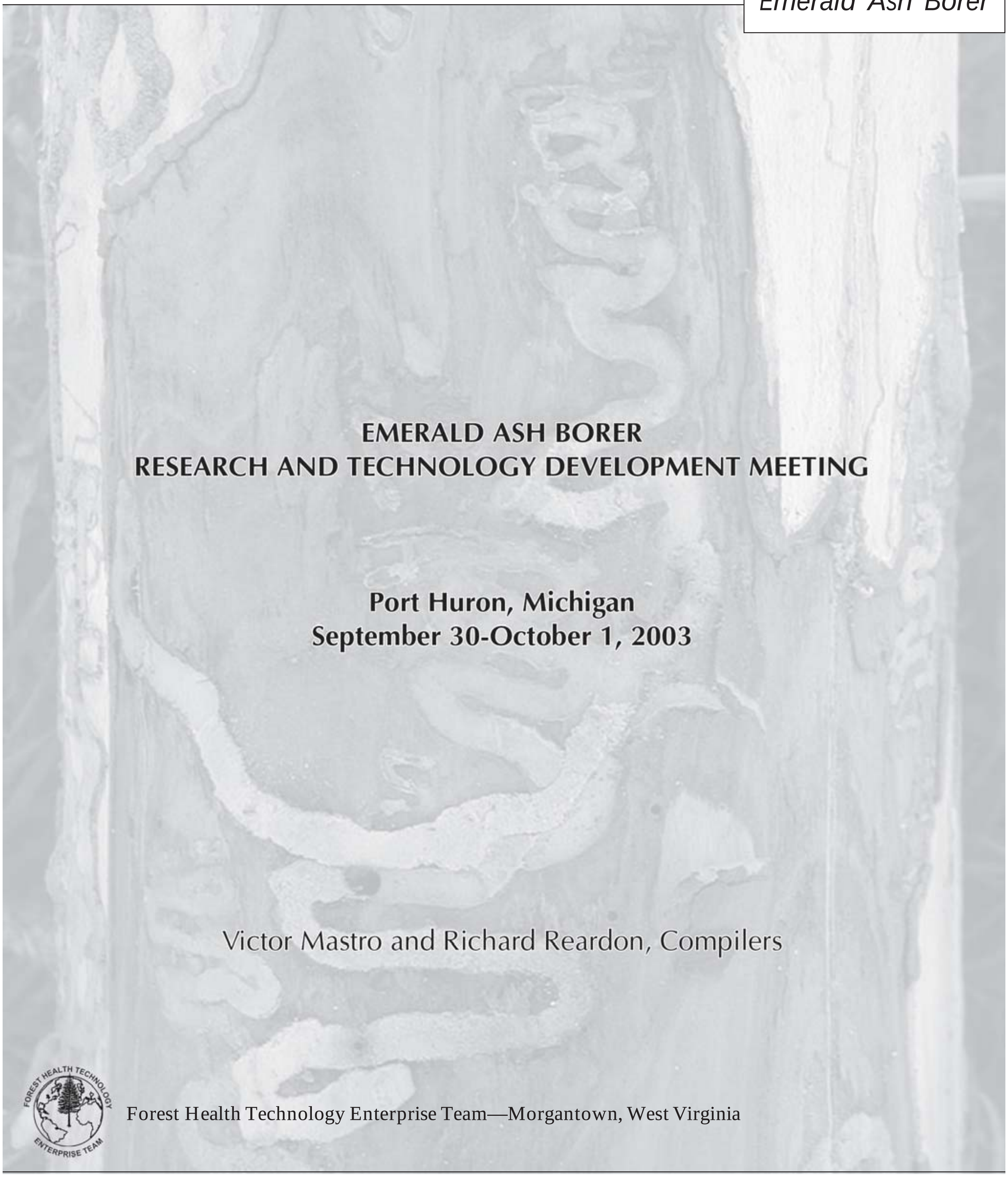
# Forest Health Technology Enterprise Team

TECHNOLOGY
TRANSFER

*Emerald Ash Borer*



# EMERALD ASH BORER
# RESEARCH AND TECHNOLOGY DEVELOPMENT MEETING

## Port Huron, Michigan
## September 30-October 1, 2003

Victor Mastro and Richard Reardon, Compilers

Forest Health Technology Enterprise Team—Morgantown, West Virginia

U.S. Department of Agriculture

Forest Service

Animal and Plant Health Inspection Service

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On the cover: year-old emerald ash borer galleries. Photo by David Cappaert, available at www.forestryimages.org as UGA1460075.

# Emerald Ash Borer
# Research and Technology Development Meeting

September 30–October 1, 2003
Thomas Edison Inn
Port Huron, Michigan

Compiled by:

Victor Mastro[1] and Richard Reardon[2]

[1]USDA-APHIS PPQ, Otis ANGB, Massachussetts
[2]USDA-FS FHTET, Morgantown, West Virginia

For additional copies, contact Lenora MacNevin in Otis ANGB, Massachussetts, at (508) 563-9303 (email: Lenora.MacNevin@aphis.usda.gov) or Richard Reardon in Morgantown, West Virginia, at (304) 285-1566 (email: rreardon@fs.fed.us).

## ACKNOWLEDGEMENTS

We thank the authors of the abstracts for providing current information on emerald ash borer. Thanks also to Mark Riffe, INTECS International, for format and design of this document, and to FHTET for providing funding to print these abstracts.

# FOREWORD

The emerald ash borer, *Agrilus planipennis* Fairmaire, a buprestid wood borer, was discovered infesting and killing trees in the area of Detroit, Michigan, in June of 2002. It was subsequently discovered in Essex Co., Ontario in August. Surveys now indicate that 13 Michigan counties encompassing greater than 2,500 square miles are now generally infested. A number of isolated small populations have also been found in Michigan, Ohio, Maryland, and Virginia. Most of these are thought to be the result of movement of infested nursery stock, logs, or firewood. Potential impacts of this insect, if allowed to spread, are substantial. In the U.S. alone, there are over 700 million ash trees and a U.S. Forest Service report estimated the loss at between 20 and 60 billion dollars. In response to the discovery of these wood borer populations, federal, state and local authorities held a number of meetings and prepared risk assessments. Both the Canadian and the United States version of the risk assessments conclude that substantial impacts would be the result of this introduction unless actions are undertaken to mitigate them. A Respective Science Panel was convened in each affected country, and their reports have similar recommendations: to develop a plan to contain and, eventually, eliminate emerald ash borer (EAB) populations in both countries. The plans are based on a zone management concept, including extensive survey efforts. The Science Panel also recommended that a strong commitment be made to developing the scientific information and technology necessary to carry out any management programs. A list of areas where research was critically needed was also developed.

As funding from various sources became available for EAB technology development and research, a number of federal, state, provincial and university groups became involved in the work. The meeting in Port Huron was an effort to pull together the many scientists involved in the work in a forum in which they could detail their interest and share their preliminary findings. The goal of the meeting was to identify areas of common interest, synergize existing endeavors, minimize duplication, and identify critical areas not being addressed. The abstracts contained in this report represent a robust response by the scientific community to the challenges offered by this exotic pest. In the future, it is hoped that this response will be sufficient to address the EAB problem, and help prepare the land managers and scientific community for other invasions.

## AGENDA
## Emerald Ash Borer Research and Technology Development Meeting

| Topic | Presenters | Facilitator |
|---|---|---|
| **Program Review** | | Victor Mastro |
| U.S. programs | Craig Kellogg | |
| | Deb Partlan | |
| | Philip Bell | |
| | Ken Rauscher | |
| | Tim Flint | |
| | Gary King | |
| | Frank Sapio | |
| Canadian program | Ken Marchant | |
| **Summary of Research Needs** | Mike Stefan & Victor Mastro | |
| **Biology and Behavior of EAB** | Barry Lyons | Deb McCullough |
| Life cycle | David Roden | |
| Dispersal | Deb McCullough | |
| Population dynamics | Leah Bauer | |
| | Bob Haack & Toby Petrice | |
| | Paul Schaefer | |
| | Gard Otis | |
| | Tanya Turk | |
| | Nichole McKenzie | |
| **Survey** | | Jason Oliver |
| Characterization of visual techniques | Bob Haack & Toby Petrice | |
| Semiochemicals | Therese Poland | |
| Other cues | Jason Oliver | |
| Development of traps for survey | Dave Williams | |
| Remote sensing | Dave Bartels | |
| | Houping Liu | |
| | David MacFarlane | |
| | Deb McCullough | |
| | Dave Cappaert | |
| | Joe Fancese | |
| **Regulatory Treatment and Mechanical Control** | Bob Haack & Toby Petrice | Bob Haack |
| | Deb McCullough | |
| **Chemical Control** | | Bill Wallner |
| Systemics | Bob Haack & Toby Petrice | |
| Cover sprays | Phil Lewis | |
| Application techniques | Deb McCullough | |
| | Dave Cappaert | |
| **Biological control** | Richard Reardon | Richard Reardon |
| Pathogens | Leah Bauer | |
| Parasites | Amy Roda & Juli Gould | |
| Predators | Bob Haack | |
| **Other Techniques–Rearing** | Leah Bauer | Juli Gould |
| **Host Range Testing** | Bob Haack | Dan Herms |
| Suitability of trees to attack | Dan Herms | |
| Site factors | L.L. Timms | |
| Stress factors | Deb McCullough | |
| Age/size of trees | Dave Cappaert | |

# Contents

# THE MICHIGAN EMERALD ASH BORER PROGRAM

**Ken Rauscher[1] and Victor Mastro[2]**

[1]Michigan State Department of Agriculture, 525 West Allegan St.,
P.O. Box 30017, Lansing, MI 48909

[2]USDA, APHIS, PPQ, Pest Survey Detection and Exclusion Laboratory,
Bldg. 1398, W. Truck Rd., Otis ANGB, MA 02542

## ABSTRACT

The emerald ash borer (EAB), *Agrilus planipennis* (Coleoptera: Buprestidae), was discovered in the Detroit, Michigan, area in July of 2002. This significant pest of ash trees (*Fraxinus*) infests and quickly kills trees by mining the cambium area and disrupting the tree's transport system. In response to this find, the Michigan Departments of Agriculture, and Natural Resources, United States Department of Agriculture, Animal and Plant Health Inspection Service (APHIS), and Forest Service (FS) developed an EAB task force to address the issue. This task force, which also includes representatives from Michigan State University and other interested parties, formulated an EAB Response Plan using the recommendations of an EAB Science Panel. The plan has the following elements: 1) detection, 2) containment, 3) eradication, and 4) restoration. The effort to detect new and delimit currently known infestations began almost immediately after the original find. A rapidly moving survey attempted to identify the area of the highest densities of infested trees and beetles. This survey initially led to the identification of EAB populations in six counties, all of which were subsequently quarantined. A more systematic survey currently being conducted has identified EAB populations in an additional seven surrounding counties, which also have been quarantined. This intensive survey effort will serve to provide a basis for establishment of various management zones, which are described below.

Detection efforts to identify new outlying infestations are also continuing. These efforts rely on visual survey around high-risk sites, such as nurseries or mills, which received trees or logs from inside of what is now known as infested areas. This effort had led to the identification of a number of localized sites of infestation in Michigan, Ohio, Virginia, and Maryland. Additional spot infestations have been identified as a result of an extensive public education campaign, a key component of the survey effort.

The containment activities include regulation of articles that are capable of transporting EAB life stages. The regulated articles include live ash trees or parts of ash trees, including limbs, branches, firewood, logs, and untreated ash lumber with bark. Chips generated from ash trees are also regulated unless they are less than one inch in length or they have been composted. The second part of the containment effort involves establishment of a containment zone or "fire break zone," which will have a low density of ash trees, either naturally or through management activities. Any ash trees remaining in this containment zone, which will exist at a variable distance from the generally infested area, will be intensely monitored to prevent EAB establishment and movement beyond the zone into the uninfested area. Between this containment zone and the generally infested area, a suppression zone will be established where populations are vigorously reduced to minimize the migration pressure on the containment zone.

Currently, 2,500 square miles are known to be infested with EAB. The area contains approximately 650,000 landscape ash trees, half of which are already in decline or dead. Eventually, all will likely be killed. In the forest environment, the number of ash trees already or potentially infested by EAB number is greater than 10.5 million. The program will work with local governments and the U.S. Forest Service to restore the tree canopy in targeted areas and provide guidance for management of woodlands for a reduced ash component.

Research efforts to support these program activities and objectives are detailed in the abstracts contained in this volume. A summary of these research initiatives will not be detailed here, but the program recognizes and supports these initiatives because their outcomes will largely determine the program's success.

