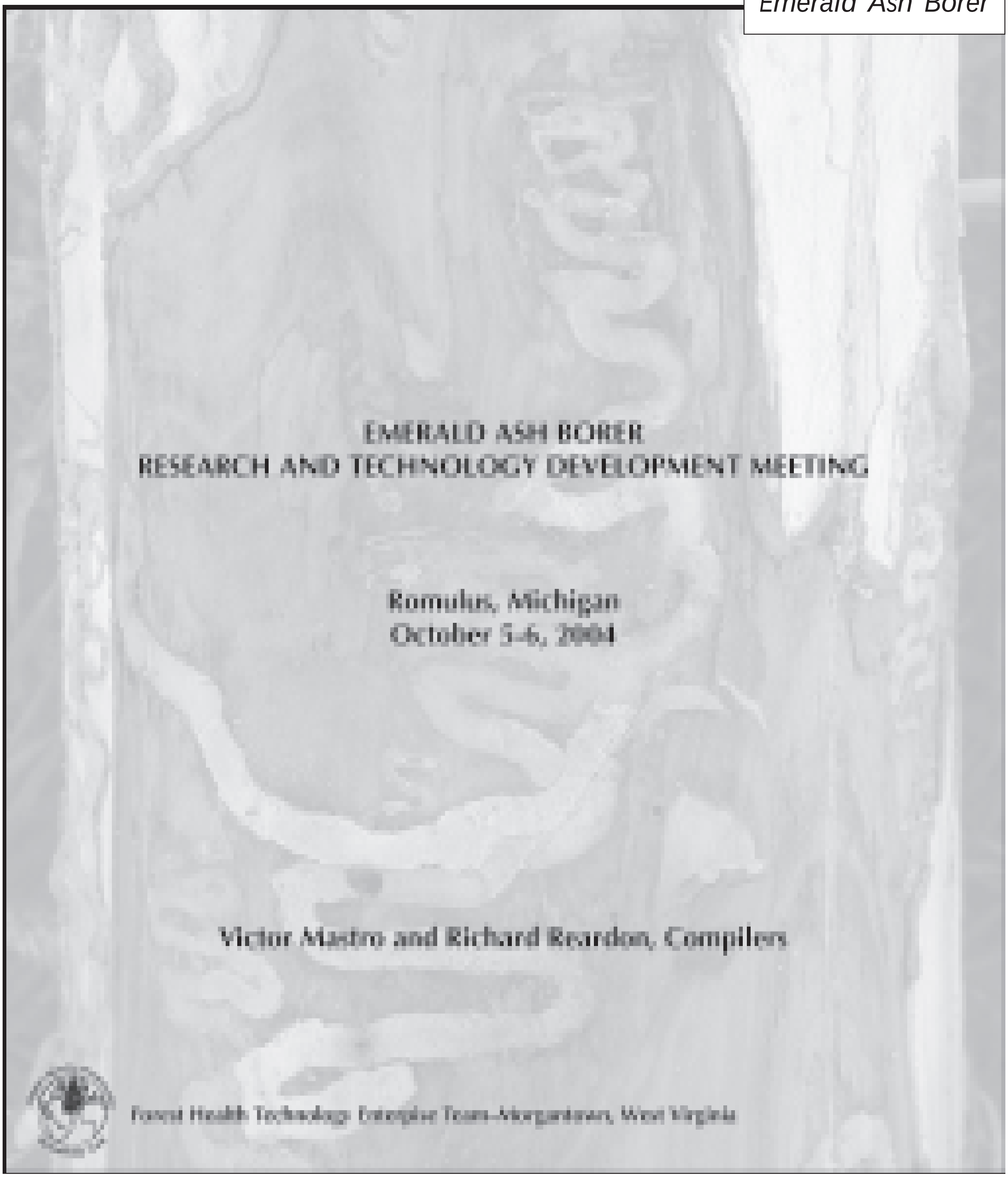
Forest Health Technology
Enterprise Team

TECHNOLOGY
TRANSFER

Emerald Ash Borer



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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

October 5-6, 2004
Crown Plaza
Romulus, Michigan

Compiled by:

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ACKNOWLEDGEMENTS

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FOREWORD

The emerald ash borer, (EAB), *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, Indiana, 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 from EAB 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 U.S. 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 Romulus was the second 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, coordinate existing efforts, 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		
Canadian Program	K. Marchant	
Canadian EAB Science and Survey Committee	H. Frazer	
National EAB Management Plan	P. Bell	
National EAB Survey Plan	D. McPartlan	
Ash Reduction Strategy	N. Schneeberger	
FHTET Assistance with Reduced Ash Zone	J. Adams and F. Sapio	
Michigan Program Update	G. King and T. Flint	
Michigan Statewide EAB Survey	A. Storer	
Ohio Program Update	T. Harrisson	
Indiana Program Update	B. Waltz	
Maryland Program Update	D. Bean	
Virginia Program Update	D. Martin	
Biology and Behavior		Barry Lyons
Phenology	D. Brown-Rytlewski	
EAB Flight Potential	R. Taylor	
mtDNA Sequences and AFL Fingerprints for EAB	A. Bray	
EAB Life Cycle: A Reassessment	D. Cappaert	
EAB Development and Dynamics in Black Ash in an Outlier Site	N. Siegert	
Monitoring and Evaluating the Health of Ash Trees in Michigan's Rural Forests	J. Witter and A. Storer	
Host Range		D. Herms
Interspecific Variation in Ash Resistance/Susceptibility to EAB	D. Herms, P. Bonello, D. Smitley, E. Rebek, and D. Cipollini	
Effects of Community Composition on Forest Susceptibility and Response to EAB	A. Smith, D. Herms, and R. Long	
Host Range Testing–Laboratory Choice Test	R. Haack and T. Petrice	
Host Range for EAB in North America and Elsewhere	A. Agius	
Tree Physiology and Site Factors Affecting Preferences/Suitability	D. McCullough	
Host Range	A. Agius	
Observations on the Within-Tree Distribution of EAB in Southwestern Ontario	S. Smith, P. de Groot, and L. Timms	
Do Purple Traps, Magenta and Green Objects Improve EAB Trapping Efficacy?	G. Otis, M. Youngs, and G. Umphrey	

