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Emerald Ash Borer: The Beginning of the End of Ash in North America?

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Introduction

Since its accidental importation from Asia, the emerald ash borer (*Agrilus planipennis*) has infested and killed more than six million ash trees (*Fraxinus* spp.) in southeastern Michigan woodlands, parks, urban forests, street-tree plantings, landscapes, and nurseries.

The core infestation of this exotic, invasive insect now extends across two to three thousand square miles in 13 counties in southeastern Michigan and Windsor, Ontario.

All major North American ash species have been killed by the emerald ash borer, which infests trees ranging in size from 1-1/2-inch-caliper nursery stock to fully mature trees in forests. While most native borers kill only severely weakened trees, the emerald ash borer kills healthy trees as well, making it especially devastating.

The threat cannot be over-estimated.

If it is not contained and eradicated, the impact of the emerald ash borer on ash in North America will be similar to that of chestnut blight and Dutch elm disease, which devastated woodland and urban forests in the 20th century.

The emerald ash borer was unknown in North America until June 2002, when it was discovered killing ash trees in southeastern Michigan and neighboring Windsor, Ontario. This borer is native to eastern Russia, northeastern China, Mongolia, Taiwan, Japan, and Korea, where it occurs on several species of ash. It was probably imported to Michigan by means of infested ash crating or pallets at least 10 years ago.

Localized infestations discovered in Ohio in 2003 in Lucas (February), Defiance (August), Paulding (August), Wood (September), and Franklin (November) counties have triggered ongoing eradication efforts in Ohio.

In September 2003, an infestation was also confirmed in Maryland near Washington, D.C. Artificial spread of the insect has been traced to movement of infested ash logs, firewood, and nursery stock.

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Economic and Ecological Impact of Emerald Ash Borer

The economic and ecological impacts of the emerald ash borer have already been substantial — and will be staggering if this exotic pest continues to spread. It clearly has the potential to reduce dramatically the importance of ash as a component of North American forests, which will have dramatic effects on forest ecosystem processes, as well as plant and animal communities.

Ash species, which inhabit a variety of soils and ecosystems, are dominant throughout the forests of eastern North America. An Ohio Department of Natural Resources study estimated that there are more than 3.8 billion ash trees in Ohio, with standing timber valued at more than $1 billion.

Furthermore, ash is one of the most important nursery and landscape species. According to the USDA, the wholesale value of ash sold by Ohio nurseries exceeded $20 million in 1998, a market threatened by the emerald ash borer.

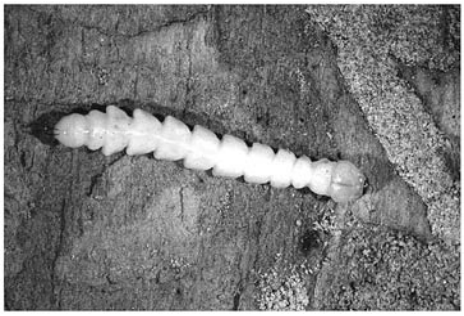
Michigan and Ohio have already experienced serious economic impacts. Ash has been one of the most commonly planted trees in landscapes and urban forests. In Michigan, the emerald ash borer has already caused an estimated $11.6 million of damage to landscapes and woodlots, and quarantines have restricted the sale of $2 million worth of nursery stock.

In addition, costs of removing dead and dying ash trees have overwhelmed municipal budgets in the affected counties, and private property owners must often pay in excess of $1,000 per tree for removal of large shade trees. A quarantine on ash timber also has had negative economic impacts on sawmills, tool handle factories, and firewood dealers in Michigan and Ohio.

Eradication costs for the localized emerald ash borer infestation in Lucas County, Ohio, in April 2003 exceeded $300,000, while projected costs of eradication in southeastern Michigan are estimated at $350 million over the next 10 to 13 years.