# EMERALD ASH BORER IN CANADA—2003

**Kenneth R. Marchant**

Forestry Specialist - Canadian Food Inspection Agency, 174 Stone Rd.,
West, Guelph, Ontario, Canada N1G 3G6

## ABSTRACT

The Emerald Ash Borer (EAB) was confirmed to be present in Canada in August of 2002. During 2002 and 2003, delimitation and detection surveys were conducted throughout southwest Ontario by the Canadian Food Inspection Agency (CFIA), and suggest that EAB is still confined to Essex County, Ontario. At present, it is believed that EAB has infested around 100,000 to 200,000 ash trees with another estimated 1,000,000 trees at risk of imminent infestation. While EAB has now been found throughout Essex County, populations in the eastern portion of the county are much lower than in the west, which is now considered to be generally infested and in which considerable tree mortality has been observed this summer. In excess of a billion ash trees in Ontario are believed threatened by EAB.

In September of 2002, the CFIA issue a Ministerial Order placing the western portion of Essex County under quarantine, with restrictions on the movement of ash trees and parts thereof and on firewood of all species. The Ministerial Order is currently being amended to include all of Essex County in the regulated area.

In addition to surveys, the CFIA removed an estimated 8,000 trees along what was believed to be the leading edge of the infestation last spring prior to the emergence of adults. The current strategy of the CFIA is to slow the spread of EAB pending final survey results for this year and reports from its Science and Risk Mitigation (SandRMSC) and Research committees.

The CFIA is currently deciding on whether to proceed with the cutting of a firebreak, or no-ash zone, on the eastern edge of the known infestation. This concept was proposed by the EAB Science and Advisory Panel in 2002 and ratified by the EAB SandRMSC, and is still seen as a valid strategy—and perhaps the only valid option at the present time that will effectively slow the spread of EAB to areas east of Essex County (all of which have a much higher percentage of forest cover and ash component). A decision is expected shortly.

# DETECTION OF EMERALD ASH BORER IN MARYLAND

**Dick Bean**

Survey Entomologist; Field Operations Supervisor,
Plant Protection and Weed Management Section,
Maryland Department of Agriculture,
50 Harry S. Truman Parkway, Annapolis MD 21401

## ABSTRACT

- On April 7, 2003, a Maryland nursery in Prince Georges County received 121 ash saplings from the quarantined area in Michigan.
- A Maryland Department of Agriculture nursery inspector discovered emerald ash borer (EAB) on September 28, 2003; USDA Agricultural Research Service, Systematic Entomology Laboratory, verified this identification on September 29. The saplings were condemned and seized, and stop-sale notices were issued. Notification of the EAB detection was sent out to appropriate parties.
- 94 trees from the shipment still at the nursery were destroyed within five days of discovery.
- Landscaping records showed trees from the shipment were used on three jobs in Maryland and one in Virginia. Sites were examined for exit holes, and infested trees were removed.
- Press reports elicited tremendous response, resulting in identification of a landscaping planting with ash from the nursery that were not from the Michigan shipment but found to contain EAB larvae. Replacement ash trees from the nursery installed on another landscaping site in July were also found to contain EAB larvae.
- Records from landscaping jobs are being examined for out-planted ash.
- Pending work at the nursery, all ash trees on the property will be surveyed and infested trees destroyed; all ash within a yet-to-be-determined buffer around nursery are to be surveyed and infested trees destroyed; records of all landscaping jobs utilizing ash trees in 2003 will be obtained and trees removed as needed. Other considerations may come to light as this situation unfolds.

# THE BIOLOGY AND PHENOLOGY OF THE EMERALD ASH BORER, *AGILUS PLANIPENNIS*

**D. Barry Lyons, Gene C. Jones and Kerrie Wainio-Keizer**

Canadian Forest Service, Sault Ste. Marie, Ontario

## ABSTRACT

The seasonality of events in the life history of the emerald ash borer is being investigated under field and controlled-laboratory conditions. The emergence period of adults was determined under field conditions by rearing adults from log bolts in cages in an outdoor insectary. Adults were collected weekly from the cages and their sex was determined. Temperature conditions were monitored onsite using data-logging equipment. Mean emergence dates for males and females were 25 and 26 June, respectively. Sex ratio approximated 1:1. To determine adult activity periods, Tangle Trap-coated plastic bands were placed on boles of host trees about 2 m above the ground. A total of 130 trees in three plots, with different levels of damage, were banded. Bands were examined for adults at weekly intervals throughout the summer. These bands captured about 7,000 beetles. Mean activity periods in the three plots were 3, 10, and 13 July. Larval and pupal development was tracked by dissecting host logs throughout the growing season.

In the laboratory, adult longevity, oviposition, fecundity, and egg development were investigated under controlled conditions. Mean longevity for males and females was 29.8 and 26.5 days at 24°C. Although fecundity was extremely variable, one female deposited 258 eggs over her lifetime. The mean number of days to first-observed mating for females was 21.9 days and the mean time to first oviposition was 22.1 days at 24°C. Females were observed mating with multiple partners. Eggs took an average of 18.4 days to hatch at 24°C and 36.8 days to hatch at 18°C. The goal of these investigations is to develop models for predicting the phenology of this insect.

# DISPERSAL OF EMERALD ASH BORER: A CASE STUDY AT TIPTON, MICHIGAN

**Deborah G. McCullough[1,2], Therese Poland[3], and David Cappaert[1]**

[1]Department of Entomology, Michigan State University,
243 Natural Science Building, East Lansing, MI 48824

[2]Department of Forestry, Michigan State University,
126 Natural Resources Building, East Lansing, MI 48824

[3]USDA Forest Service, North Central Research Station,
220 Nisbet Building, 1407 S. Harrison Rd., East Lansing, MI 48823

## ABSTRACT

We had a unique opportunity to assess the dispersal of one generation of emerald ash borer adults for spread pattern in a rural area near Tipton, Lenawee County, Michigan. A Michigan Department of Agriculture inspector discovered adult beetles ovipositing on small ash trees in 2002 in this area, well beyond the core infestation area. Discussions with the property owner revealed that the infestation originated from a load of infested ash firewood brought in from southeastern Michigan in the spring of 2002. The infested firewood, which effectively served as the point source of the infestation, had been piled along the side of a drainage ditch. A mixture of green ash, soft maple, black walnut, and other hardwoods grew along the sides of the drainage ditch, generally from 20 to 125 meters outward of the ditch. We were confident that any emerald ash borer galleries on trees in this area were the result of adults that had emerged from the firewood pile in 2002.

In February, 2003, we marked and recorded location and diameter of the roughly 235 ash trees growing along both sides of the ditch, up to 400 meters away from the firewood pile. We randomly selected two small, two medium and two large ash trees for sampling within each 50-meter contour interval around the firewood pile. We returned with more than 20 volunteers and felled 84 trees. A section of bark, at least 600 $cm^2$, was removed from the trunk, lower, middle, and upper canopy of each tree (a minimum of four samples per tree).

Galleries were found in a few trees that were 350–400 meters north of the firewood pile. Therefore, we returned in early March and sampled more than 100 additional ash trees. This sample included trees that were growing along the ditch from 400 to roughly 850 meters away from the firewood pile and trees growing in a woodlot that was roughly 400 meters west of the drainage ditch. A cornfield lay between the woodlot and the ditch.

Preliminary results showed that more than 70 percent of the emerald ash borer galleries occurred on trees growing within 100 m of the firewood pile. Gallery density decreased substantially with increasing distance, but a gallery was discovered in one tree that was 750 meters from the firewood pile. Beetles appeared to exhibit directional dispersal, and followed the corridor provided by the drainage ditch. No galleries were found on trees growing in the woodlot across the cornfield. There were no significant effects of tree size on infestation. Galleries were most often found on medium-sized trees (15–20 cm DBH), but trees ranging from 10 to 25+ cm DBH had one or more galleries. Galleries were more likely to be found in the middle and upper canopies of trees

than on the trunk or lower canopy as distance from the firewood pile increased. Analysis of data is continuing. All ash trees within an 800-meter radius of the infested firewood pile were destroyed by the Michigan Department of Agriculture later in the spring before the new generation of beetles could emerge.

# EMERALD ASH BORER LIFE CYCLE

**Leah S. Bauer[1,2], Robert A. Haack[1,2], Deborah L. Miller[1], Toby R. Petrice[1], and Houping Liu[2]**

[1]USDA Forest Service, North Central Research Station,
220 Nisbet Building, 1407 S. Harrison Rd., East Lansing, MI 48823

[2]Department of Entomology, Michigan State University,
243 Natural Science Building, East Lansing, MI 48824

## ABSTRACT

The emerald ash borer (EAB), *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), native to several Asian countries, was discovered in southeastern Michigan and nearby Ontario in June of 2002. EAB was identified as the cause of extensive ash (*Fraxinus* spp.) mortality in approximately 2,500 mi$^2$, and surveys revealed 6–7 million ash trees are dead and dying. Apparently EAB was inadvertently introduced approximately 5–10 years ago in infested solid wood packing materials or dunnage. In 2003, isolated EAB infestations were found throughout Michigan, northern Ohio, Maryland, and Virginia as a result of transportation of infested nursery stock, firewood, and ash timber. Limited information and literature are available for EAB because it is a minor pest in Asia. Below is a brief description of the EAB life cycle, compiled from our 2002-2003 EAB field and laboratory studies.

Emerald ash borer eggs are approximately 1 mm in diameter, gradually changing from white to amber in color after being laid on the bark. Larvae hatch directly into the bark, and tunnel until reaching the cambial region where they feed, etching a serpentine gallery in the phloem and outer sapwood. Based on measurements of sclerotized larval structures, we identified four distinct larval stages. Last-instar larvae enter the sapwood or outer bark during late summer and fall, and excavate a pupation chamber where they overwinter as prepupae; diapause is facultative. Pupation generally occurs in late spring, although larvae too small to prepupate before winter may overwinter as larvae under the bark and complete development the following summer. EAB pupae are exarate (naked), and gradually develop to adults in the pupation chamber. When mature, the adults chew out of the tree through exit tunnels that had been initiated by the last-instar larvae. Adults emerge from distinct D-shaped exit holes in the tree bark and are capable of immediate flight upon emergence. EAB adults feed on ash foliage throughout their lives, and are most conspicuous on hot sunny afternoons (3–6 P.M.), hovering about ash tree trunks, landing to mate or oviposit. Eggs are laid between layers of bark and in bark crevices. In 2003, the peak oviposition period was late June to early July, and most eggs were enclosed by mid-July.

# FLIGHT POTENTIAL OF THE EMERALD ASH BORER

**Leah S. Bauer[1], Deborah L. Miller[1], Robin A. J. Taylor[2], and Robert A. Haack[1]**

[1]USDA Forest Service, North Central Research Station,
220 Nisbet Building, 1407 S. Harrison Rd., East Lansing, MI 48823

[2]Department of Entomology, OARDC, The Ohio State University,
Wooster, Ohio 44691

## ABSTRACT

The emerald ash borer (EAB), *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), is an invasive pest of ash trees (*Fraxinus spp.*) in North America. Native to several Asian countries, EAB was discovered in six southeastern Michigan counties and southwestern Ontario in 2002. EAB presumably emerged from infested solid wood packing materials and/or dunnage about 10 years ago. Isolated infestations continue to be discovered in lower Michigan, Ohio, Maryland, and Virginia as a result of transportation of infested ash nursery stock, firewood, and logs. Federal and state agencies are developing an EAB eradication plan to contain the core infestation and eradicate EAB from isolated infestations. Knowledge of EAB flight behavior and physiology is needed to predict dispersal beyond identifiable boundaries of the core and to estimate the size of isolated infestations. Failure to understand dispersal prior to development and implementation of an eradication plan will clearly reduce its efficacy.