AGENDA (continued)

Topic	Presenters	Facilitator
Chemical Control		Deb McCullough
Trunk Surface Treatments and 2003 Systemic Studies	R. Haack and T. Petrice	
EAB Survival in Stumps with/without Treatment	R. Haack and T. Petrice	
Surface Treatments and Systemics	D. McCullough and D. Cappaert	
Imidacloprid Residues from Soil-injected Ash Trees	P. Lewis	
BotaniGard® Evaluation	L. Bauer	
Efficacy of Trunk Injection of Imidacloprid and Azadirachtin	N. McKenzie	
Fate and Metabolism of 14C Imidacloprid	B. Cregg and D. Mota-Sanchez	
Survey		David Lance
Remote Sensing	D. Williams	
Remote Sensing	D. Bartels	
Effectiveness of Visual Survey and Enhancements	D. McCullough	
Trapping and Trap Trees	T. Poland, D. McCullough, P. de Groot, D. Cappaert, D. Grant, and L. McDonald	
Cuticular Hydrocarbons and Contact Pheromones	L. Hanks	
Exploring the Use of Spatially Stratified Ash Host Distribution Maps for Improving the Efficiency of Emerald Ash Borer Detectors	D. MacFarlane, B. Rubin, and S. Friedman	
Ecological Spatial Patterns of Ash in Southern Michigan	S. Friedman, D. MacFarlane, and B. Rubin	
Traps Designs and Colors	J. Francese	
Effectiveness of Tree Bands	I. Fraser	
Visual Clues for Beetle Attraction	D. McCullough	
Distribution of Infested Trees in an Outlier Site	L. Bauer, H. Liu, and D. Miller	
Problematic Agrilus Identifications from Trap Tree Buprestid Identifications	J. Zablotny	
Biological Control		Richard Reardon and Juli Gould
Exploration in Korea for Natural Enemies	D. Williams	
Woodpecker Predation	D. McCullough	
Insect Natural Enemies in SE Michigan and China	L. Bauer, H. Liu, and D. Miller	
Exploration in China and Rearing Development	J. Gould and J. Tanner	
Taxonomy of Parasites	J. Strazanac	
Foreign Exploration for EAB Natural Enemies	P. Schaefer	
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EMERALD ASH BORER: PROGRAM REVIEW

MANAGING THE EMERALD ASH BORER IN CANADA

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ABSTRACT

The emerald ash borer (EAB) is believed responsible for the death of an estimated 100,000 ash trees in Ontario in 2004 with significant mortality being observed in Essex County this summer. In all, over a billion ash trees are at risk in Ontario alone with an estimated additional billion ash trees threatened in the rest of Canada.

In January of 2004, the Canadian Food Inspection Agency (CFIA) established a firebreak or ash-free zone (AFZ) in advance of the known leading edge of the infestation. In excess of 100,000 trees were removed from a 30x10 km. zone running from Lake Erie to Lake St. Clair in an effort to provide a barrier to the natural spread of EAB to more forested areas to the east of the zone.

Throughout 2004, detection surveys have continued at high risk areas in southern Ontario and other locations across the province. Unfortunately, EAB has been detected in significant numbers beyond the AFZ in the vicinity of the former City of Chatham. No other populations have been detected, and infested trees in Chatham are being removed.

In addition to surveillance, the CFIA has also placed considerable emphasis on enforcing regulations on the movement of firewood and other forest products and on communication of the EAB hazard.

The CFIA is currently evaluating survey data and developing management options for review by its Science and Survey Committee and senior management and will make a decision on next steps early this fall.

National Emerald Ash Borer Management Plan

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ABSTRACT

The USDA's Animal and Plant Health Inspection Service (APHIS) continues it's partnership with state cooperators from Departments of Agriculture in Michigan, Ohio, Virginia, and Maryland and the Department of Natural Resources in Indiana, to carry out program delivery activities designed to detect, contain, and eradicate emerald ash borer (EAB). In addition, APHIS collaborates with USDA Forest Service in tree restoration of eradication sites following tree removals, and the development of a Reduced Ash Zone.

The EAB program currently employs 21 APHIS employees to carry out regulatory, environmental monitoring, administrative, and methods development components of the program. Total staff for all program activities, including state cooperator participation, totals nearly 180 positions.

The EAB program relies heavily on the Science Advisory Panel (SAP) for scientific recommendations to use in developing program strategies and establishing protocols for program delivery operations. APHIS formed the Science Advisory Panel in Oct. of 2002 to provide science-based guidance for program implementation. This group of forest entomologist was selected by the SAP Chairman Dr. Vic Mastro and National Program Manager Mike Stefan to review data regarding EAB biology and forest pest behavior to provide guidance and program direction. To further develop and refine SAP recommendations for program delivery, APHIS established an EAB Management Team to write programmatic protocols and implement various components procedures into program initiatives.

EAB is a costly pest. The ash nursery stock industry has collapsed in Ohio, Indiana, and Michigan as a result of infestation, and the transportation of firewood is severely restricted in all three states. Local governments in Michigan are saddled with enormous cleanup costs associated with dead and dying trees.

Since October of 2002, APHIS has provided funding for EAB program delivery on a year-by-year basis:

2002	$ 900,000
2003	$15,200,000
2004	$43,000,000

APHIS plans to continue established program strategies by utilizing current program direction outlined in the EAB National Management Plan.