Taxonomy and Biology

Taxonomically, the emerald ash borer is a beetle (Coleoptera) belonging to the family known as metallic wood-borers (Buprestidae). Adults of many species



Larvae of the Emerald Ash Borer

Adult Emerald Ash Borer
Note the D-shaped exit hole, a sure sign of infestation.

in this family are brightly colored with a metallic glint, making them favorites of collectors.

Larvae of these beetles are known as *flatheaded* borers, deriving this common name from the larvae which appear to have a broadly flattened head (it is actually the thorax which mostly conceals the much smaller head). Emerald ash borer larvae are white with a long (about one inch when mature) narrow, segmented abdomen that is also flattened, which gives them the appearance of small tapeworms. Adults are elongate, 1/2-inch-long beetles with striking metallic-green coloration.

The emerald ash borer belongs to the same genus (*Agrilus*) as bronze birch borer (*A. anxius*) and twolined chestnut borer (*A. bilineatus*), which are both native to North America. The biology of emerald ash borer is quite similar to its native relatives. There is one generation each year. Adults emerge from late May through early August, with emergence peaking in early July.

As adults emerge, they leave small (1/8 inch), distinctly D-shaped exit holes in the trunk and main branches, which are a sure sign of infestation. Adults feed on foliage for one to two weeks prior to mating.

Females produce 50 to 100 eggs, which are laid individually on the bark surface, or within bark cracks and crevices. Observations indicate that upper portions of the trunk are colonized initially, making it difficult to detect early infestations.

As larvae hatch, they tunnel into the tree, where they feed on the phloem and outer sapwood, excavating S-shaped, serpentine galleries just under the bark. Larvae continue to feed through summer and into the fall, with most completing their development prior to over-wintering in the outer bark or just under the inner bark within the outer inch of sapwood. Pupation occurs in mid- to late spring. Adults emerge soon thereafter to complete the typical one-year cycle.

Diagnosing Emerald Ash Borer: Signs and Symptoms

Infestations of emerald ash borer are difficult to detect until they become severe. This is because larvae are hidden under bark; they colonize the upper portion of the trunk first; and symptoms resemble other causes of tree decline.

There are few external signs or symptoms of early infestations. When trees are still vigorous, small, vertical splits may form in the bark in response to the growth of wound-periderm (callus) tissue that forces out the bark as it forms over larval galleries in the phloem.

To confirm the presence of emerald ash borer, widen the splits to reveal larvae and galleries under the bark. Larval galleries are distinctly S-shaped or serpentine, and are packed tightly with frass, a mixture of sawdust and excrement. The galleries are also visible on the inner surface of the outer bark when removed.

The presence of small (1/8 inch) D-shaped exit holes in the trunk or main branches, caused by emerging adults, is a sure sign of infestation. As infestations progress into the second year, the canopy will start to thin, and branch dieback may occur. Decline accelerates rapidly, and trees are generally killed within two to four years of

infestation. Epicormic shoots often sprout from the main trunk of declining trees.

Woodpeckers are proving to be important predators of the emerald ash borer. A noticeable increase in woodpecker activity on ash trees can provide an early indication of an infestation, especially during winter.

Distinguishing Emerald Ash Borer From Native Borers

Green Industry professionals and Extension personnel called to inspect declining ash trees may have the first opportunity to detect new emerald ash borer infestations before they become well established. However, there are several native clearwing and roundheaded borers that also commonly infest ash. Hence, the ability to distinguish emerald ash borer infestations from those of native borers is extremely important.

Among the most common of the native ash borers are the banded ash clearwing borer (*Podosesia aureocincta*) and ash/lilac borer (*P. syringae*), both of which are the larvae of clearwing moths. The banded ash clearwing borer has become especially common in Ohio's urban forests.

The presence of D-shaped emergence holes in the trunk and main branches is the most distinctive diagnostic guide.

Although many signs and symptoms of native borers resemble those of emerald ash borer, there are several important characteristics that are useful in distinguishing clearwing borer infestations from those of emerald ash borer. In particular, the nature of the galleries and the shape of the exit holes are distinctly different.