We are using computer-monitored flight mills with tethered EAB adults to measure flight distance, periodicity, and speed over approximately 24-hour time intervals. Preliminary results from 28 adults, flying without rest, food, or water, showed that approximately half of the tethered beetles flew less than 50 m. Of those that flew greater than 50 m, flight distances ranged from 71 to 2,426 m for fed, 6-day-old females. Two unfed, newly emerged females flew 716 and 804 m. Flight ranged from 53 to 4258 m for fed, 6-day-old males. Although few EAB continued to fly after 20 hours of tethering, one 3-day-old male flew 1,653 m and 3,580 m in two consecutive 20-hour blocks of time, for a total of 5,233 m in 40 hours. We believe these results may be conservative estimates for EAB flight potential due to the restrictions imposed on beetles hanging on tethers. Pending hardware and software upgrades, we are planning to monitor flights under varying biotic and abiotic conditions, as well as the studying the relationship between dispersal and reproduction.E

# EMERALD ASH BORER ADULT DISPERSAL

**Robert A. Haack and Toby R. Petrice**

USDA Forest Service, North Central Research Station,
220 Nisbet Building, 1407 S. Harrison Rd., East Lansing, MI 48823

## ABSTRACT

The emerald ash borer (EAB), *Agrilus planipennis* Fairmaire, is an Asian buprestid beetle that was first discovered in Michigan and Ontario in 2002 (Haack et al. 2002). Smaller populations, resulting from movement of infested host material, were found in Ohio, Maryland, and Virginia in 2003. EAB adult dispersal has not been studied in Asia; however, observations made by a buprestid collector in Japan estimated that EAB adults can fly at least 1 km (Haack et al. 2002).

We conducted a field study to evaluate EAB adult dispersal at two Michigan sites in early summer 2003. At each site, we placed several EAB-infested logs at a central release point, and then put out uninfested, vertically positioned, sticky-banded ash trap logs at specified distances and directions from each release site. The EAB-infested logs had been maintained indoors in a heated room for a few weeks to speed up development relative to wild EAB populations outdoors. We placed the infested logs in the field when adults started to emerge indoors in early May. We estimated that emergence from our test logs was at least two weeks ahead of the wild EAB populations.

One site consisted of a power line corridor that ran through a rural area north of Ann Arbor, Michigan. We used a straight 4-km-long section of the corridor, which was about 100 m wide and was generally free of trees. Trap logs were placed at 100, 250, and 500 m to the west of the release site, as well as 100, 250, 500, 1,000, 1,500, 2,000, 2,500, and 3,000 m to the east of the release site. Only one EAB adult of an estimated 2,118 released adults (based on a subsequent count of exit holes) was captured on the trap logs by late May, and this was at a distance of 250 m. The second site was the Ann Arbor airport, where we were able to place trap logs at distances out to 150 m to the west, 500 m to the north, 2,000 m to the east, and 500 m to the south. Again, only a single EAB adult of an estimated 1,059 released adults was captured on any of the trap logs by late May, and this beetle was captured at a distance of 1,500 m. If repeated in 2004, we will release marked beetles and use girdled ash trees (with sticky traps) instead of trap logs.

Haack, R.A., E. Jendek, H. Liu, K.R. Marchant, T.R. Petrice, T.M. Poland, and H. Ye. 2002. The emerald ash borer: a new exotic pest in North America. *Newsletter of the Michigan Entomological Society* 47(3-4): 1-5.

# TRACKING THE EMERGENCE OF EMERALD ASH BORER ADULTS

**D. E. Brown-Rytlewski[1] and M.A. Wilson[2]**

[1]Department of Entomology, Michigan State University,
243 Natural Science Building, East Lansing, MI 48824

[2]Michigan State University Extension, Genesee County

## ABSTRACT

Correlating bloom time of common plants (and corresponding degree-day accumulations) with emergence of emerald ash borer adults (*Agrilus plannipenis* Fairmaire) could be a useful tool to enable homeowners and professionals to accurately time pest management strategies, and improve their efficacy. Twenty green ash trees (*Fraxinus pennsylvanica*) of approximately the same age were used in the study; eleven were planted in parking lot islands mulched with stone, and nine were planted in grassed lawn areas. Emergence of adult emerald ash borers was monitored by counting D-shaped emergence holes from the first week in May through the end of August. Bloom stages of common landscape plants (i.e., first bloom, full bloom) and corresponding degree-day accumulations were tracked at four locations in Michigan, including the site where adult EAB emergence was monitored.

There were statistically significant (p=0.0009) differences in adult beetle emergence from the tree trunks as measured by direction (SW, SE, NW, NE). Earliest and greatest emergence occurred on the southwest and southeast sides of the trees planted in the parking lots and mulched with stone. First emergence of adult beetles at the monitored site occurred sometime between June 5 and June 13, 2003. During that time (at the site), black locust (*Robinia pseudoacacia*) and dame's rocket (*Hesperis matronalis*) were in full to late bloom; the corresponding degree-day accumulations (base 50°F) for that time period were 471.5-584.0 degree-days.

# GENETIC ANALYSIS OF EMERALD ASH BORER (*AGRILUS PLANIPENNIS* FAIRMAIRE) TO DETERMINE POINT OF ORIGIN IN NORTH AMERICAN INFESTATIONS

**Jim Smith [1,2], Bob Haack [1,3], and Leah Bauer [1,3]**

[1] Department of Entomology, Michigan State University,
243 Natural Science Building, East Lansing, MI 48824

[2] Department of Zoology and Lyman Briggs School of Science,
Michigan State University, 203 Natural Science Building, East Lansing, MI 48824

[3] USDA Forest Service, North Central Research Station,
220 Nisbet Building, 1407 S. Harrison Rd., East Lansing, MI 48823

## ABSTRACT

The objective of this project is to estimate the geographic origin of emerald ash borer (EAB) populations in Asia that gave rise to EAB in North America. Knowledge of EAB genetics will be useful in understanding the invasion dynamics of the beetle, and to help identify geographic localities of potential biocontrol agents. EAB naturally ranges from Mongolia, northeastern China, and the Russian Far East to Korea, Japan, and Taiwan. We are sampling populations of EAB in Asia and comparing them genetically with introduced populations in North America (Michigan, Ohio, and southwestern Ontario) using mitochondrial DNA sequences and amplified fragment length polymorphism (AFLP) fingerprints. Genetic data will be analyzed by phylogenetic analysis and population assignment tests.

Our EAB collection from spring 2003 included 20 adults and 20 larvae from SE Michigan, 4 adults and 3 larvae from Harbin, Heilongjiang Province, China, and 21 adults (dried or pinned) from Dagong and Hangu (Tianjin Province, China). Initial analysis of mitochondrial cytochrome oxidase subunit I (COI) sequences placed an EAB individual from Michigan in a group with the other buprestid in the taxon sample. Subsequent analysis of COI sequences (500 nucleotides) from three adult EAB from Michigan, one adult EAB from Dagong, and one adult EAB from Hangu indicated that these sequences were identical. The insects obtained from Heilongjiang Province did not yield DNA that could be used for mtDNA analysis. In addition, EAB has not yet yielded analyzable AFLP profiles. Work in these areas is continuing. In fall 2004, we received samples of larval EAB from China including Jilin, Liaoning, Hebei, and additional sites in Tianjin and Heilongjiang Provinces (collections by H. Liu and T. Petrice).

# *AGRILUS PLANIPENNIS* (=*A. MARCOPOLI*) (COLEOPTERA: BUPRESTIDAE) IN JAPAN AND MONGOLIA—PRELIMINARY FINDINGS

**Paul W. Schaefer**

USDA, ARS, Beneficial Insects Introduction Research,
501 S. Chapel St., Newark, DE 19713-3814

## ABSTRACT

JAPAN: Travels in Japan (May 9 to 21, June 26 to July 9, and July 31 to August 11, 2003) permitted me to drive from Tokyo (35º N) north to Bibai (43º N) on Hokkaido in late June. I repeatedly inspected foliage, including some Mandshurian Ash, *Fraxinus mandshurica* var. *japonica* Maxim., for presence of beetles. No live beetles nor characteristic emergence holes were found. Meanwhile, a Japanese buprestologist and private collector was informed of my interest in collecting *Agrilus planipennis* from Japan. He went to a previously known collection site and found one lone specimen on a leaf of *Fraxinus* sp. in Honshu, Miyagi Prefecture (Shiroishi City, Misumi, 800 m altitude, 2 Aug. 2003, M. Kaneko leg.) which he has presented to me.

At the National Museum, Tokyo, I was permitted to examine specimens once belonging to the late Dr. Yoshihiko Kurosawa. In 1956, he had recognized the following three subspecies of *Agrilus marcopoli* with their general distributions (as based solely on specimens in this collection):

1) *A. m. marcopoli* Obenberger, 1930 (in Korea; Japan, Kyoto Prefecture);
2) *A. m. ulmi* Kurosawa, 1956 (Japan, Hokkaido Prefecture; Honshu, Gumma and Tokyo Prefectures; Shikoku, Tokushima Prefecture; Kyushu, Kumamoto, and Fukuoka Prefectures); and
3) *A. m. teretrius* Obenberger, 1936 (Taiwan, Taoyuan Province).

At this time, I am unaware of the basis on which these subspecies are founded.

MONGOLIA: Travel to Ulaanbaatar, Mongolia, (July 9-30, August 12-20, 2003) and then north to Hatgal (51º N.), allowed several opportunities to consult with local entomologists and foresters and to examine some appropriate literature. In no case did anybody recognize *A. planipennis* specimens from Michigan as being an insect they had seen in Mongolia. The literature, which states that this beetle has been collected in Mongolia, could not be verified. I can only assume that records of *A. planipennis* (= *A. marcopoli)* are based on old Russian collections, and which must now be properly reconfirmed.

# EMERALD ASH BORER ATTRACTION TO TRAP LOGS OF DIFFERENT LENGTHS AND SPECIES

**Robert A. Haack and Toby R. Petrice**

USDA Forest Service, North Central Research Station,
220 Nisbet Building, 1407 S. Harrison Rd., East Lansing, MI 48823

## ABSTRACT

The emerald ash borer (EAB), *Agrilus planipennis* Fairmaire (Buprestidae), a native of Asia, was discovered in the USA and Canada in 2002. In summer 2003, we conducted two studies to evaluate EAB attraction to trap logs that varied in length and species. In the first study, we investigated how EAB attraction to ash (*Fraxinus*) logs varied by log length. We cut live ash trees into 2-ft, 4-ft, and 8-ft lengths. A total of 54 logs were placed at each of two study sites in areas with high EAB populations. The logs were oriented vertically, being supported with metal fence posts. Tanglefoot was applied to a 30-cm tall plastic band that was wrapped around the center of each log. The number of EAB adults captured in the Tanglefoot was recorded for each log. The mean number of EAB captured per unit area of trap was similar among the three lengths of logs studied. However, given that EAB are likely captured as they land on a log, our trap results suggest that twice as many EAB likely landed on the 4-ft logs compared with the 2-ft logs, and similarly four times as many EAB likely landed on the 8-ft logs compared with the 2 ft logs. Such results suggest that more EAB will be collected as more of the surface area of the log is covered with Tanglefoot.

The second study was conducted to compare EAB attraction trap log that were similar in size but varied by tree species. We tested white ash (*Fraxinus americana*), green ash (*F. pennsylvanica*), black ash (*F. nigra*), blue ash (*F. quadrangulata*), American elm (*Ulmus americana*), hackberry (*Celtis occidentalis*), black walnut (*Juglans nigra*), and pignut hickory (*Carya glabra*). Logs were placed in the field using the same methods described above. Eighteen logs for each species (only nine for *F. quadrangulata*) were placed at each of three different locations in the EAB infested area. EAB adults were captured on all species of trap logs, both ash and non-ash. Overall, EAB tended to land more on ash logs than non-ash logs. White ash was the most attractive species of ash tested. Of the non-ash species tested, black walnut was the most attractive species and hackberry, the least.

# DEVELOPING ATTRACTANTS AND TRAPPING TECHNIQUES FOR THE EMERALD ASH BORER

**Therese M. Poland[1], Peter de Groot[2], Gary Grant[2], Linda MacDonald[2], and Deborah G. McCullough[3]**

[1]USDA Forest Service, North Central Research Station,
220 Nisbet Building, 1407 S. Harrison Rd., East Lansing, MI 48823

[2]Canadian Forest Service, Great Lakes Forestry Centre,
1219 Queen St. E., Sault Ste. Marie, Ontario, Canada P6A 5M7

[3]Department of Entomology, Michigan State University,
243 Natural Science Building, East Lansing, MI 48824

## ABSTRACT

Shortly after the 2002 discovery of emerald ash borer (EAB), A*grilus planipennis* Fairmaire (Coleoptera: Buprestidae), in southeastern Michigan and Windsor, Ontario, quarantines regulating the movement of ash logs, firewood, and nursery stock were established to reduce the risk of human-assisted spread of this exotic forest insect pest. Accurate delimitation of the infested area is critical for regulatory officials who must establish the quarantine boundaries and implement control measures. Survey crews primarily use signs and symptoms, such as adult exit holes, bark splits over galleries, epicormic shoots, or canopy dieback, to identify potentially infested trees. Newly infested trees, however, typically demonstrate no external symptoms, making it difficult to truly delineate the EAB infestation. Methods to attract and trap adult beetles, which are likely to be present for 10 to 12 weeks in the summer, would substantially increase our ability to identify the leading edge and extent of the EAB distribution.