FHTET Assistance with the Reduced Ash Zone

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The Forest Health Technology Enterprise Team (FHTET), in cooperation with the Northeast Area, is providing technology assistance to the emerald ash borer (EAB) eradication effort. The EAB management effort is based upon a zone strategy in which different activities target different population levels of EAB. One such zone, the Reduced Ash Zone (RAZ), coupled with other regulatory activities, is designed to reduce the natural spread of EAB.

FHTET was asked to delineate the RAZ based upon ash density and known EAB infestations. Tabular county-level data from the USFS Forest Inventory and Analysis (FIA) was used in proof of concept, documenting the wide range of ash density, and assessing the feasibilityof establishing an RAZ. Urban areas or areas classed as "non-forest" are currently not well-represented in FIA, creating a need to capture additional information on ash density where FIA plots do not exist.

A more spatially explicit approach is warranted as ash density is a critical factor for the location and maintenance of a RAZ. In order to create this critical management zone, natural resources managers need to understand various factors describing ash populations. Critical questions regarding implementation of a RAZ include: where are the trees? how many are there? how big are they? and how difficult will they be to harvest?

Geographic information system (GIS) analysis of remote sensing data was utilized initially to define the location of a potential RAZ. These results were compared with those of colleagues in other agencies, and a potential RAZ corridor was negotiated. In order to locate the RAZ and determine the feasibility of implementing a zone of reduced ash, FHTET collected color-infrared (CIR) aerial photography for Ohio, Indiana, and Michigan covering 5,000 photo points and producing 2,500 images. Digital ortho-quads (DOQs) provided by the State of Michigan and State of Ohio were also used in this plot characterization phase.

The survey used available aerial photography to inventory land use patterns across the potential RAZ corridor. FHTET staff conducted the photo interpretation producing a land use stratification across the entire RAZ corridor. That land use stratification provided the basis for allocating ground plots more efficiently than a simple random sample. The survey design for data collection was developed for field crews and implemented through a custom data entry and GIS application. Field data from over 600 plots were collected by Emerald Ash Borer Response Program Staff representing four cooperating agencies. The final data set will be analyzed and results summarized for an EAB science panel meeting in mid-December 2004. FHTET will continue to provide assistance throughout the data analysis phase, generating ash density output reports and maps as the feasibility of implementing a RAZ is investigated.

The field data sheet layout is provided below to show the variables collected.

Reduced Ash Zone Survey

Survey Plot ID 20002 | State Michigan | County Ionia | Political Township Sebewa Twp | Town & Range: Township 5 North Range 6 West

Aerial Photo Information

Roll Num. 3 | Block Code | Photo ID:

Line Number 9 | Frame Number 25

Sample Point Information

Photo sample point: B 09-025 | Sample Area 2 | Photo or DOQ 09-025 | Land Use Strata 2 P P

Geographic Coordinates (from GPS)

N. Latitude ○ | W. Longitude ○ | Spheroid

Status | Date (of visit) | Time (of visit) | Info Recorded by: | Crew Leader | Reason Not Visited

General Site Information:

Driving Directions

Tree Information:
# of Non-Ash Trees
Broadleaf: ○
Conifer: ○

Tree Information:
Number of Ash Trees by Diameter

1.0" to 1.99"	○	16.0" to 17.99"	○
2.0" to 3.99"	○	18.0" to	○
4.0" to 5.99"	○	20.0" to 21.99"	○
6.0" to 7.99"	○	22.0" to 23.9"	○
8.0" to 9.99"	○	24.0" to 25.9"	○
10.0" to 11.9"	○	26.0" to 27.9"	○
12.0" to 13.9"	○	28.0" to 29.9"	○

Site Condition

Ash Reproduction, less than 1" in 50 ft radius
None
Few 1 - 15
Many 16-30
Doghair 30+

Accessibility for Trt.

Comments:

Michigan's Emerald Ash Borer Response Project

Tim Flint

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MDA STATUS REPORT

In 2004, the Michigan Department of Agriculture (MDA) and its task force partners continue to adapt and respond to the impact of the emerald ash borer (EAB) in Michigan. Objectives for 2004 include containment and restoration activities in the core infestation area, a statewide EAB survey, removal of isolated infestations of EAB outside the EAB quarantine, and a quarantine enforcement element supported by a strong communication and regulatory plan.

Southeast Michigan core area activities now include maintaining seven marshalling yards for no-cost disposal of ash materials. This process has generated over 170,000 tons of fuel wood for green power in addition to the now operational wood utilization activities that are creating lumber, railroad ties, tool handles, etc. EAB marshalling yards accomplish two program objectives: mitigation of EAB populations and a reduction of the economic impact of EAB in affected communities. Restoration of tree canopy is a priority in this area.

In survey activities designed to establish the distribution of EAB in Michigan, a statewide system of 10,000 "trap trees" has been installed to detect the presence of EAB outside known areas of infestation. The trap tree distribution has the highest densities in Lower Michigan, ranging from 36 traps per township down to a density in some UP townships of 1 or 2 per township. Trap tree recovery is ongoing, the results of which will be used to formulate response strategies in support of program goals. In related actions with partner agencies, the Michagan Department of Natural Resources has trap trees in place at strategic locations such as campgrounds that may have been destinations for collection of ash firewood and similar activities. All data will be shared and evaluated for development of response plans.

Where EAB infestation is identified in isolated sites outside the generally infested area, MDA and response partners will develop and implement a response strategy designed to eliminate EAB from the sites and suppress EAB at sites where the objective is to reduce the pressure to spread. Once trap tree results are compiled, response strategies will begin.

MDA continues to work with program partners to evaluate the ability to define an area of reduced ash presence, a "Reduced Ash Zone," in support of the science panel objective of defining an area where the natural spread of EAB can be interrupted by survey and response. Additional activities may include development of voluntary mechanisms to reduce ash by timber sale and the sale of ash wood fiber in the wood utilization markets. This zone must be defined after the distribution of EAB is mapped following the recovery of the trap trees in Michigan and neighboring states.