Clearwing larvae bore deep into the sapwood, while galleries of emerald ash borer are confined to the phloem tissue just under the bark. Clearwing borers expel their frass from the tree, which can accumulate in large quantities in bark crevices, branch crotches, and on the ground, providing a good sign of an infestation. Conversely, emerald ash borer larvae pack their frass tightly within their galleries as they feed. Upon emerging, clearwing borers leave behind a pupal case, which is sometimes found protruding from the emergence hole. Flatheaded borers, on the other hand, do not produce a pupal case.

The shape of adult emergence holes in the trunk is the most distinctive diagnostic guide. The emergence holes of emerald ash borer are distinctly D-shaped, while emergence holes of clearwing borers of ash are larger (1/4-inch diameter) and round. Because the galleries of clearwing borers penetrate into the sapwood, one can insert a thin wire through the emergence hole well into the tree. This is not possible with emerald ash borer exit holes, as the galleries wind just under the bark and are plugged with frass.

There is a native species of *Agrilus* that infests ash, and it probably also produces D-shaped emergence holes. However, it is much smaller than emerald ash borer, and colonizes only small branches and twigs.

Several species of roundheaded borers also infest ash, with the redheaded ash borer (*Neoclytus acuminatus*) being the most common in Ohio. Roundheaded borers are larvae of longhorned beetles (Order: Coleoptera; Family: Cerambycidae), which derive their name from the very long antennae of adults. As their name implies, the larvae of redheaded ash borer

and other roundheaded borers are round in cross section, in contrast to the highly flattened profile of flatheaded borers.

Redheaded ash borer infestations can also be distinguished from emerald ash borer by the presence of large (3/8-inch wide), oval exit holes. Galleries initially form just under the bark and are packed with frass, as is the case with emerald ash borer. However, redheaded ash borer galleries are not nearly as serpentine.

As larvae mature, they extend their galleries well into the sapwood, usually following the grain of the wood, while emerald ash borer galleries are restricted to the phloem. Furthermore, redheaded ash borer is restricted to severely weakened, dying, and freshly killed trees *(e.g.,* freshly cut timber and firewood), while emerald ash borers colonize even healthy trees.

In summary, the presence of serpentine galleries packed tightly with frass just under the outer bark, coupled with D-shaped emergence holes in the trunk and main branches, are the tell-tale signs of an emerald ash borer infestation.

Host Plants and Host Impact

Ash species known to be infested in Michigan include green ash (*Fraxinus pennsylvanica*), white ash (*F. americana*), black ash (*F. nigra*), and blue ash (*F. quadrangulata*), as well as horticultural cultivars of these species. Only living trees are colonized. The emerald ash borer will not colonize a dead tree. Native host plants in Asia also include ash species, with *F. mandshurica* (Manchurian ash) and *F. chinensis* being primary hosts.

In China, the emerald ash borer is known only to colonize ash. In Japan, species of *Juglans* (walnuts and bitternuts), *Ulmus* (elms), and *Pterocarya* (wingnuts) have also been recorded as hosts. However, the emerald ash borer has not been well studied in Japan.

Furthermore, host records for borers are notoriously unreliable. For example, host records for wood-borers often include species from which adults were collected, even when they do not colonize that species in the larval stage. Research this past year at Michigan State University strongly suggests that walnut and elm are not viable hosts for emerald ash borer larvae.

Adult beetles feed on foliage, resulting in irregular, jagged-edged patches of missing tissue along the leaf margin, the impact of which is negligible. The larva is the damaging stage, girdling the tree as it tunnels under the bark where it feeds primarily on phloem tissue. This disrupts the flow of carbohydrates between the canopy and the roots, which results in canopy thinning, branch dieback, and finally tree death, typically within two to four years of initial infestation.

Larvae also engrave the outer layers of the water-conducting sapwood (xylem) as they feed. This type of feeding by *Agrilus* spp. actually causes relatively little harm to trees such as birches with a xylem anatomy known as *diffuse porous,* because water is conducted through a number of annual growth rings, most of which are not injured. Rather, flatheaded borers, such as bronze birch borer (*A. anxius*), tend to kill diffuse porous species gradually as girdling of phloem starves the roots.