We collected volatiles from ash leaves using solid phase micro-extraction (SPME), and prepared extracts of ash leaves, bark, and wood by crushing host tissues in hexane. Host compounds were identified by gas chromatography (GC) and mass spectrometry (MS). Antennal responses by adult EABs were determined using coupled gas chromatographic electro-antennal detection (GC-EAD). Compounds that elicited antennal responses were tested in a walking olfactometer bioassay and those with the highest percentage of positive responders were then selected for field-testing.

Three types of field experiments were conducted to compare different trapping techniques for EAB. The first experiment used a single lure comprised of a blend of the most active ash volatiles. The lure was tested in four different types of traps: multiple funnel traps, Intercept panel traps, Japanese beetle traps, and yellow sticky traps. Of the trap types tested, the multiple funnel traps caught significantly more EABs than the panel traps or yellow sticky traps. Japanese beetle trap catches were intermediate. Multiple funnel traps also captured more EABs when raised in the tree canopy as opposed to being placed at ground level. The second field experiment used only multiple funnel traps, and compared different combinations of ash volatiles. There were no significant differences in the number of EABs captured with the different types of lures. The third field experiment compared the number of EABs captured on sticky bands on trap trees (healthy, girdled, or herbicide-treated green ash trees) or vertically-placed trap logs (2-m-long logs cut from healthy

green, white, or black ash trees). The girdled trees captured significantly more EABs than the other types of trap trees or trap logs.

# DEVELOPMENT OF TRAPS TO SURVEY FOR EMERALD ASH BORER

**Jason B. Oliver[1], Victor Mastro[2], David Lance[2], Joseph Francese[2], Nadeer Youssef[1], Stephen Lavallee[2], and Donna Fare[3]**

[1] Tennessee State University, Otis L. Floyd Nursery Research Center,
472 Cadillac Lane, McMinnville, TN 37110

[2] USDA-APHIS-PPQ, Otis Pest Survey, Detection and Exclusion Laboratory,
Bldg. 1398, W. Truck Rd., Otis ANGB, MA 02542

[3] USDA-ARS National Arboretum, TSU Otis L. Floyd Nursery Research Center,
472 Cadillac Lane, McMinnville, TN 37110

## ABSTRACT

Emerald ash borer (*Agrilus planipennis* Fairmaire) (EAB) is a serious pest of ash trees (*Fraxinus* spp.) recently discovered in southern Michigan and adjacent areas of Canada. The EAB aggressively attacks both young and old ash trees and is a threat to native ash throughout the United States. An effective method to survey for EAB is needed to delineate the extent of the current infestation and to determine if the borer currently occurs in any areas outside of the federal quarantine zone. To date, few traps have been found to effectively capture borers in the family Buprestidae. The most effective buprestid traps have been those providing a visual stimulus, like wooden sticky posts. There are few reports of buprestids responding to olfactory lures in the literature—the exceptions being some *Agrilus* and *Melanophila* species. A trap simulating a young tree silhouette was tested at the Tennessee State University Otis L. Floyd Nursery Research Center during the summers of 2000 to 2002 for the ability to attract and capture buprestid species in general. The silhouette trap consisted of a wallpaper tube (~ 0.9 m tall by 2.5 cm diameter) sheathed over a metal nursery stake and painted with Pestik™ Insect Glue (Hummert International Horticultural Supplies). The primary colors of red, yellow, blue, green, gray, and white were evaluated for attraction to buprestids. The color red was found to be very attractive to buprestids among the chosen colors. During 2001 and 2002 field seasons, a variety of color shades classified as 'red-like' were selected for testing using the Royal Horticultural Color Chart. During these tests, it was determined that colors in the violet to pink range of the electromagnetic spectrum (i.e., 400–450 nm) were very attractive to buprestids (including the genera of *Acmaeodera*, *Agrilus*, *Anthaxia*, and *Chrysobothris*).

Based on findings from middle Tennessee buprestid studies, a similar study was initiated in the Detroit area (within the EAB core infestation zone) near Van Born and Ford roads to evaluate whether the tree silhouette trap could be used as a survey tool for EAB. A number of trap colors were selected using one color per trap stake in blocks of 11 stakes (blocks were replicated five times at each site). Total EAB collections were low (5 males and 14 females) and included 3 (purple), 1 (magenta), 6 (pink), 0 (blue), 0 (green), 2 (brown), 2 (yellow), 1 (red), 1 (black), 3 (gray), and 0 (white). Trap collections on purple, pink, and magenta colors represented 53 percent of total EAB collections. Other non-EAB buprestids (predominantly other *Agrilus* spp.) were collected on 10 (purple), 5 (magenta), 11 (pink), 2 (blue), 3 (green), 0 (brown), 2 (yellow), 5 (red), 5 (black), 6 (gray), and 7 (white). Trap colors used during the 2003 field season are currently being scanned to

determine their predominant reflectance wavelength in the electromagnetic spectrum (nm). Trap sites are being rated for EAB infestation by harvesting nearby ash trees and peeling bark to count larval densities. The infestation status of adjacent ash will be used to assess whether low trap captures were due to an ineffective trap or low borer populations in the area.

Other non-baited traps were tested at a nursery site near 8 Mile Road (Detroit, MI). These traps included 8-funnel Lindgrens, Theysohns, pan traps, windowpane traps, circle trunk traps (Great Lakes IPM), and hanging log traps (0.5 m log suspended approximately 1 m from ground and covered in Pestik glue) replicated six times in an ash nursery block. The hanging log trap was the only moderately effective trap (17 EAB total). All other traps had less than three EAB total for the entire summer. Another ash nursery block at the site was used to evaluate different damage treatments for their attractiveness to EAB, including severe pruning (50 percent of canopy), root girdling (two concentric circles about 15 and 30 cm from trunk and 30 cm deep), and trunk girdling (five vertical cuts from 80 to 100 cm on trunk and one horizontal circumference cut at 90 cm height). Nursery trees were either covered with Pestik glue or red-colored paper bands at 30 to 60 and 130 to 160 cm or had the previously described red-colored silhouette trap placed adjacent to the trunk. None of these treatments were very effective at attracting and capturing EAB. Total EAB collections were: 21 (pruned), 8 (root cut), 6 (control), and 2 (girdled). Among trap types, total EAB collections were 21 (glue on trunk), 9 (red bands on trunk), and 7 (red silhouette trap). A variety of traps will again be tested in 2004 using predominantly violet colors.

# HYPERSPECTRAL REMOTE SENSING FOR EMERALD ASH BORER

**David W. Bartels**

USDA APHIS PPQ CPHST, Pest Detection, Diagnostics, and Management Laboratory,
Moore Air Base, Bldg. S-6414, Edinburg, TX 78541

## ABSTRACT

With advances in remote sensing technology, we are looking at using hyperspectral data for the survey and detection of trees stress by the emerald ash borer infestations. Working mainly with a hand-held spectrometer, I am focusing on two main questions: Can hyperspectral imagery be used to separate trees species from each other and can it separate stressed ash trees from healthy trees? By building a spectral library of different hardwood tree species at different stages of phenology over the growing season, I will be able to determine the feasibility of distinguishing tree species using spectral characteristics. In addition to looking at tree species, I will also be building a spectral library of ash trees with a range of emerald ash borer infestation as well as of trees stress by manual girdling and herbicide injections.

Working with David Williams and the CPHST group at Otis, Massachusetts, I will also be using the field spectrometer for ground truthing hyperspectral data collected with an airborne imaging spectrometer. If successful, researchers will be able to generate accurate host distribution maps looking at the distribution of ash trees within the area and their relative stress level, which may indicate infestation by emerald ash borer.

# EXPLORATION FOR EMERALD ASH BORER IN CHINA

**Houping Liu[1], Toby R. Petrice[2], Leah S. Bauer[1,2], Robert A. Haack[1,2], Ruitong Gao[3], and Tonghai Zhao[3]**

[1] Department of Entomology, Michigan State University,
243 Natural Science Building, East Lansing, MI 48824

[2] USDA Forest Service, North Central Research Station,
220 Nisbet Building, 1407 S. Harrison Rd., East Lansing, MI 48823

[3] Research Institute of Forest Protection, Chinese Academy of Forestry,
Beijing 10091, People's Republic of China

## ABSTRACT

In June 2002, the emerald ash borer (EAB), *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), native to several Asian countries, was identified as the cause of ash (*Fraxinus* spp.) mortality in greater than 2,500 square miles of southeastern Michigan and southwestern Ontario; more recent infestations were found in Ohio, Maryland, and Virginia in 2003. Federal and state agencies adopted a strategy of EAB eradication in North America. Should eradication fail, EAB management will require augmentation of existing natural enemies or introduction of EAB natural enemies from Asia. The only literature known for EAB is from China, where EAB is a sporadic pest of ash (Yu 1992); a braconid parasitoid, *Spathius* sp. (Hymenoptera: Braconidae), was recently reported from EAB in Tianjin Province in an ash plantation (Xu Gongtian 2003).

In addition to our survey of EAB natural enemies in Michigan, we are studying the natural enemy complex of EAB in China. To this end, we explored 29 field sites in Heilongjiang, Jilin, Liaoning, Hebei, Tianjin, and Shandong Provinces in northeastern China from 21 October to nine November 2003. The habitats were variable, ranging from natural forests, nurseries, plantations, city parks, streets, and yards; ash species included *Fraxinus mandshurica*, *F. chinensis* subsp. *chinensis*, and *F. chinensis* subsp. *rhychophylla*. At each site we surveyed 30-60 trees for EAB and potential natural enemies. EAB was present in all provinces except Shandong and in 9 of the 29 sites; five sites showed signs of past infestation such as old exit holes, callused galleries, bark splits, and epicormic branches. EAB seems to prefer ash trees in open areas and at the edges of the forests. Gregarious ectoparasitoid larvae and pupae, probably *Spathius* sp., were found attacking EAB at four of these sites; at one site, 50 percent of EAB larvae were parasitized.

Yu C. 1992. *Agrilus marcopoli* Obenberger. Pages 400-401 in G. Xiao (ed.), Forest Insects China (2nd edition). China Forestry Publishing House, Beijing, China.

Xu Gongtian. 2003. *Agrilus marcopoli* Obenberger, pp. 321-322, In Xu G-T (ed.), Atlas of ornamental pests and diseases. China Agriculture Press, Beijing, China.

# ENHANCED SURVEY METHODOLOGIES AND STRATEGIC RISK ASSESSMENT FOR EMERALD ASH BORER USING SPATIAL MODELS OF HOST TREE DISTRIBUTION

**David W. MacFarlane and Steven K. Friedman**

Department of Forestry, Michigan State University,
126 Natural Resources Building, East Lansing, MI 48824

## ABSTRACT

The emerald ash borer, or EAB (*Agrilus planipennis*), is an exotic insect pest, discovered in July 2002, which has caused the death of many ash trees (*Fraxinus spp.*) in the Detroit Metropolitan area, and is spreading into others areas in the upper Midwest, Canada and beyond. Little is known regarding the abundance and distribution of the host (ash trees) in the complex, heterogeneous landscape of southern lower Michigan because the forest resource consists of a matrix of small, fragmented, non-timber producing patches of forest, in the urban-suburban-agricultural land continuum that is typically under-represented in forest inventory. Estimating the potential impact of the emerald ash borer is crucial, but cannot be properly evaluated without an understanding of the spatial distribution and abundance of the ash tree host. Thus, a statistical estimate of the abundance and spatial distribution of ash trees across the landscape of southern lower Michigan will be developed toward the goal of developing a host-based spatial risk assessment for EAB. A spatial model of the arrangement of potential host space in the greater landscape matrix will provide a strategic picture of the potential risk of establishment and spread of EAB and allow for more precise allocation of sampling effort. A spatial model of host distribution might also serve as a data surface for linking remotely sensed indicators of ash tree decline with patterns of decline associated with EAB.

# DEVELOPMENT OF SURVEY TOOLS FOR THE EMERALD ASH BORER

**Joseph A. Francese[1], Victor C. Mastro[1], David R. Lance[1], Stephen G. Lavallee[1], Jason B. Oliver[2], and Nadeer Youseff[2]**

[1]USDA APHIS-PPQ CPHST Otis Pest Survey, Detection and Exclusion Lab, Bldg. 1398, W. Truck Rd., Otis ANGB, MA 02542

[2]Tennessee State University, Otis L. Floyd Nursery Research Center, 472 Cadillac Lane, McMinnville, TN 37110

## ABSTRACT

Currently, detection of the emerald ash borer, *Agrilus planipennis* (Coleoptera: Buprestidae) Fairmaire (EAB), consists of visual identification of beetles and damaged trees. The objective of this study is to develop a trap and a semiochemical lure system for EAB. An effective trapping system could improve the sensitivity and efficiency of EAB survey programs.