MICHIGAN EMERALD ASH BORER DETECTION SURVEY

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ABSTRACT

Emerald ash borer (EAB), *Agrilus planipennis* (Coleoptera: Buprestidae), was first identified in southeast Michigan in 2002, where it has killed millions of ash trees (*Fraxinus* spp.). In the summer of 2004, trap trees were established at over 100 sites throughout Michigan in an effort to detect sub-damage threshold populations of this exotic species. This study combined the most effective known method for detecting this insect with the locations where emerald ash borer is most likely to have been introduced through the movement of firewood.

Field sites were located in proximity to campgrounds at Michigan State Parks, Michigan State Forest Campgrounds, County Parks, and USDA Forest Service Campgrounds. The Michigan State Parks Visitor Database, which tracks visitors to state parks by zipcode, was used to select campgrounds with the highest cumulative number of visitor days by visitors from EAB-infested zipcodes between 2001 and 2003. This information, in combination with the distribution of ash throughout Michigan, was used to select state park and state forest campground high-risk EAB survey sites. USDA Forest Service Campgrounds were selected based on the local presence of ash resources. Sites were also established in parks within the core EAB-infested area.

Trap trees were girdled by removing the bark from a portion of the stem. Sticky traps were placed on trees and monitored every two weeks during the flight period of the beetle. Additional data were collected by inspection of firewood piles and declining ash trees near the survey sites.

During the survey, no EAB were detected on trap trees in areas outside the core infested area. During inspections of over 2,000 firewood piles, EAB was detected in three new locations: Merrill Lake County Park in Mecosta County, Rifle River State Recreation Area in Ogemaw County, and North Higgins Lake State Park in Roscommon County. At infested sites in southeastern Michigan, girdled trap trees caught more beetles than non-girdled trees. Some trees at infested sites were more attractive to EAB than others throughout the season as

trap catches in the first two week period were positively correlated with total catch in the remainder of the season. This relationship was evident for both girdled and non-girdled trees.

At the end of the survey, a subsample of trap trees were cut and had portions of bark peeled from them to survey for EAB larvae. Selections of trees for cutting were based on a decision tree that considered tree hazard, number of trees cut per site, and the wishes of the local land manager. Remaining standing trees will be a resource for further EAB detection work. Information about this project can be found at www.emeraldashborer.org.

Ohio Emerald Ash Borer Update

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ABSTRACT

This presentation describes the current emerald ash borer (EAB) situation in Ohio. There have been approximately 13 infestations identified in Ohio. Several are located in Toledo and the southwest portion of Lucas County, and one infestation is located east of the Maumee River in Lucas County. Tree removals are currently underway at one infestation in southern Wood County; another eradication area is the result of a Michigan infestation just over the border from central Williams County. Recently, all of Lucas County east of the Maumee River and eastern portions of Fulton and Henry Counties were added as regulated areas under the Ohio EAB Quarantine. The current plan is to pursue eradication of all infestations.

There are currently 22 fulltime EAB staff people. Regulatory activities include contacting firewood dealers, landscapers, nurseries, trees services, and nursery stock dealers throughout northwest Ohio and in quarantined areas. A Labor Day firewood blitz was recently held along the Michigan border. Approximately 850 trap trees were established throughout the proposed Reduced Ash Zone and areas surrounding previous eradications resulting in a few new EAB finds, and all traps should be down by the end of November.

Maryland Emerald Ash Borer Update

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ABSTRACT

The following activities have been implemented since completing the ash removal from the ½-mile buffer area around the affected nursery in Brandywine, Maryland (Prince George's County) on April 7, 2004:

April 9, 2004 – Six stumps in the buffer area were set up as sentinel trap trees (wrapped in purple tinted Saran Wrap and coated in Tangle Trap). Checked 13 times: no EAB detected. 150 2" dbh, bare root, dormant green ash were ordered from Bailey's Nurseries; the trees arrived on May 17, 2004.

May 18-20, 2004 – Sixty ash were planted at Brandywine, 20 at Fort Washington (Prince Georges County) and 20, at the Odenton (Anne Arundel County) sites. The remainder of trees (50) were used by Forest Pest Management as trap logs. All planted ash sentinel trees were wrapped as above on May 20.

May 25, 2004 – An EAB emergence hole was detected at the Fort Washington site. Ten ash trees were removed and stripped from the parking lot landscaping, revealing only one beetle was present. These trees had been reported as planted in 2002. Other trees had been previously removed when they were identified by landscaper as ash trees and replaced in 2003. A stripped trunk was set up as trap tree experiment.

May 26, 2004 - An EAB emergence hole was detected at the Odenton site. The tree with the emergence hole was stripped, and evidence of only a single beetle was found. Approximately 80 ash trees planted in 2002 remain at the site and have been examined seven times for emergence holes. No additional emergence holes have been detected.

Thirty-eight ash trees, either missed in the original destruction at the nursery or brought in afterward, were seized and destroyed June 28–July 8, 2004. All trees were stripped and no evidence of EAB found.

Sentinel trees were regularly serviced between 10 and 12 times. The Saran Wrap was replaced every other service period. Gaye Williams (MDA Entomologist) examined the removed wraps and Buprestids collected and stored for future identification. No EAB detected.

Mike Galvin, Maryland DNR Forest Service, Supervisor, Urban and Community Forestry, mailed vouchers the first week of August to the affected landowners for trees removed

from their properties. The replacement trees were supplied by Shemin's Nursery as part of the Tree-mendous program.

Qualifying: 155 trees on 55 sites owned by 26 property owners in four counties

Redeemed: 99 trees (63 percent) on 35 sites (64 percent) by 11 property owners in three counties

Preference for shade trees (80 percent) to ornamental (20 percent): 32 red maple, 47 pin oak, 8 dogwood, and 12 redbud

The burn area was seeded during the second week of April and a good cover of grass presently exists. Small ash pieces buried in the process are sending up shoots. Trees were felled across the entrance to prevent access per the directive of the property overseers.

