through an impressive programme of tree maintenance and planting. With a budget of around 70 million Canadian dollars, the urban forestry department has over 300 FTE staff and 300 contract staff, and supports numerous community initiatives.

The first case of EAB in Toronto was confirmed in 2007. An invasive species strategy was already in place under the direction of the Canadian Food Inspection Agency, with support from other federal, provincial and municipal agencies. Initially a survey was conducted and as many trees as possible were removed for research purposes. However, it was quickly clear that EAB could not be contained (Fig. 6). A five-point plan was approved in 2011 to control and manage the ongoing infestation. Key elements were: (1) monitoring and surveying the ash resource; (2) removal of dead and dying ash trees; (3) insecticide treatment of selected trees; (4) tree replacement and proactive planting with alternative tree species; (5) communication and public outreach. By 2012 the entire city was infested with EAB. A budget of 74.5 million Canadian dollars was approved to deliver the EAB plan to 2019–20. Major considerations included mitigation of public risk, minimising impact on natural heritage features, and co-operation with both public and private sectors in research and development.

Experience from Detroit and Windsor was important in managing the Toronto infestation. Data from these earlier outbreaks made it possible to develop a cumulative mortality curve, which predicted that the peak year for tree mortality would be 2014 (24,000 trees) and peak year for budget spend would be 2015 (15.1 million Canadian dollars). In the absence of any control measures, it was also predicted that the ash population of 860,000 trees (9% of the city's trees) would be dead by 2019.

The true scale of the challenge is perhaps best visualised in terms of numbers. Of the 860,000 ash trees in Toronto, 54% (470k trees) were on private property and 46% (390k trees) were city-owned. Trees on privately-owned land are the responsibility of landowners, both in terms of the cost of removal and liability. Across the city's estate, approximately 82,000 trees (50k park trees, 32k street trees) required active management. These were trees in areas where there was public risk, such as along paths or in high-access areas. The rate of tree mortality was such that it was not possible to actively manage the remaining 312,000 trees, mostly located in woodland areas away from paths and rides.


Fig. 7

In the active management response, the city had two options: felling trees that represent a public risk or treating a sub-population of high value trees with TreeAzin® insecticide (Fig. 7). TreeAzin® is a botanical injectable insecticide formulated with azadirachtin (an extract of neem tree seeds). It was developed by the Canadian Forest Service in collaboration with BioForest Technologies and is considered safe for use in urban areas. Approximately 16k park and street trees


Fig. 8

were selected for protection with TreeAzin®. This was estimated to drop to 11k trees by 2017 due to mortality in 5–10% of treated trees. Treatment costs 185 Canadian dollars per tree and effective control usually requires two injections in three years.

Critical to the success of EAB management measures has been a programme of public engagement, community outreach and communication. Support was required from across the community to ensure adequate funding and address concerns about safety issues and tree canopy loss. The EAB infestation has also presented a powerful opportunity for communities to engage with issues of environmental adaptation and resilience, especially in the selection of alternative tree species as replacements for ash. However, despite all the attention and funding, the stark reality is that less than 2% of the ash population in Toronto has been saved, and that the future of these trees depends on continuing management, resources and funding.

LESSONS LEARNED

As with Chalara dieback of ash in the UK, the EAB infestation in Toronto, and more widely across Canada and the US, presents an important opportunity to learn and adapt in the face of future forest health threats.

Prevention: Once EAB becomes established in a new region it is very difficult to eradicate and control. Tree mortality, stand loss, and slowing the spread become the main management concerns. Preventing EAB introduction is the most effective way to reduce the threat of widespread ecosystem change. A key measure is controlling the movement of ash timber and firewood outside regulated areas. Also important is increased awareness of the identifying features of EAB, signs and symptoms of infestation, and established protocols for reporting suspected cases. As with Chalara dieback, restricting the planting and composition of ash in stands as well as the development of more resistant provenances are effective for preventing EAB spread.

Detection: Where EAB is suspected in a new area, detection becomes a critical issue enabling rapid response and treatment. Two methods for detection of EAB have been developed: (1) detection traps baited with plant volatiles (Fig. 8); (2) branch sampling, where skilled surveyors use established guidelines to check for the presence of larvae below the bark.

Control: There are three methods of control currently being used to contain the spread of EAB: mechanical, chemical and biological. Mechanical control involves removal and destruction of infested trees. This is effective on a small scale in local areas for reducing the rate of spread of EAB. Chemical control in Canada is based on the use of a systemic insecticide that includes one of three active ingredients, imidacloprid, acephate or azadirachtin. Four injectable insecticides are registered for use in Canada against EAB, with TreeAzin® being used in Toronto. Repeat treatments are required for long-term protection of a treated individual tree. Biological control is being implemented with the movement of native parasitic wasps and the introduction of non-native ones from China that predate EAB. One species from China, *Tetrastichus planipennisi*, has been released in Ontario, but requires monitoring and research to determine efficacy.

Collaborative Research: Research has proven critical in the response to EAB in North America. Significant advances have been made in prevention, detection and control of EAB through inter-agency and public–private collaborations, leading to best-practice guidelines for EAB management. Already several initiatives have been launched where UK researchers are collaborating with colleagues in the US and Canada. This work is likely to give our forest health experts a strategic advantage in minimising the risks and potential impacts of EAB. Ultimately, however, it is the effectiveness of our plant health regulations and import controls that are our greatest defence.

CONCLUSIONS

Emerald ash borer has proven to be a devastating introduced pest to forests in North America. The estimated cost of EAB management in Canada may reach 2 billion Canadian dollars for affected municipalities over a 30-year period. In the United States, estimates suggest that 17 million trees will need to be replaced in urban areas over a ten-year period. This would cost USD 10.7 billion, but could double if both urban and rural areas are considered. Research is only beginning to assess the ecological impacts of ash mortality on aquatic and terrestrial ecosystems and bird populations.

The city of Toronto has been seriously affected by EAB. However, the development of a detailed management plan has made it possible to deliver an effective EAB-control programme with broad community support. Skills and expertise acquired by forestry professionals in Toronto are helping colleagues in other regions address the challenges presented by EAB.

Here in Britain we must remain in a state of high alert for the potential introduction of EAB. The continuing spread of EAB in North America and Russia, and the global movement of wood and wood packaging, pose major threats to our biosecurity. A contingency plan is in place, but most important is wider awareness and vigilance among forestry professionals, and the public, together with early reporting of suspected cases to plant health experts.

FURTHER INFORMATION

- CABI Invasive Species Compendium – www.cabi.org/isc/datasheet/3780
- Emerald Ash Borer Information Network – www.emeraldashborer.info
- Forestry Commission – www.forestry.gov.uk/emeraldashborer
- Forestry Commission EAB Contingency Plan (2017) – www.forestry.gov.uk/pdf/EABContingencyPlanUpdated26-09-2017.pdf
- Forestry Commission Tree Alert - www.forestry.gov.uk/treealert

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