A four panel trap design was employed to test four colors simultaneously. Corrugated plastic panels (0.6 cm thick) were 37.5 cm x 60.0 cm, and were coated with insect trapping glue. Two sets of four colors (black–yellow–white–purple and red–green–navy–silver) were tested at two heights (1.5 m and 7.0 m). Over 500 beetles were caught in a three-week period. More beetles were caught on purple traps than on any other color. Red and yellow traps caught significantly less beetles than any other colors. More beetles caught on low traps than on high traps for all colors except black and yellow. More females were caught on purple and black traps than males. Later in the field season, we also deployed a third set of four colors (brown–orange–teal blue–light blue). These colors, however, did not catch many beetles as the deployment occurred after the peak flight. Single-color, three-panel traps were also put out late in the field season, and the catch was low. We are currently developing a single-color trap to be tested in 2004.

Commercially available semiochemical lures were tested in conjunction with two trap designs—a single purple panel (37.5 cm x 60.0 cm) and the IPM Tech Intercept Panel Trap. The single-panel trap caught 34 beetles, compared to none for the IPM Tech trap. There was no significant difference in catch between the eight lures and the blanks, although traps baited with lures that contained ethanol as an ingredient accounted for 20 of the beetles caught.

We began collecting volatiles from beetles and host material in 2003. We plan to continue this work in 2004. Using gas chromatography coupled with an electroantennographic detector (GC-EAD) we hope to identify antennally-active compounds which will then be tested in lab and field bioassays.

# EMERALD ASH BORER SURVIVAL IN FIREWOOD

**Robert A. Haack and Toby R. Petrice**

USDA Forest Service, North Central Research Station,
220 Nisbet Building, 1407 S. Harrison Rd., East Lansing, MI 48823

## ABSTRACT

The emerald ash borer (EAB), *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), is native to several countries in Asia (e.g., China, Korea, and Japan). EAB was discovered in Michigan and Ontario in 2002, and then in Ohio, Maryland, and Virginia in 2003. As of November 2003, EAB has only been found to infest ash (*Fraxinus*) trees in North America, although other hardwoods (e.g., *Juglans*, *Pterocarya*, *Ulmus*) are listed as hosts in Korea and Japan. EAB is spreading naturally through adult flight as well as artificially through movement of infested ash nursery stock, logs, and firewood. EAB larvae feed and develop in the cambial region of host trees during summer and fall, and then overwinter in the outer sapwood or outer bark. Because of EAB's staggered development, infested trees can contain different EAB life stages throughout the year. As is typical for *Agrilus* species, early larval stages of EAB require a living host. Therefore, if infested trees are cut early during larval development, host tissues should dry and thus reduce *Agrilus* survival. This has been documented for the native two-lined chestnut borer, *Agrilus bilineatus*, which attacks oak (*Quercus*) (Haack and Benjamin 1980).

In 2002, we felled and stacked EAB-infested firewood in Michigan at various intervals from July to October. The firewood was either placed in direct sunlight or in shade. Exit holes were counted on the firewood during summer 2003. EAB were able to survive and emerge from all treatment combinations. However, survival was significantly lower on logs that had been cut during July and August vs. September and October. Similarly, EAB survival was greater on logs that had been stored in shade vs. direct sunlight. Therefore, cutting infested trees early during larval development and placing the logs in full sunlight will dramatically lower EAB survival, but apparently not kill all larvae. A larger study was initiated in 2003, which had the following treatments: month of felling, sun vs. shade, split vs. whole bolts, and tarped vs. not tarped.

Haack R.A., D.M. Benjamin. 1980. Influence of time of summer felling of infested oaks on larval development and adult emergence of the twolined chestnut borer, *Agrilus bilineatus*. University Wisconsin Forestry Research Note 236. 4 pp.

# SURVIVAL OF EMERALD ASH BORER IN WOOD CHIPS

**Deborah G. McCullough[1,2], Therese M. Poland[2], and David Cappaert[1]**

[1]Department of Entomology, Michigan State University,
243 Natural Science Building, East Lansing, MI 48824

[2]Department of Forestry, Michigan State University,
126 Natural Resources Building, East Lansing, MI 48824

[2]USDA Forest Service, North Central Research Station,
220 Nisbet Building, 1407 S. Harrison Rd., East Lansing, MI 48823

## ABSTRACT

Tremendous numbers of infested ash trees are being removed for control and ultimate eradication of the exotic emerald ash borer (EAB), *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae) which was discovered in southeastern Michigan and Windsor, Ontario in 2002. Quarantine regulations have been imposed which restrict movement of all life stages of the beetle in ash trees, limbs or cut firewood, ash logs and untreated ash lumber with bark attached, uncomposted ash wood chips and bark chips larger than one inch in diameter, and any other articles determined to present a risk. The greatest threat to the success of the eradication plan is artificial spread of EAB as a result of improper disposal or movement of infested material. The Michigan Department of Agriculture has implemented an incentive program for ensuring infested ash material is chipped within the core infested area by providing collection yards for ash trees and free access to a large grinder. The fate of EAB life stages in chip piles and bark chips used for incineration or landscaping, however, is unknown.

We conducted a study to determine survival of EAB in chips of different sizes. In late October 2002, eight heavily infested ash trees were felled and transported to a collection yard with a large grinder. Samples from each tree were dissected to determine larval density. Half of the remaining portions of each tree were ground into 1" chips and the other half into 4" chips. We collected samples of 1" and 4" chips from each tree using large plastic boxes (approximately 60 x 45 x 45 cm). The remaining chips were combined into a 1" chip pile or a 4" chip pile. No surviving EAB larvae were found in the sample box material, which was thoroughly hand-sifted. We also inspected the remaining chips in the two chip piles. No chips containing larvae were found in the 1" pile, whereas eight large chips in the 4" chip pile were found to contain live EAB larvae.

We prepared 49 sentinel chips by chiseling small sections of wood (approximately 5 x 8 cm) containing live overwintering larvae from infested ash logs and attaching a long section of nylon rope to each chip. The sentinel chips were buried at different depths within the two chip piles. In addition, temperature-recording dataloggers were buried in each chip pile. The chip piles were enclosed in screen tents and held outdoors until May 2003. Sentinel chips were removed from the chip piles and inspected for surviving larvae. Three prepupae were found in the one-inch chip pile, and three in the four-inch chip pile. Temperatures within the chip piles tracked ambient temperatures closely indicating that little or no heat was generated from composting within the relatively small chip piles. No EAB adults were captured in the screen tents. Overall, the results suggest that

if chips are to be stored for any length of time, they should be ground to a one-inch size to adequately destroy all EAB larvae. Larger chips should be incinerated promptly.

# EVALUATION OF PERMA GUARD D-20 AND IMIDACLOPRID TO CONTROL EMERALD ASH BORER

**Robert A. Haack and Toby R. Petrice**

USDA Forest Service, North Central Research Station,
220 Nisbet Building, 1407 S. Harrison Rd., East Lansing, MI 48823

## ABSTRACT

The emerald ash borer (EAB), *Agrilus planipennis* Fairmaire (Buprestidae), a native of Asia, was discovered in the USA and Canada in 2002. Drs. Deborah McCullough (Michigan State University) and Therese Poland (USDA-FS) tested several systemic and topical insecticides for EAB control, which they reported elsewhere. One additional insecticide that we tested was D-20 by Perma Guard (Albuquerque, NM), which is composed of diatomaceous earth and natural pyrethrins (0.2 percent a.i.). The study included 40 newly transplanted green ash trees, 4-5 m tall, which were moved from a nursery in a non EAB-infested area of Michigan to an area that was heavily infested with EAB near Ann Arbor, MI. The trees were moved on 26 June, transplanted on 26–27 June, and treated on 27 June 2003. EAB adults were able to freely infest any tree. In fact, a few EAB adults were seen on the test trees on 27 June 2003. There were five treatments, using eight trees per treatment: untreated control trees, one application of D-20, two applications of D-20, three applications of D-20, and trees treated with imidacloprid (Imicide by Mauget). We used a backpack sprayer to apply D-20 to both the foliage and trunk. D-20 was applied on 27 June, 14 July, and 30 July. D-20 was mixed with water at a rate of 1 tablespoon per gallon, as recommended by Mr. Wallace Tharp of Perma Guard. Later, after early results showed little mortality of adults in leaf-feeding bioassays, we treated additional foliage at a rate of 1 cup of D-20 per gallon of water. Soon after each application of D-20, feeding bioassays were set up, using EAB adults and foliage from each of the test trees. Overall, EAB mortality after three days of feeding was very low on the control trees (4 percent mortality), low on foliage treated with D-20 at the 1 tablespoon/gallon rate (approximately 30 percent), but high on trees treated with D-20 (approximately 85 percent) at the 1 cup per gallon of water or with imidacloprid (approximately 90 percent). The test trees will be felled and debarked in winter 2003/2004 to evaluate EAB attack density by treatment.

In a second study in 2003, we also sprayed infested ash logs with two concentrations of D-20 (1 tablespoon/gallon and 1 cup/gallon), and imidacloprid (Merit 2; 21.4 percent a.i.; mixed at 0.9 ml/ gal.) approximately five days prior to estimated adult emergence. Prior to treatment, 18 logs were cut, 6 logs per treatment. We sprayed half of each log with insecticide, while the other half served as a control. Logs were placed in separate containers and monitored daily for adult emergence. Overall, neither concentration of D20 reduced EAB emergence. By contrast, no adults completely emerged from the logs treated with imidacloprid; however, several dead adults were found that had partially emerged prior to their death.

# CONTROL OF EMERALD ASH BORER ADULTS AND LARVAE WITH INSECTICIDES

**Deborah G. McCullough[1,2], David Cappaert[1], Therese Poland[3], and David R. Smitley[1]**

[1]Department of Entomology, Michigan State University,
243 Natural Science Building, East Lansing, MI 48824

[2]Department of Forestry, Michigan State University,
126 Natural Resources Building, East Lansing, MI 48824

[3]USDA Forest Service, North Central Research Station,
220 Nisbet Building, 1407 S. Harrison Rd., East Lansing, MI 48823

## ABSTRACT

Virtually no information is available from Asia regarding the ability of insecticide products and application methods to protect ash trees from emerald ash borer. Many landscapers in the Core infestation in southeastern Michigan have promoted various treatments to their customers, but there has been no objective evaluation of these products. Insecticides may also be useful for treating ash trees in outlying populations targeted for eradication.

Our objectives were to 1) evaluate registered insecticide products and application methods for adult and larval control; 2) identify optimal timing for soil, trunk and spray applications; 3) monitor persistence of insecticides over time; and 4) identify factors such as tree age or previous injury that could affect insecticide efficacy. In 2003, we set up insecticide studies at eight different sites with relatively light emerald ash borer densities. Trees at each site ranged from 2 to 22 inches in diameter and appeared relatively healthy. Different combinations of insecticide treatments along with untreated controls were evaluated at each site. There were at least six trees per treatment per site.

Soil injected imidacloprid (Merit 75 WP) was applied with either a Kiortiz injector or as a high pressure soil injection in mid April. On May 20-21, we applied trunk injections of imidacloprid. Products tested included Imicide (injected with Mauget capsules) and Pointer (applied with a Wedgle injection system). On June 2, we applied trunk injections of bidrin (Injecticide-B injected with Mauget capsules). Additional trees at one site were treated again with bidrin on July 14 or on September 5. Bark and foliage cover sprays (Orthene, Sevin, Tempo, and Onyx) were applied on May 30. Half of the trees in each treatment were sprayed again on July 2.

Xylem sap from shoots in the upper and lower crown of trees treated with imidacloprid (high pressure Merit, Imicide, and Pointer) at one site were collected at roughly two-week intervals from 3 June to 31 July. Samples were submitted to cooperating USDA APHIS scientists for ELISA analysis to assess imidacloprid concentration over time.

We conducted bioassays to evaluate effectiveness of insecticide applications for adult beetle control. In these bioassays, five adult beetles were caged on a leaf from treated or control trees for eight days. Survival and foliage consumption were monitored.

Removal of bark to quantify larval density in treated and control trees began in early September. On each tree, we carefully sampled bark windows, each roughly 600 $cm^2$, on two aspects of the trunk, on lower and upper canopy. At least 14 bark windows were sampled on each tree.