A follow up walk through of the ½-mile buffer detected a couple of small trees that were missed. These will be felled and stripped. The Garlon 3 stump treatment was very successful: the stumps show no signs of sprouting.

In 2005, an intensive survey effort will be conducted for EAB around the state.

EMERALD ASH BORER: BIOLOGY AND BEHAVIOR

Tracking the Emergence of Emerald Ash Borer Adults

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ABSTRACT

Emerald ash borer (*Agrilus planipennis)* is a serious exotic pest of ash trees. Determining when emerald ash borer (EAB) adults first emerge, reach their emergence peak, and reach the end of emergence has important implications for its management. Determining when adult emergence begins and ends is critical for cutting infested ash trees and deciding when transport of the wood can safely be accomplished. It is also important to predict when adult emergence will begin to set monitoring traps out on a timely basis. Predicting when peak emergence will occur may be critical for timing certain pesticide applications. In this study, weekly observations of new emergence holes were recorded to track emergence from the trunk by direction (NW, NE, SW, and SE), track key stages of emergence, record corresponding degree day accumulations, and look at concurrent bloom stages of common landscape plants to develop easily observable benchmarks for key periods of adult EAB activity.

In 2003, adult EAB emergence was tracked weekly at a single site in Ann Arbor, Michigan, from early May until the end of August (sampling discontinued two weeks after the last detected adult emergence). Eleven trees were planted in parking lots and mulched with stone; nine were planted in lawns. In 2004, adult EAB emergence was tracked weekly at locations in Troy and Novi, Michigan, from early May until late September (sampling discontinued two weeks after the last detected adult emergence). All trees monitored in 2004 were planted in grassed parkways between the sidewalk and road. Degree-day accumulations and bloom stage of common landscape plants were recorded both years at the adult monitoring sites along with three other locations (gardens with large collections of ornamental plant materials) in Flint, East Lansing, and Novi, Michigan.

Adult emergence was monitored by counting and marking all emergence holes found within two-foot sections of trunk (4-6 ft. and 10-12 ft) on each of twenty ash trees of approximately the same age at each location. Dataloggers (Watchdog model 400, Spectrum Technologies, Plainfield, Illinois) were used to record hourly temperature readings. The modified sine-

wave method (Baskerville-Emmons) was used to calculate degree-days, using a base temperature of 50º F.

The 2003 data were analyzed as a split-split plot; for each tree a whole plot and high/low locations on the trunk and direction of emergence holes (NE, NW, SE, or SW) as within tree measurements. There were significant differences in emergence by direction on the trunk. Greater emergence of adults occurred on the sunniest exposures of the trees (SW and SE), and earlier emergence on trees mulched with stone and planted in parking lots. There was greater emergence of EAB adults high on the trunk than low on the trunk for trees planted in grass. Adult emergence began sometime between June 5-13, 2003, within the degree-day range of 471-584 GDD base 50ºF; peak was between June 13-19, 2003 (584-705 GDD base 50ºF); date of last recorded emergence was August 16, 2003 (2083 GDD base 50ºF). Adult emergence continued for a ten-week period.

The data from 2004 have not yet been analyzed, but it appears that direction of emergence may not be as significant this year. First emergence at the Novi site began sometime between May 11 and May 18, 2004 (348- 463 GDD base 50ºF), and emergence peaked between June 1- June 8, 2004 (572-759 GDD base 50ºF). A second emergence period began sometime between August 17-24 and continued until sometime between September 2-7, 2004 (2089-2230 GDD base 50ºF). Emergence from the SW and SE quadrants occurred several weeks earlier than emergence from the NW and NE quadrants. At the Troy site, first emergence occurred sometime between May 25-June1, 2004 (444-518 GDD base 50ºF), and peak emergence between June 22-29 (894-1027 GDD base 50ºF). A second emergence period began sometime between August 17-24 and continued until sometime between September 2-7, 2004 (1948-2052 GDD base 50ºF). Adult emergence continued for a seventeen-week period. The significance of the second emergence period is not yet known.

It appears that black locust (*Robinia pseudoacacia*) from early to late bloom and doublefile viburnum (*Viburnum plicatum tomentosum*) from full to late bloom may be good indicators for first emergence of adults. Japanese tree lilac (*Syringa reticulata*) from first to full bloom may be a good indicator for peak emergence, and purple coneflower (*Echinacea purpurea*) at late bloom and Joe-Pye weed (*Eupatorium purpureum*) at full to late bloom may be good indicators for the end of adult emergence. Plans are to continue monitoring emergence of adults, degree day accumulations and bloom times of selected landscape plants in 2005.

Emerald Ash Borer Flight Potential

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ABSTRACT

The emerald ash borer (EAB), *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), is an invasive pest of ash trees (*Fraxinus spp*.) that is rapidly spreading from the probable introduction site in Detroit, Michigan. The rapid spread to areas outside Michigan is undoubtedly due to phoretic transport on nursery stock, logs, and firewood. However, not all the range expansion can be attributed to human agency. Despite attempts to contain the core infestation to the counties surrounding Detroit and Essex County, Ontario, EAB range has continued to expand. This is due in part to the natural dispersal of EAB. Failure to understand the natural dispersal will impede attempts contain and control EAB; knowledge of flight behavior and physiology is needed to estimate dispersal capabilities in order to develop effective containment strategies.