On the other hand, *ring porous* trees, such as ash, can be killed rapidly by flatheaded borers, such as the emerald ash borer (*A. planipennis).* The functional xylem of ring porous trees is confined to the current growth increment just under

the bark. Borers, such as the emerald ash borer that scar the surface of the xylem, cause extensive damage to this very thin layer of water-conducting tissue as they engrave the surface of the sapwood. This disrupts the transpiration stream, which can result in rapid decline and death of infested trees, especially during periods of drought.

Ohio State University's Research on Host Plant Resistance

In Asia, the emerald ash borer does not devastate its native hosts. Reports indicate that outbreaks are isolated and associated with stress events such as drought. This suggests that in Asia, native ashes may be generally resistant, and that the emerald ash borer preferentially colonizes stressed trees.

Thus, the emerald ash borer behaves in Asia much as its close native relatives do in North America, including the bronze birch borer and the twolined chestnut borer, which also preferentially colonize stressed trees.

Native trees may be more resistant to their native pests because of natural defenses that have evolved over eons. Hence, Asian ash trees may be a source of resistance genes.

Researchers at Ohio State University — Daniel Herms, Entomology, and Enrico Bonello, Plant Pathology — are collaborating with colleagues at Michigan State University to investigate this possibility. An experimental ash planting was established in 2003 in Novi, Michigan (with trees donated by Bailey Nurseries, Inc.), to compare resistance of native and Asian ashes to the emerald ash borer, identify mechanisms of resistance, and determine the effects of drought and other stressors on borer susceptibility.

The planting includes white ash, green ash, Manchurian ash (with which the emerald ash borer shares an evolutionary history in Asia), and Northern Treasure ash (*F.* x Northern Treasure), which is a hybrid between native black ash and Manchurian ash.

Our working hypothesis is that the Asian ash will prove to be most resistant because of natural defenses resulting from coevolution with the insect. The inclusion of the native-Asian hybrid may provide insight into patterns of inheritance of resistance genes and facilitate their identification.

Identification of resistant genotypes will be critical for reforestation.

Identification of resistant genotypes will be critical for reforestation, as well as maintaining market demand for ash in the nursery industry. Identification of resistance mechanisms and their relationship to whole-tree physiology will facilitate screening, selection, and/or breeding of resistant trees, as well as cultural management of the emerald ash borer in urban and natural forests.

The Plan to Eradicate the Emerald Ash Borer

USDA-APHIS (Animal and Plant Health Inspection Service) and its Canadian counterparts, in cooperation with Departments of Agriculture in infested states, are in the early stages of implementing a program to eradicate emerald ash borer from North America. The plan in the core infestation area of southeastern Michigan, where millions of trees are already infested, is to first contain the pest, then reduce beetle density, and finally eradicate the insect.

There are so many infested trees in the core infestation zone in southeastern Michigan that it will be physically impossible to remove them all before insects can emerge. Rather, the core infestation is being managed following strategies similar to those used to manage large forest fires. A *firebreak* will be created around the core to contain the infestation. Once contained within the firebreak, the infestation should extinguish itself by killing all of its host trees, thereby starving itself out of existence.

The plan is for the firebreak to be wide enough to prevent the emerald ash borer from crossing it in search of new hosts, at least in large numbers. The firebreak will be constructed by removing ash trees in a zone around the periphery of the infestation, a task that will be facilitated by routing it through areas with naturally low densities of ash such as agricultural land, industrialized areas, and large bodies of water. Surveys and research are ongoing to determine just where the firebreak should be located, and how wide it should be.

Rapid elimination of outlier infestations is critical.

An aggressive emerald ash borer suppression program will occur just inside the firebreak to relieve pressure on the containment zone and minimize emerald ash borer breakouts. An intensive monitoring program around the periphery of the firebreak is designed to detect any spot infestations caused by *sparks* that jump the firebreak, which will be quickly extinguished.