Results of ELISA tests indicated that imidacloprid applied by either soil or trunk injections had moved into the branches and upper shoots of trees by June 3. Trees treated with high pressure soil injection had the greatest imidacloprid concentrations, but between-tree variability was high. Concentrations peaked around June 24, and then declined over the next five weeks, suggesting that imidacloprid was translocated out of xylem sap.

Preliminary results of adult bioassays indicated that bidrin was highly toxic to adults. For example, on June 25, beetles caged for five days with foliage from bidrin trees sustained 100 percent mortality. Even 38 days after injection, more than 90 percent of beetles died when caged on foliage from bidrin trees for five days.

Imidacloprid was not highly toxic to adult beetles, but did act as an antifeedant. In the June 25 bioassay, less than 50 percent of beetles caged on leaves from trees treated with Merit, Imicide, or Pointer had died after five days. Beetles on imidacloprid trees consumed less than half as much foliage as beetles on control trees and many simply starved rather than feed. Cover sprays were relatively effective for at least 2-3 weeks. Beetle mortality in bioassays conducted eight days after application of the second cover spray ranged from 80–100 percent.

Larval density data was available for only one site; sampling was in progress at other sites. Preliminary data showed that larval density on untreated control trees at this site averaged roughly 45 larvae/$m^2$ of phloem. In comparison, larval density was less than 10 larvae/$m^2$ on trees treated with bidrin, high pressure soil injection of imidacloprid, or two cover sprays. Sampling and data analysis are continuing.

# CONTROL OF EMERALD ASH BORER: DIRECT TRUNK INJECTION TECHNOLOGIES

**Phillip A. Lewis**

USDA APHIS-PPQ CPHST Otis Pest Survey Pest Survey,
Detection and Exclusion Laboratory,
Bldg. 1398, W. Truck Rd., Otis ANGB, MA 02542

## ABSTRACT

An alternative to soil or foliar applied pesticide applications for a tree is the use of a pesticide injection directly into the trunk. Varieties of direct trunk injection (DTI) systems are available commercially, and were initially tested by our laboratory for the asian longhorn beetle (ALB) program for efficacy, cost, ease of use, and resultant damage. The systems and basic use specifications are as follows: The systems compared to the Mauget capsule injection method (11/64-inch hole, ½-inch deep) were: Quik Inject System (by Mauget, 3/8-inch hole, 2-inch deep), Arborsystem's Wedgle using a Wedgechek (cambial layer injection method), an injector designed at our laboratory (ALB injector) (7/32-inch hole, ½-inch deep), and two high pressure systems, Sidewinder (15/64-inch hole, 1-inch deep), Arborjet's VIPER (18/64-inch, 0.63-inch deep, with a 0.33-inch plug). The Mauget capsule system delivers the pesticide over a period of up to 4 hours, while the remaining systems provide an almost immediate delivery. Efficacy of the injections was monitored by subjecting sap residue samples to an ELISA assay for imidacloprid. This assay is sensitive in the parts per billion and costs approximately $10 per sample, as compared to parts per million sensitivity and hundreds of dollars per sample for a typical HPLC analysis of leaf and twig tissue.

Suspension formulations of imidacloprid were more difficult to administer into trees and yielded residue levels no different than control trees after one month. A 25 percent formulation resulted in significantly lower residue levels than paired injections of a 10 percent formulation. The Quik Inject, Wedgle, and Sidewinder injection systems gave inconsistent and/or lower residue levels than the Mauget capsule injection method. Quik Inject and the two high pressure (typically 600+ p.s.i.) systems—Sidewinder and Arborjet's VIPER—resulted in significant vertical cracking above and below the injection holes nine months after application. Based on field experience, the ALB injector was least intrusive and most consistent with the standard Mauget method in terms of residue levels and damage.

For this reason, the ALB injector was utilized to test several insecticides for efficacy against the emerald ash borer (EAB). Dinotefuran (a neonicotinal) and the Imicide formulation of imidacloprid were equally effective, both showing significantly higher larval mortality than control trees. A small laboratory assay that looked at adult mortality tested foliar sprays of Merit, Tempo, and Sevin (maximum label rates), as well as ash sprigs, allowed to absorb solutions of 1, 5, 10, and 50 ppm imidacloprid. All treatments were effective in killing adult EAB.

# TAXONOMY AND DISTRIBUTION OF NATURAL ENEMIES OF EMERALD ASH BORER

**Richard Reardon**

USDA Forest Service, 180 Canfield Street, Morgantown, WV 26505

## ABSTRACT

The Forest Service Forest Health and Technology Enterprise Team (FHTET) is participating in a cooperative effort with West Virginia University involving John Strazanac and Paul Marsh (retired, braconid specialist with the US National Museum) to:

1) Validate the newly described species of *Spathius* (Hymenoptera: Braconidae) by Dr. Yang of the Research Institute of Forest Protection, Chinese Academy of Forestry (i.e., Dr. Yang has recorded high levels of parasitism by this braconid and there is some urgency to import this species into quarantine facilities in the U.S.);

2) Revise the genus *Spathius* with pictorial keys for North American species (approximately 16 species) and for Asian species associated with Buprestides (approximately 20 species);

3) Develop taxonomic keys to native natural enemies of North American *Agrilus*; and

4) Make available to scientists taxonomic expertise in the identification of natural enemies collected from or associated with the emerald ash borer in the USA or Asia.

The Forest Service FHTET and Animal and Plant Health Inspection Service (APHIS) have a cooperative agreement with Dr. Yang Zhong-qi of the Research Institute of Forest Protection Chinese Academy of Forestry to:

1) Survey for and document locations of emerald ash borer (EAB) populations in northeast China;
2) Elucidate the biology of EAB;
3) Survey for natural enemies of EAB, conduct host range tests, and ship promising species to quarantine facilities in the SUA; and
4) Document the biology and ecology of a newly described species of *Spathius*.

Exploration for natural enemies in South Korea and Russia will be initiated in 2004:

1) Dave Williams (USDA-APHIS) will visit South Korea in the Spring of 2004 to discuss with scientists, visit museums, etc. to obtain information on natural enemies of EAB; and

2) Vic maestro (USDA-APHIS) has initiated a cooperative effort with Galina Yurchenko of the Far East Forestry Research Institute, Khabarovak, Russia, to survey for natural enemies of EAB.

# MICROBIAL CONTROL OF THE EMERALD ASH BORER

**Leah S. Bauer[1,2], Houping Liu[2], and Deborah L. Miller[1]**

[1]USDA Forest Service, North Central Research Station,
1407 S. Harrison Rd., East Lansing, MI 48823

[2]Department of Entomology, Michigan State University,
243 Natural Science Building, East Lansing, MI 48824

## ABSTRACT

In June 2002, emerald ash borer (EAB), *Agrilus planipennis* Fairmaire, a buprestid native to several Asian countries, was identified as the causative agent of ash (*Fraxinus* spp.) mortality in southeastern Michigan and southwestern Ontario. Currently, the only method known to control EAB is limited to identifying and destroying infested trees. Conventional insecticides, when identified, will be broadly toxic, expensive, and may require handling by licensed applicators, making their widespread use in parks, woodlots, forests, wetlands, and riparian areas unlikely. Public acceptance remains high for microbial insecticides formulated with *Bacillus thuringiensis* (Bt) and *Beauveria bassiana* due to good safety records and compatibility with other management strategies, including biocontrol.

We screened EAB adults with four registered Bt-based microbial insecticides formulated with different Bt strains. Using a spray tower, we applied Bt at 20 gal/acre and found some products were toxic to EAB adults in the laboratory, but at relatively high concentrations. We are identifying the EAB-active toxins produced by Bt, and will evaluate if Bt products can be developed for use in EAB management using aerial application technologies.

BotaniGard® is a microbial insecticide made from the insect pathogenic fungus *Beauveria bassiana* var. GHA and was registered for control of insects pests of forest and shade trees in 1999. We are developing EAB control methods using BotaniGard® for use by homeowners and managers of municipalities, parks, and other in environmentally sensitive areas such as forests, woodlots, and wetlands. In summary:

1. Using laboratory bioassays, we determined that adults were more susceptible than larvae to *B. bassiana* GHA. Additional laboratory studies involved comparisons of two BotaniGard® formulations: BotaniGard ES® is formulated with petroleum-based oils; BotaniGard O® is formulated with vegetable oils, for use by growers of organic food. In subsequent the laboratory bioassays, we exposed EAB adults for 24 hrs to ash leaves sprayed with serial dilutions of BotaniGard ES® and BotaniGard O® with a spray tower at the rate of 20 gal/acre. EAB were cultured for *B. bassiana* infection after death. The $LC_{50}$ of the BotaniGard® formulations were similar, and averaged 4.9 and 4.7 spores/cm$^2$ for BotaniGard ES® and BotaniGard O®, respectively; these values demonstrate similar virulence of these two formulations and high virulence *B. bassiana* GHA against EAB. The $LT_{50}$s for BotaniGard ranged from 4 to 10 days, depending on spore concentration.

2. In the greenhouse, we compared the efficacy of BotaniGard ES® against adults when sprayed on leaves vs. logs; 2 qts BotaniGard®/acre was applied with a spray tower to:

   a) foliage of potted ash trees caged with adults;
   b) uninfested ash logs caged with adults; and
   c) caged pre-emergent infested ash logs.

   After death, beetles were cultured for fungal infection; we determined that 10 percent of adults caged with sprayed trees, 18 percent of adults caged with sprayed logs, and 61 percent of adults emerging from sprayed logs were infected with *B. bassiana*; no controls were infected.

3. In the field, we sprayed EAB-infested tree trunks prior to beetle emergence (spring 2003), with 2 and 20 qts BotaniGard®/acre in a hand-held sprayer; treated and control tree trunks with epicormic shoots were then caged, and EAB were allowed to complete their life cycle within the cage. After death, EAB were cultured for fungal infection; at 0, 2, and 20 qts/acre, prevalence of *B. bassiana* infection among adults was 0 percent, 43 percent, and 76 percent, respectively. At present, we are dissecting these ash trees to determine if pre-emergent BotaniGard-trunk treatments resulted in lower EAB infestation due to larval infections.

4. In the field, we sprayed EAB-infested ash trees (fall 2003) with 14 qts BotaniGard®/acre using a hand-held sprayer. Although there were no emergence holes on these trees, bark cracks suggested the presence of EAB larvae under the bark. We are currently dissecting the trees to determine if BotaniGard® infects larvae under tree bark via bark cracks. Although less than half of the trees have been dissected to date, we have found 10-20 percent of EAB larvae infected with *B. bassiana* in the sprayed trees vs. 0 percent in unsprayed control trees. Based on the results of this study, we recommend earlier BotaniGard® trunk sprays as many of the EAB larvae had begun to enter the sapwood for overwintering.

In 2004, we plan to expand these and other studies of BotaniGard to include additives such as surfactants and UV protectants; larger field trials are planned. In conclusion, the results of our studies demonstrate that BotaniGard® shows promise for control of EAB.

# NATURAL ENEMIES OF EMERALD ASH BORER IN SOUTHEASTERN MICHIGAN

**Leah S. Bauer[1,2], Houping Liu[2], Robert A. Haack[1,2], Toby R. Petrice[1], and Deborah L. Miller[1]**

[1]USDA Forest Service, North Central Research Station,
220 Nisbet Building, 1407 S. Harrison Rd., East Lansing, MI 48823

[2]Department of Entomology, Michigan State University,
243 Natural Science Building, East Lansing, MI 48824

## ABSTRACT

*Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), the emerald ash borer (EAB), is native to China, Japan, Korea, Mongolia, Russian Far East, and Taiwan. In 2002, EAB was identified as the causative agent of extensive ash (*Fraxinus* spp.) mortality in southeastern Michigan and nearby southwestern Ontario. EAB was inadvertently introduced in solid wood packing materials or dunnage approximately 5-10 years ago, resulting in millions of dead and dying ash trees. In 2003, satellite infestations were found in Lower Michigan, northern Ohio, Maryland and Virginia due to transport of infested ash nursery stock, firewood, and logs. Federal and state agencies adopted a strategy of EAB eradication in North America. Should these efforts fail, however, EAB management will require augmentation of existing natural enemies or introduction of EAB natural enemies from Asia. As EAB is only a minor pest in Asia, information and literature are scant; however, one braconid parasitoid (*Spathius* sp.) was recently reported from EAB (Xu Gongtian 2003).