A cooperative research venture between The Ohio State University and USDA-Forest Service is using computer-monitored flight mills with tethered EAB adults to measure flight speed, duration, and periodicity. Preliminary results from 28 adults, flying without rest, food, or water, showed that about half of the tethered beetles flew >50 m, while one 3-day old male flew a total of 5.2 km in 40 hrs. Subsequent data have confirmed the maximum flight speed as 1.5 m/sec (3.5 mph) which occurs in bouts of about 1 min each. The individual that flew the furthest in 24 hrs started with 70 sec flight bouts followed by an idle periods of about 130 sec. After about 2 hr, the idle time increased, rising to about 20 min at 24 hr. Although the detailed bout patterns differ between individuals, this overall pattern appears to be the norm. Bigger differences are observed in the length of time spent flying. In particular, females flew twice as far as males in 24 hr ($P < 0.002$) and mated females flew twice as far as unmated females ($P < 0.0001$). The average distance flown in 24 hrs by mated females was 1.7 km. The frequency

distribution of distance flown by all females in 24 hrs is skewed to the right (mode = 800 m, median = 1 km, mean = 1.7 km, 20 percent flew >2km, 1 percent flew > 4km).

The discovery that mated females fly longer, farther, and faster than either males or unmated females is rather alarming as it suggests females are programmed to make a dispersal flight. The absence of a correlation ($R^2 = 0.007$) between distance flown and size (mg) of mated females suggests there are no other distinct classes of migrants.

A simple random walk model suggests that ~20 percent of mated females are displaced >250 m while flying 2 km; ~1 percent are displaced ~500m while flying 4 km. The random walk assumption is probably optimistic; the flight is probably less random, which means that these are underestimates of the actual displacement of gravid females in their dispersal flight. In order to determine how significant this is for control and containment efforts, we need to know how directional the flights actually are and how receptive gravid females are to cues from ash trees for stopping their dispersal flight to settle.

Genetic Analysis of Emerald Ash Borer to Determine the Point of Origin of Michigan Infestations

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ABSTRACT

Emerald ash borer (EAB) was first detected in Michigan and Canada in 2002. Efforts to eradicate this destructive pest by federal and state regulatory agencies continue. 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. Genetic techniques, such as mtDNA gene sequencing and amplified fragment length polymorphisms (AFLP) will help determine the geographic origin of EAB in its native range throughout eastern Asia.

In an initial analysis, we collected EAB individuals from several localities in Michigan and three populations in China. Analysis of mtDNA cytochrome oxidase subunit I (COI) sequences from 20 individuals from Michigan, three individuals from Dagong (Tianjin City), one individual from Hangu (Tianjin City), and three individuals from Harbin (Heilongjiang Province) indicated that all COI sequences (~500 nucleotides) were identical. However, differences between individuals were observed using AFLPs. AFLP analysis using three primer pairs yielded fingerprints from EAB individuals from Michigan (19), Dagong (2) and Hangu (1) (Tianjin City), and Harbin (4) (Heilongjiang Province). Eighty-two scoreable bands, coded as binary characters (presence/absence), were analyzed in a neighbor-joining (NJ) analysis. The NJ tree showed that individuals from MI cluster with individuals from Dagong and Hangu (Tianjin City), while EAB individuals from Harbin (Heilongjiang Province) fell into a separate, more distantly related group. Therefore, with this limited sample, AFLP appears to reveal population-level differences between EAB populations, and the Michigan populations appear more closely related to EAB from Tianjin Province than to EAB from Heilongjiang Province. Nonetheless, more thorough sampling in China is necessary to better characterize the relationships of the Michigan and Chinese EAB populations. Due to the rarity of EAB in Korea, Japan, Mongolia, Taiwan, and Russia, no samples have yet been found for genetics. We now

plan more intensive sampling of EAB populations within Michigan to provide information on invasion genetics and possible age of infestation. We also plan more extensive sampling in North America including EAB from Ohio, Maryland, Virginia, Indiana, and Ontario, Canada, to determine if there was a single or multiple introductions of EAB into North America. Overall, mtDNA sequences appear to be a good positive control that ensures all individuals in our analyses are indeed EAB. AFLP fingerprints detected differences between EAB populations, important when locating potential biological control agents.

Emerald Ash Borer Life Cycle: A Reassessment

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ABSTRACT

To establish the life cycle of EAB was one of the first objectives of EAB research. Our expectation was that *Agrilus planipennis* phenology would coincide roughly with that of well-characterized *Agrilus* species such as *A. anxius* and *A. bilineatus*: 1) mid-summer adult flight and oviposition; 2) complete four stages of larval development by fall; 3) non-feeding prepupal stage overwinter; and 4) pupation in late spring. Evidence in support of this assumption includes observations demonstrating synchronous pupation and adult flight and summer/fall dissection series showing steady progression of larval size. However, several anomalies raised questions about the universality of a synchronous, one-year cycle. At some locations, a majority of larvae failed to complete feeding in the fall. Most conspicuously, winter/spring dissections of very lightly infested trees at outlier sites revealed mostly 2nd and 3rd stage larvae. A dissection series in spring 2004 confirmed that small winter/spring larvae did not complete development before mid-summer, and failed to form pupae during the annual "window" for that life stage.

Several lines of evidence now demonstrate that some fraction of EAB requires two years for development:

1. In a series of dissections of lightly-to-moderately infested trees during spring/summer 2004, we found that 2nd and 3rd stage larvae (oviposited the previous summer) present in April did not complete larval development before the summer pupation window. Prepupae formed by these larvae in late summer had not resulted in adult emergence by October.
2. A 2004 experiment compared larval density between unsprayed trees or trees treated with a Tempo cover spray. Despite bioassay evidence indicating excellent coverage and persistence of toxin, there was no significant effect of the treatment. Subsequent re-examination revealed that the poor performance of Tempo was attributable to protected prepupae present in the trees before the May treatments began.
3. Examination of larval galleries clearly demonstrates two-year development. In the Tempo study and other dissections conducted in fall of 2004, galleries of mature larvae were of

two types: a continuous track contained entirely within 2004 growth tissue (1- or 2-year larvae), or a two-stage track beginning in (now) dead wood overgrown by 2003 tissue and concluding in a final tunnel through 2004 growth (2-year larvae).