Preventing the artificial spread of the emerald ash borer to new areas is another major component of the eradication plan. Accordingly, quarantines have been enacted in Michigan and Ohio to prohibit movement of ash trees, logs, branches, firewood, and untreated lumber. Currently, quarantines in Ohio are very isolated, impacting areas only in the immediate vicinity of some known infestations, but they are subject to change as the status of emerald ash borer infestations change.

Questions about the current status of quarantines in Ohio should be directed to the Ohio Department of Agriculture, Plant Pest Control. The Ohio Department of Agriculture is also conducting systematic surveys throughout Ohio in order to rapidly detect any additional outlier infestations that may occur in the state.

Rapid elimination of these outlier infestations is also a critical aspect of the eradication plan. Isolated infestations that flare up when *sparks* jump the firebreak will be quickly extinguished before they can become well established. This is the situation in Ohio, where a small infestation was detected in Lucas County in February 2003. In response to this discovery, the Ohio Department of Agriculture, in accordance with its responsibility under the Ohio Revised Code to protect Ohio's plant industries from exotic pests, immediately initiated an eradication program that was completed by the end April, before any adult beetles could emerge and spread the infestation.

The Lucas County eradication program entailed removal and destruction of more than 8,000 ash trees in a quarter-mile radius surrounding the known infestation. Since infested trees do not show external signs or symptoms of attack during the first year, there is no way to determine which trees in the vicinity of infested trees were themselves infested. However, the presence of D-shaped emergence holes on the obviously infested trees was evidence

that females had emerged to lay eggs on other trees, making the existence of asymptomatic carriers a certainty.

Consequently, it was necessary to cut even apparently healthy trees to destroy the insects lurking within before they could emerge to infest even more trees. Bark removed from some of these asymptomatic trees confirmed that they were in fact infested. To destroy the insects, felled trees were chipped and then incinerated at a co-generation power plant.

The assumption behind this strategy was that a cutting zone with a quarter-mile radius was sufficient to destroy the entire emerald ash borer population, including insects in trees that had yet to show symptoms of infestation. However, in the event that some emerald ash borer adults had dispersed beyond one-fourth mile, all ash trees just outside the cutting zone were treated preventively with the systemic insecticide imidacloprid in April 2003.

This treatment zone extended from the edge of the cutting zone out to one-half mile from visibly infested trees. The strategy behind the insecticide treatment was that any adults that escaped the cutting program would lay their eggs in the adjacent zone of treated trees, where their offspring would be killed.

Treating already infested trees with insecticides as an alternative to destroying them was not a viable option, as it would not have prevented adults from emerging and spreading to other trees. Insecticides are effective against borers only when applied preventively, in advance of infestations, and have no impact on borers already in the tree. This is true even of the systemically applied imidacloprid, which requires six to eight weeks for uptake and distribution.

Thus, imidacloprid must be applied in early to mid-spring to impact newly hatched larvae in July. By late summer, many larvae have matured, ceased feeding, and moved to over-wintering sites in the outer bark, where they would not be exposed to insecticide. Furthermore, larval feeding injures the xylem and phloem, which disrupts uptake and distribution of systemic insecticides by infested trees.

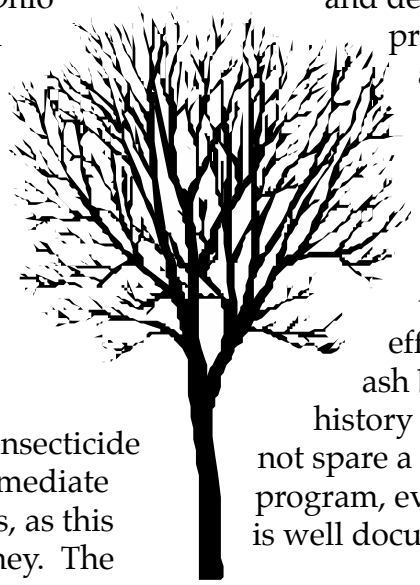
Should I Treat My Tree for Emerald Ash Borer?