To this end, we surveyed natural enemies attacking EAB in a woodlot in Wayne County, Michigan from August 2002 through July 2003. Infested ash trees were felled every other week, and from paired logs, we either 1) removed the insects and placed them on artificial diet, or 2) allowed the insects to emerge directly from infested ash logs in cardboard tubes in a greenhouse. Live EAB and parasitoids were reared to the adult stage, and dead EAB were cultured for insect pathogenic fungi. In July 2003, we collected EAB eggs from ash trees in the woodlot, placed them in petri dishes in the laboratory, and allowed them to hatch. We sent the potential insect parasitoids and predators to USDA Agricultural Research Service, Systematic Entomology Laboratory, for identification.

During the course of our one-year survey, we dissected approximately 6,000 EAB from infested ash logs to culture entomopathogenic fungi and rear natural enemies. Less than 2 percent of immature EAB were infected with five species of fungi: *Beauveria bassiana* (24 isolates), *Paecilomyces farinosus* (30 isolates), *Paecilomyces fumosoroseus* (7 isolates), *Verticillium lecanii* (36 isolates), and *Metarhizium anisopliae* (2 isolates). We reared seven potential hymenopteran parasitoids of immature EAB from infested logs: a braconid (*Heterospilus* sp.), a chalcid (*Phasgonophora sulcata*), two eupelmids (*Balcha* sp. and *Eupelmis* sp.), and three ichneumonids (identification not complete). *Balcha* sp., a solitary ectoparasitoid, was the most prevalent EAB parasitoid, and some were successfully reared to adult in the laboratory. *Balcha* exotic parasitoid from Asia and was recently discovered in Maryland and Virginia (Michael Gates, USDA Agricultural Research Service, Systematic Entomology Laboratory, personal communication). A species of eupelmid (*Pediobius*

sp.) was reared from 0.3 percent of EAB eggs collected in early July. Two other braconid species, reared from EAB-infested logs cut in different woodlots, included *Atanycolus* sp. and *Spathius simillimus*. Predators included a species of clerid (*Enoclerus* sp.), a passandrid (*Catogenus* sp.), and a trogossitid (*Tenebroides* sp.). Other EAB mortality factors included woodpecker predation, starvation, desiccation, and cannibalism, especially in heavily infested logs. Our results revealed that mortality of EAB in Michigan due to parasitoids is low compared to that reported for some of our native *Agrilus* spp.

Xu Gongtian. 2003. *Agrilus marcopoli* Obenberger, pp. 321-322, In Xu G-T (ed.), Atlas of ornamental pests and diseases. China Agriculture Press, Beijing, China

# BIOCONTROL OF THE EMERALD ASH BORER

**Juli Gould[1], Amy Roda[2], and Dick Reardon[3]**

[1]USDA APHIS-PPQ CPHST Otis Pest Survey Pest Survey,
Detection and Exclusion Laboratory,
Bldg. 1398, W. Truck Rd., Otis ANGB, MA 02542

[2]USDA-APHIS, Invasive Pest Management Laboratory,
2534 South 11th Street, Niles, MI 49120

[3]USDA-Forest Service, 180 Canfield Street,
Morgantown, WV 26505

## ABSTRACT

The overall goal of this project is to provide the emerald ash borer (EAB) program with biocontrol agents that can be integrated into a control strategy. APHIS and the Forest Service have contracted with Chinese scientists to survey for natural enemies in China and to describe their natural history. Collections in 2003 were difficult because the SARS outbreak restricted travel. One parasitoid in the genus *Spathius* (Hymenoptera: Braconidae) was found and reared. It is gregarious (3-18 per EAB) with five to six generations per year. The parasitoid does not seem to be physiologically host-specific. A list of borers native to the United States that might be at risk from attack by imported EAB natural enemies was developed. The list included borers closely related to the EAB, those that attack the trunk and large branches of ash trees, and those species with similar seasonal phenology, egg laying and larval feeding sites, and geographic range. The non-targets selected for study include *Agrilus anxius* (Coleoptera: Buprestidae), *Chrysobothris femorata* (Coleoptera: Buprestidae), *Neoclytus acuminatus* (Coleoptera: Cerambicidae), and *Podosesia syringae* (Lepidoptera: Sesiidae).

Several native parasitoid and predator species are generalists that attack borers that are closely related to the EAB. We plan to collect, study, and rear these native natural enemies. The impact that these natural enemies are having on EAB populations will be determined. Native borers will also be collected and reared for host-specificity testing. Techniques for getting ash logs infested with EAB larvae for host-specificity testing have been successfully developed. Artificial rearing of both EAB and natural enemies will be conducted.

# LABORATORY REARING OF EMERALD ASH BORER

**Leah S. Bauer[1,2], Robert A. Haack [1,2], Deborah L. Miller[1], Houping Liu[2], and Toby Petrice[1]**

[1]USDA Forest Service, North Central Research Station,
220 Nisbet Building, 1407 S. Harrison Rd., East Lansing, MI 48823

[2]Department of Entomology, Michigan State University,
243 Natural Science Building, East Lansing, MI 48824

## ABSTRACT

The emerald ash borer (EAB), *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), native to several Asian countries, was identified in 2002 as the cause of ash (*Fraxinus* spp.) mortality throughout southeastern Michigan and southwestern Ontario. More isolated infestations continue to be found throughout Lower Michigan, northern Ohio, Maryland, and Virginia, resulting from transport of infested host materials. An eradication plan is being developed for EAB as this invasive pest threatens ash resources throughout North America. Collaborative research among researchers in Michigan on EAB biology, control, detection, dispersal, host range, and natural enemies required large numbers of healthy insects for bioassay and other experimental treatments. Our methods for mass rearing EAB adults are described below. We are also developing an artificial larval diet and laboratory rearing methods for EAB.

EAB adults are readily reared from infested ash. By winter 2002, the majority of EAB were prepupae in the sapwood or thick outer bark. To provide adequate numbers of EAB adults for our research, infested ash logs and bark were obtained throughout the winter and spring and stored in a 2°C walk-in cold-room. A chill period is not required by EAB and adult production can begin at any time, although emergence from non-chilled logs is less synchronized.

Adults were reared as needed by bringing logs out of cold storage and placing them in large, sealed cardboard tubes with a clear, screw-top collection cup at one end. The tubes were stacked in a greenhouse where adults began emerging after approximately 3 to 6 weeks, depending on ambient temperatures. For comparison, adults emerged in approximately 4 weeks from logs held at 24°C in a growth chamber. Once emergence began, adults were removed daily from the collection cups and maintained on evergreen ash foliage (*F. uhdei*) grown in the greenhouse. As of December 2003, adults continue to emerge from logs cut approximately 10 months ago. Another, more labor intensive method of rearing adults involves removing prepupae from infested logs or bark and placing them on small disks of paper toweling in individual wells of 24-well tissue culture plates stored in a dark incubator at 24ÚC. After pupation, the naked pupae develop into feeding adults in approximately 25 days.

Adults can be maintained individually or in small groups on ash foliage in cups, petri dishes, cages, etc. For oviposition studies, newly enclosed adults were sexed and placed in individual petri dishes, allowed a minimum of 7 days for maturation feeding; a female and a male were then placed together in a single dish, and observed for mating. Mating occurred within 30 minutes, and successful pairs were maintained in cages with ash foliage for food and an ash log for oviposition until death. Females oviposit in bark crevices and between layers of bark, but also in tight spaces and

narrow cracks found in rearing boxes and cages. Eggs, collected from infested ash trees in the field and placed in petri dishes, hatched in about a week.

# HOST RANGE OF EMERALD ASH BORER

**Robert A. Haack[1], Toby R. Petrice[1], Deborah L. Miller[1], Leah S. Bauer[1], and Nathan M. Schiff[2]**

[1]USDA Forest Service, North Central Research Station,
220 Nisbet Building, 1407 S. Harrison Rd., East Lansing, MI 48823

[2]USDA Forest Service, Southern Research Station,
432 Stoneville Rd., Stoneville, MS 38776

## ABSTRACT

The emerald ash borer (EAB), *Agrilus planipennis* Fairmaire, is native to China, Korea, Japan, Mongolia, Russia, and Taiwan (Haack et al. 2002). Established populations of EAB were first discovered in Michigan and Ontario in 2002. Smaller populations, which resulted from human-assisted movement of infested host material, were found in Ohio, Maryland, and Virginia in 2003. As of November 2003, EAB has only been found to attack ash (*Fraxinus*) trees in North America. Ash is the only host listed for EAB in China, and ash is also listed as a host in Japan. In Japan, ash, elm (*Ulmus*), walnut (*Juglans*) and wingnut (*Pterocarya*) are reported as hosts, while elm is listed as a host in Korea (Haack et al. 2002).

In 2003, we evaluated foliage of several trees and shrubs as food for EAB adults in a series of no-choice and choice tests that were conducted indoors in Michigan. We tested members of the olive family (Oleaceae: *Chionanthus*, *Forestiera*, *Forsythia*, *Fraxinus*, *Ligustrum*, *Syringa*), elm family (Ulmaceae: *Celtis*, *Ulmus*), and walnut family (Juglandaceae: *Carya*, *Juglans*). In spring and early summer 2003, using young foliage primarily from nursery stock that was maintained in a greenhouse, we gave foliage of a single plant species to EAB adult males and females until their death. For males, results showed that adults given no food and low humidity lived an average of 6 days, while males given no food but high humidity lived 9 days. Male longevity was 17 to 21 days on black ash (*F. nigra*), green ash (*F. pennsylvanica*), evergreen ash (*F. uhdei*), and velvet ash (*F. velutina*). Males lived an average of 20 days on privet (*Ligustrum*) and 13 days on swamp privet (*Forestiera*). Average male longevity was only 6 to 8 days on Chinese elm, Siberian elm, hackberry, butternut, black walnut, forsythia, and lilac.

In 48-hour no-choice tests using fully-expanded foliage, EAB adults fed readily on ash, although blue ash (*F. quadrangulata*) was the least preferred. There was some feeding on the other members of the ash family, such as forsythia, fringe tree, lilac, privet, and swamp privet. There was almost no feeding on elm, hackberry, hickory, and walnut. Two-choice tests were also conducted using green ash as the "standard," although the data from have not been fully analyzed yet. Further testing of EAB host range will be conducted both indoors and outdoors in 2004.

Haack R.A., E. Jendek, H. Liu, K.R. Marchant, T.R. Petrice, T.M. Poland, and H. Ye. 2002. The emerald ash borer: a new exotic pest in North America. *Newsletter of the Michigan Entomological Society* 47(3-4): 1-5.

# HOST RANGE AND HOST PREFERENCE OF EMERALD ASH BORER

**Deborah G. McCullough[1,2], Andrea Agius[1], David Cappaert[1], Therese Poland[3], Debbie Miller[3], and Leah Bauer[3]**

[1]Department of Entomology, Michigan State University,
243 Natural Science Building, East Lansing, MI 48824

[2]Department of Forestry, Michigan State University,
126 Natural Resources Building, East Lansing, MI 48824

[3]USDA Forest Service, North Central Research Station,
220 Nisbet Building, 1407 S. Harrison Rd., East Lansing, MI 48823

## ABSTRACT

Currently, emerald ash borer (*Agrilus planipennis* Fairmaire) is known to infest only ash (*Fraxinus* sp.) trees. Reports from Asia, however, indicate that this or a closely related beetle have been collected from Asian species of elm, walnut, and wingnut (*Pterocarya* sp.). The ability of emerald ash borer to utilize alternative hosts would obviously have major implications for survey activities the overall success of the eradication effort. In addition, we have observed that North American ash species may differ in their susceptibility to emerald ash borer or in their vulnerability once infested. Green ash (*F. pennsylvanica*) trees, for example, appear to decline more rapidly than white ash (*F. americana*) trees, even when trees are growing in the same area and subject to similar infestation pressure.

Our first objective is to evaluate alternate species of concern to determine whether they are acceptable to ovipositing adult beetles and whether they are suitable for larval development. In addition, we are comparing attack rates and damage between green and white ash and assessing whether stressed trees are more attractive to beetles than vigorous trees.

Our primary focus this summer was on potential alternate host species for emerald ash borer. We conducted controlled studies in the laboratory to evaluate oviposition preference by caging adult females with green ash leaves and small sections of wood (with bark) of potential alternate hosts. Alternate hosts evaluated in this study included green, white, and black ash (*F. nigra*), black walnut (*Juglans nigra*), American elm (*Ulmus americana*), privet (*Ligustrum* sp. and in the same family as ash), shagbark hickory (*Carya ovata*), and hackberry (*Celtis occidentalis*, related to elm). Females were allowed to feed and oviposite until they died. Four weeks later, the wood sections were carefully examined and number of eggs recorded. The sections were dissected, and the number of first stage larval galleries per $cm^2$ of phloem were quantified.