We are not yet clear on the mechanisms that determine the proportions of one and two-year EAB. Clearly, the seasonal temperature profile may be important: we know that many insects including other *Agrilus* species have prolonged development where temperatures are lower. However, our data suggest host condition may be key: proportions of two-year larvae tend to be higher in lightly infested trees.

The occurrence of two-year larvae has many implications for research, management, and the containment/eradication effort. The likelihood that trees have some degree of resistance (inhibiting larval development) suggests that there may be opportunities for enhancing resistance via breeding or chemical treatment. The presence of mature larvae in the spring/summer creates a new (and more difficult) target for pesticide applications. Two-year larvae at outlier sites may mean a delay in detection of initial outbreak or resurgence from outliers; on the plus side, dissemination from an outlier will be slowed. Further research will focus on determining the prevalence and underlying mechanism of the two-year phenomenon.

Reconstructing the Temporal and Spatial Dynamics of Emerald Ash Borer in Black Ash: A Case Study of an Outlier Site in Roscommon County, Michigan

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ABSTRACT

The temporal and spatial dynamics of emerald ash borer (EAB), *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), in an outlier site in Roscommon County, Michigan, were reconstructed using dendrochronological analyses. The site was characterized by pockets of black ash, *Fraxinus nigra* Marsh., located in swampy areas surrounded by ash-free, higher terrain consisting mainly of oaks (*Quercus* spp.) and pines (*Pinus* spp.). Ash eradication operations were underway during the summer of 2004 within an elongated eradication zone delimited by Michigan Department of Agriculture personnel. Within the eradication zone were two main swampy areas that were separated by a distance of more than a half mile. Thirty black ash trees, ranging in vitality from '*apparently healthy*' to '*declining*' (i.e., reduced leaf size and canopy dieback) to '*dead*', in the two main swampy areas were selected, partially debarked, and cored in late June to early July 2004. Signs of EAB presence were evident on all dead and declining ash trees sampled. Increment cores were prepared using standard dendrochronological techniques and crossdated using skeleton-plots and verified using COFECHA software. Crossdating analyses indicated that trees began to die in 2001 in one of the swampy areas. Preliminary results suggest that three trees in close proximity were initially infested with EAB and the infestation radiated out from that point in subsequent years. In the other swampy area,

EAB infestations did not begin causing tree mortality until 2003. Phenological development of EAB in the lower portions of the trees was considerably less advanced than in the upper portions of the trees. Dendrochronological examination of wood growth during gallery formation indicated that, under certain conditions, successful EAB development from egg to adult can be extended over multiple years (e.g., early instars present in 2002 and adult emergence in 2004). Additional dendrochronological analyses are in progress to determine when EAB initially infested the sample trees. Implications of this research were discussed in relation to future management guidelines.

Monitoring Michigan's Ash in Rural Forests and Recreational Areas

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ABSTRACT

Two ash monitoring systems are being established throughout rural forests and recreational areas of Michigan to address three objectives:

1. detect presence of emerald ash borer (EAB),
2. monitor current conditions and changes over time in rural forests and recreational sites throughout Michigan with and without EAB, and
3. determine other factors responsible for variations in ash health over the state.

The Rural Ash Monitoring Plot System (RAMPS) was initiated during Summer 2004 with the establishment of 160 plots along five gradients running through the state of Michigan. As of October 2004, we have established approximately 65 percent of the plots along the Upper Peninsula (U.P.) gradient, 50 percent of the plots along the southern Lower Peninsula (L.P.) gradient, and portions of both the northern and eastern L.P. gradients. A western L.P. gradient will also be established. To date, approximately 30 percent of the plots fall within the quarantine area and contain EAB. We expect to establish 240 additional plots by the end of Summer 2005, for a total of 400 rural forest plots in this system. At these plots, variables measured include stand age, soil texture, live and dead basal area by species, crown variables (live crown ratio, light exposure, transparency, density, and dieback), tree vigor, presence of EAB, and other types of tree damage. During 2004 in the L.P., the percent of dead ash varied from 0–100 percent by plot. When plot data were pooled by county, examples of the average percent of dead ash in 2004 are: Arenac County—1 percent, Midland County—3 percent, Gladwin County—5 percent, Lapeer County—6 percent, Cheboygan County—7 percent, Oakland County—15 percent, Washtenaw County—31 percent, and Wayne County—61 percent.

The second ash monitoring system examines ash at over 250 sites in Lower Michigan that are in or near recreational areas (parks, picnic areas, rest areas, boat landings, campsites,

etc.). A variety of tree health variables are measured at these sites, along with recording presence of EAB and other types of tree damage.

The major results from Summer 2003 are:

1. green ash and white ash were by far the most common ash species at our sites,
2. the origin of ash (natural, planted, or both) differed by site, with 44 percent of the sites containing all natural ash or almost all natural ash,
3. size of ash trees varied greatly by site, but 55 percent of all sites had mean diameters above 25 cm,
4. 11 percent of the sites visited had detectable levels of EAB,
5. mean percent ash dieback by site ranged from 1 – 30 percent, both for sites with and without EAB,
6. mean tree vigor was generally high, with only 5 percent of the sites having ratings that indicated very poor vigor, and
7. the potential EAB risk of sites may vary considerably due to presence or absence of ash and percent of ash dieback.

Data for recreational plots from Summer 2004 are currently being analyzed.

EMERALD ASH BORER: HOST RANGE

Does Forest Community Structure Influence Susceptibility and Response to Emerald Ash Borer?