Ohio State Extension personnel have received many questions from homeowners and Green Industry professionals wondering if preventive insecticide applications are necessary in Ohio to protect ash trees from the emerald ash borer. Members of the OSU Extension Nursery, Landscape, and Turf Team, in consultation with Ohio Department of Agriculture officials, have developed the following recommendation:

Currently, we do not recommend that any ash trees in Ohio be treated with insecticides for emerald ash borer, even if the tree is in the immediate vicinity of a known infestation.

First, it is important to maintain perspective on the problem. Although infestations in Ohio have received a great deal of attention, the fact remains that

in the entire state only a handful of trees are infested. The known infestations are all very small and very isolated, and the vast majority of ash trees in Ohio are not currently at risk, even in counties with known infestations. We've received reports of aggressive marketing of emerald ash borer insecticide treatments, but given the current status of the infestation, these programs are not warranted and cannot be justified.



We do not even recommend insecticide treatments for trees in the immediate vicinity of known infestations, as this also would be a waste of money. The logic behind this recommendation, which may seem counter-intuitive, is based on the interaction between the biology of the insect and regulatory issues associated with the program to eradicate the emerald ash borer from North America. The situation is different within the core infestation in quarantined counties in Michigan (for reasons discussed later), where many property owners are choosing to protect their trees with insecticides.

The emerald ash borer is an exotic insect that is currently regulated by USDA-APHIS, and is subject to eradication. Hence, if an infested tree is discovered in Ohio, it will have to be removed and destroyed.

Female emerald ash borers are highly mobile and lay eggs on many trees. Infested trees do not show any external symptoms during the first year of the infestation. Therefore, in the vicinity of any tree showing visible signs of infestation, there will be many more trees that are infested but with no external symptoms (asymptomatic carriers). Since there is no way to tell if these trees are infested, all trees in the vicinity of the infested tree will have to be removed and destroyed, as per eradication protocols, before larvae mature and adults can emerge, even if the trees appear healthy. This will be true even if that tree has been treated previously with insecticide, as research has shown that no insecticide is 100% effective against the emerald ash borer. Therefore, a previous history of insecticide treatment will not spare a tree from the eradication program, even if that treatment history is well documented.

But What About Trees in the Immediate Vicinity of Known Infestations?

As of December 2003, very small, isolated infestations have been discovered in Ohio in Lucas, Defiance, Franklin, Paulding, and Wood Counties, and programs already have or soon will be implemented by the Ohio Department of Agriculture to eradicate these infestations.

If the eradication programs are successful, it will not be necessary to treat nearby trees with insecticides. People near an eradication zone may be tempted to treat their trees as insurance in case an emerald ash borer escapes the eradication program.

However, if a borer does escape, it is extremely unlikely that it will lay eggs only on trees that have been treated with insecticides, as the emerald ash borer lays many eggs as it moves from tree to tree.

If an emerald ash borer does lay eggs even on one untreated tree in the same neighborhood as the treated tree (for example, on wild trees along a fence

row, ditch, or in a woodlot), eventually the untreated tree will show signs or symptoms of infestation and will have to be destroyed. In this case, all trees in the vicinity of the infested tree will also have to be destroyed, even if they have been previously treated.

In the core infestation in southeastern Michigan, the situation is different. Because there are too many infested trees to cut down as part of the eradication program (discussed previously) and because property owners there are financially responsible for removal of dead trees on their property, many people in the core infestation zone are taking steps to protect their ash trees, including preventive insecticide applications.

In Closing

Emerald ash borer has the potential to decimate ash throughout their range in North America, and efforts to eradicate this invasive pest are now underway. Eradication is possible, but if these efforts are not successful, emerald ash borer will have devastating economic and ecological impacts in natural and urban forests.

The threat cannot be over-estimated

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