Results showed that there were roughly twice as many eggs laid on the ash species as on elm, walnut, hickory, and hackberry, while privet was intermediate. First stage larval galleries were found on at least one section of all species except hickory. Gallery density was highest for the ash species and privet, and relatively low for elm, walnut, and hackberry. Galleries on the alternate species appeared to be small and malformed, suggesting larvae would be unlikely to complete development.

We also assessed alternate hosts with a series of field tests. In one test, similarly-sized green ash, walnut, and elm logs (roughly 10 cm in diameter, 60 cm long) were tied together and attached to the upper trunk in the canopy of heavily infested green ash trees. The three logs were suspended from five large trees in two sites where emerald ash borer density was high (30 logs total). Our goal was to see if emerald ash borer females would make a mistake and oviposite on either the elm or walnut logs. Logs were retrieved in August, held for four weeks, and then dissected. There were roughly 40 first stage galleries on the ten ash logs, one small gallery on a walnut log, and no galleries on the elm logs.

In another test, logs of green ash, white ash, black ash, hickory, hackberry, elm and black walnut were attached to t-posts at four heavily infested sites. Black drain pipe was cut to a similar length and used as a "control." Plastic shrink-wrap and tanglefoot were applied to half of the logs and drain pipe sections. The tanglefoot bands were checked weekly to monitor adult landing rates. Adults were collected in relatively higher numbers from all logs than from the drain pipe, but there were no substantial difference among log species. Dissection of logs is in progress to quantify first stage larval galleries.

We also inserted first and second instar larvae just under the bark on live green ash, walnut and elm trees, and freshly cut sections of each species at one site. Larvae were left undisturbed for eight weeks. Dissection of the branches and the insertion areas on live trees is in progress.

Preliminary results of our host range work suggest that under no-choice conditions, female beetles will oviposite on alternate species. Ovipositional "mistakes" do occur in the field, but appear to be rare. First-stage larvae fed readily on all three ash species. A few larvae attempted to feed on the alternate species, but development appeared to be impaired. Privet, however, did appear to be suitable for first-stage larvae in the lab test. Privet and other species related to ash warrant additional evaluation.

# EVALUATION OF RESISTANCE OF ASIAN AND NORTH AMERICAN ASHES TO EMERALD ASH BORER

**Daniel Herms[1], David Smitley[2], Deborah McCullough[2], and Pierluigi Bonello[3]**

[1]Department of Entomology, The Ohio State University,
Ohio Agricultural Research and Development Center, Wooster, OH 44691

[2]Department of Entomology, Michigan State University,
243 Natural Science Building, East Lansing, MI 48824

[3]Department of Plant Pathology, The Ohio State University,
Columbus, OH 43210

## ABSTRACT

A replicated ash planting was established in Novi, Michigan in May of 2003 to:

1) Compare resistance of native and Asian ashes to emerald ash borer;
2) Identify mechanisms of resistance and susceptibility by quantifying biochemical and physical responses of phloem to wounding; and
3) Determine the effects of drought and other stress on borer susceptibility.

The planting includes white ash (*Fraxinus americana)* and green ash (*F. pennsylvanica*), Manchurian ash (*F. mandshurica*)—with which 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 (*F. nigra*) and Manchurian ash. The inclusion of this hybrid may provide insight into patterns of inheritance of resistance genes, and facilitate their identification. Because of the size of the trees (1½–2-inch caliper), we expect them to be colonized during 2004. Our hypothesis is that the Asian ash is most resistant because of natural defenses resulting from coevolution with the insect. 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 silvicultural management of emerald ash borer in urban natural forests.

# TREE SUSCEPTIBILITY AND WITHIN-TREE DISTRIBUTION OF THE EMERALD ASH BORER, *AGRILUS PLANIPENNIS* FAIRMAIRE, IN SOUTHWESTERN ONTARIO

**L.L. Timms[1], R. Morgan, S.M. Smith[1], and P. de Groot[2]**

[1]Faculty of Forestry, University of Toronto, 33 Willcocks Street, Toronto, ON M5S 3B3

[2]Canadian Forest Service, Great Lakes Forestry Centre,
1219 Queen Street East, Sault Ste. Marie, ON P6A 2E5

## ABSTRACT

The emerald ash borer (EAB—*Agrilus planipennis* Fairmaire) is a recently-introduced invasive insect threatening the forests of southwestern Ontario. Accurately detecting EAB in trees or stands is difficult because there is little known about its biology and behaviour, either in North America or its native China. Two studies have been initiated in Canada to examine the patterns of within-tree and within-stand distribution of EAB feeding galleries in order to develop improved survey methods.

To assess within-tree distribution, 31 ash trees were selected between 3 and 12 m in height, and 3 and 12 cm in diameter during the summer of 2003. The trees were cut and stripped of their bark to study the possible effects of stem height, stem diameter, cardinal direction, bark thickness, and branch location on gallery distribution within the tree. Preliminary results suggest that the within-tree distribution of EAB galleries may be significantly affected by stem diameter, with an optimum diameter of approximately 9.3 cm for this group of trees.

To assess within-stand distribution, 50 green or white ash trees, between 5-17 cm DBH and with no evidence of previous borer colonization, will be selected from four stands in Essex County during the fall of 2003. Tissue samples will be removed during January 2004 from each tree to determine winter starch reserves and relate that to overall tree health. During the spring, tree parameters (including DBH, height, bark thickness, crown length, crown width, crown density, evidence of other pests or pathogens, and beetle attractiveness using sticky band traps) will also be measured. All parameters will be compared at the end of the summer to infestation levels in dissected trees.

# MEETING ATTENDEES

| Name | Organization | Phone | Email |
|---|---|---|---|
| Bartels, David | USDA-APHIS-PPQ | 956-580-7301 | david.w.bartels@aphis.usda.gov |
| Bauer, Leah | USDA FS NCRS | 517-355-7740 ext: 34 | lbauer@fs.fed.us |
| Bean, Dick | MDA | 410-841-2743 | beanra@mda.state.md.us |
| Bell, Philip | USDA-APHIS | 919-716-5590 | philip.d.bell@aphis.usda.gov |
| Bullington, Stephen | USDA-APHIS-PPQ | 717-241-2465 | swb@key-net.net |
| Cappaert, David | MSU | 734-635-7750 | cappaert@comcast.net |
| Clark, Erin | USDA-FS | 517-355-7740 | elclark@fs.fed.us |
| Cregg, Bert | MSU | 517-353-9226 | cregg@pilot.msu.edu |
| Duer, Donald | USDA-FHP | 404-347-3541 | dduerr@fs.fed.us |
| Evans, Hugh | CFS | 705-541-5543 | hevans@nrcan.gc.ca |
| Flint, Tim | MDA | 517-335-7390 | flintt@michigan.gov |
| Francese, Joe | APHIS-PPQ | 508-563-9303 ext: 238 | joe.francese@aphis.usda.gov |
| Friedman, Steve | MSU | 517-353-9320 | friedm69@msu.edu |
| Gill, Bruce | CFIA-CPQP | 613-759-1842 | gillbd@inspection.gc.ca |
| Gould, Juli | APHIS | 508-563-9303 ext: 220 | juli.r.gould@aphis.usda.gov |
| Haack, Bob | USDA-FS | 517-355-7740 ext: 36 | rhaack@fs.fed.us |
| Heltzel, Dennis | USDA-APHIS-PPQ | 540-265-6071 | dheltzel@aphis.usda.gov |
| Herms, Dan | Ohio State U | 330-202-3506 | herms.2@osu.edu |
| Hofacker, Tom | USDA-FS | 703-605-5338 | thofacker@fs.fed.us |
| Hunt, Lucia | ODA | 614-271-7764 | luciah@yahoo.com |
| Kaplan, David | APHIS, PPQ, CPHST | 919-513-5090 | david.t.kapha@aphis.usda.gov |
| Kellogg, Craig | USDA-APHIS-PPQ | 810-844-2705 | craig.kellogg@aphis.usda.gov |
| Klein, Michael | USDA-ARS | 330-263-3896 | klein.10@osu.edu |
| Lance, Dave | APHIS, PPQ | 508-563-9303 | david.r.lance@aphis.usda.gov |
| Lewis, Phil | APHIS | 508-563-9303 ext: 215 | phillip.a.lewis@aphis.usda.gov |
| Lyons, Barry | CFS | 705-541-5617 | blyons@nrcan.gc.ca |
| MacFarlane, David | MSU | 517-355-2399 | macfar24@msu.edu |
| Man, Gary | USDA-FS-IP | 202-273-4740 | gman@fs.fed.us |
| Mann, Fred | USDA-APHIS-PPQ | 410-224-3452 | cfredric.mann@aphis.usda.gov |
| Marchant, Ken | CFIA-Ontario | 519-837-9400 ext: 2111 | marchantk@inspection.gc.ca |
| Markham, Christine | USDA-APHIS-PPQ | 919-716-5535 | christine.markham@aphis.usda.gov |
| Mastro, Vic | USDA-APHIS-PPQ | 508-563-9303 ext: 212 | vic.mastro@aphis.usda.gov |
| McCullough, Deb | MSU | 517-355-7445 | mccullod@msu.edu |
| McKay, David | USDA-APHIS-PPQ | 734-942-9005 | david.r.mckay@aphis.usda.gov |
| McKenzie, Nicole | U of Guelph | 519-823-1147 | nmckenzi@uoguelph.ca |
| McPartlan, Deb | USDA-APHIS-PPQ | 301-734-5356 | deborah.l.mcpartlan@usda.gov |
| Merten, Paul | USDA-FHP | 828-257-4845 | pmerten@fs.fed.us |
| Morgan, Ryan | University of Toronto | 519-744-2572 | ryan.morgan@utoronto.ca |
| Oliver, Jason | Tennessee State Univ. | 931-668-3572 | joliver@tnstate.edu |
| Onken, Amy | USDA-FS | 304-285-1565 | aonken@fs.fed.us |
| Otis, Gard | University of Guelph | 519-824-4120 ext: 52478 | gotis@evb.uoguelph.ca |
| Poland, Therese | USDA-FS | 517-355-7740 | tpoland@fs.fed.us |
| Reardon, Rich | USDA-FS-FHTET | 304-285-1566 | rreardon@fs.fed.us |
| Reding, Michael | USDA-ARS | 330-263-3629 | reding.2@osu.edu |
| Roda, Amy | APHIS | 269-683-3563 | amy.l.roda@aphis.usda.gov |
| Roden, Dave | CFS | 705-541-5666 | droden@nrcan.gc.ca |
| Rytlewski, Diane | MSU | 517-432-0480 | rytlews1@msu.edu |
| Schaefer, Paul | USDA, ARS | 302-731-7330 ext: 226 | pschaefer@biir.ars.usda.gov |
| Schneeberger, Noel | USDA-FS | 610-557-4121 | nschneeberger@fs.fed.us |

| Name | Organization | Phone | Email |
|---|---|---|---|
| Simon, Gary | USDA-APHIS-PPQ | 765-446-0267 | gary.w.simon@aphis.usda.gov |
| Smith, Jim | MSU | 517-432-2029 | jimsmith@msu.edu |
| Smith, Sandy | University of Toronto | 416-978-5482 | s.smith.a@utoronto.ca |
| Smitley, Dave | MSU | 517-355-3385 | smitley@msu.edu |
| South, Mike | USDA-APHIS-PPQ | 772-334-4035 | michael.south@aphis.usda.gov |
| Stefan, Mike | USDA-APHIS-PPQ | 301-734-7338 | michael.b.stefan@usda.gov |
| Taylor, Robin | OSU | 330-263-3961 | Rajt@osu.edu |
| Timms, Laura | University of Toronto | 416-531-9205 | laura.timms@utoronto.ca |
| Wallner, Bill | USDA | 203-453-6870 | amandawbw@earthlink.com |
| Waltz, Robert | IN DNR | 317-232-4120 | bwaltz@dnr.state.in.us |
| Wang, Baode | APHIS | 508-563-9303 ext: 224 | baode.wang@aphis.usda.gov |
| Williams, Dave | USDA, APHIS | 508-563-9303 ext: 217 | david.w.williams@aphis.usda.gov |
| Williams, John | PA, FS | 814-765-0810 | johnwill@state.pa.us |
| Writer, Jim | USDA-APHIS-PPQ | 301-734-7121 | james.v.writer@aphis.usda.gov |
| Zablotny, Jim | USDA-APHIS-PPQ | 734-942-8695 | james.e.zablotny@aphis.usda.gov |