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ABSTRACT

The ability of invasive species to invade native landscapes may be influenced by community composition. Emerald ash borer (*Agrilus planipennis*) has already caused considerable mortality of ash in southeast Michigan forests and is now invading forests in northwest Ohio. However, the ecological impact of this mortality is unknown. The objectives of this research are to 1) characterize effects of community composition and structure on forest susceptibility to emerald ash borer invasion, and 2) quantify community response to ash (*Fraxinus* spp.) decline and death. Invaded stands are being characterized by quantifying density and basal area of ash and other woody species, percent canopy cover, and soil moisture along a gradient from dry upland sites to low wetland sites. Degree of emerald ash borer colonization is being quantified by estimating ash canopy dieback and counting D-shaped emergence holes and woodpecker attacks on the boles of infested trees. Community response to ash decline and death is focused on species replacing ash in the canopy, sapling release, and seedling establishment, as well as exploitation of canopy gaps by invasive plants. Plots are being mapped via GIS to provide opportunities for study of long-term effects of emerald ash borer on successional trajectories. This study will increase understanding of impacts of invasive insects on forested ecosystems, and enhance implementation of emerald ash borer containment and eradication efforts.

HOST RANGE OF EMERALD ASH BORER

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ABSTRACT

The emerald ash borer (EAB), *Agrilus planipennis* Fairmaire, is native to China, Korea, Japan, Mongolia, Russia, and Taiwan. Established populations of EAB were first discovered in Michigan and Ontario in 2002, and since then additional infestations have been found in Indiana, Ohio, Maryland, and Virginia. As of October 2004, EAB has only been found to breed in ash (*Fraxinus*) trees in North America. Ash is the only host listed for EAB in China. Ash is also listed as a host in Japan, as well as elm (*Ulmus*), walnut (*Juglans*) and wingnut (*Pterocarya*). In Korea, elm is listed as a host of EAB.

In 2003 and 2004, 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 48-hour no-choice tests in 2003, 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 olive family, such as forsythia, fringe tree, lilac, privet, and swamp privet. There was almost no feeding on elm, hackberry, hickory, and walnut. In two-choice tests, using green ash as the "standard," EAB fed readily on the other ash species tested as well as the Oleaceae shrub species. There was significantly less feeding on the Juglandaceae and Ulmaceae species tested when in the presence of green ash.

In 2004, we conducted a series of multiple choice tests. In the first test, we used seven species of ash, including five native and two Asian species. Overall, EAB fed most on green and white ash and least on blue ash. Feeding on the two Asian ash species (*F. chinensis* subsp. *rhychophylla* and *F. mandshurica*) was intermediate. In the second test, we allowed EAB to choose among green ash and four shrub species in the Oleaceae. EAB preferred green ash over any of the four shrubs tested, including forsythia, fringetree, lilac, and privet. Of the four shrubs, forsythia was the least preferred. In the third test, we used green ash and four non-ash tree species. Overall, EAB fed almost exclusively on ash while in the presence of hackberry, slippery elm, shagbark hickory, and black walnut.

Host Range and Preference of the Emerald Ash Borer in North America: Preliminary Results

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ABSTRACT

Previous literature on the emerald ash borer (EAB) indicated that, in its native range, this beetle was recovered from several Asian species including *Ulmus* sp., *Juglans* sp., and *Pterocarya* sp., in addition to Asian ash tree (*Fraxinus* sp.). If EAB can complete development on alternate hosts, impacts of this nonindigenous pest would in North America would increase dramatically.

Our objectives are to 1) determine if EAB can oviposit and develop on potential alternate host species and 2) evaluate preference among four North American species of ash. In 2003 and 2004, we monitored adult landing rates and evaluated early instar development on logs of ash and potential alternate host species placed out in the field and used in no-choice laboratory bioassays. We studied four ash species common in Michigan: green ash (*F. pennsylvanica)*, white ash (*F. americana)*, black ash (*F. nigra)*, and blue ash (*F. quadrangulata)*. Potential alternate host species that we evaluated included American elm (*U. americana)*, black walnut (*J. nigra)*, hackberry *(Celtis occidentalis)*, Japanese tree lilac *(Syringa reticulata)*, hickory *(Carya sp.)*, and privet *(Ligustrum sp.*). We also assessed host preference with two-choice leaf-feeding bioassays in the laboratory and at field sites with multiple species of ash growing in close proximity.

In the no-choice laboratory bioassay, female EAB laid eggs on all species. There was larval feeding under the bark on all species except hickory. Larval feeding and development on the ash species appeared normal, while development on the non-ash species was highly impaired when feeding was attempted.

Logs (ca 1 m x 150 cm diam) of green ash, white ash, elm, walnut, hickory, and hackberry were attached to t-posts at four sites in the core zone. Similarly-size sections of black drain pipe served as a control. Half of the logs were wrapped in Tanglefoot® to monitor landing rates. Landing rates were similar for all species, although significantly fewer beetles landed on the "control" pipe than on green ash when data from all sites were combined. Logs were dissected to count galleries. Green ash and white ash had 14 and 36 galleries per m²,

respectively, while elm, hackberry and hickory had zero. Black walnut had seven galleries per m^2, but all were impaired.

In a field study in 2003, logs of green ash, walnut, and elm were attached to the main stem of infested green ash trees, 5 to 7 meters above ground. We repeated this study in 2004; white ash and blue ash logs were included and logs were attached to infested white ash trees. Logs were dissected in autumn. In both studies, less than four galleries were found on walnut and none were found on elm. Nearly 200 galleries per m^2 were found on green ash in 2003 and on white ash in 2004.

Host preference was evaluated in 2003 and 2004 at three sites in the core zone that had both green and white ash street trees growing in close proximity. At all sites, there were more exit holes per m^2 in the green ash trees than in the white ash trees. The level of canopy dieback was also visually estimated for each tree at these sites. In both 2003 and 2004, the green ash trees showed significantly more canopy dieback than the white ash trees. These results and other observations indicate that EAB prefer green ash over white ash when the two species occur together. Studies that are still in progress include a no-choice oviposition bioassay using live trees (green ash, white ash, black walnut, and Japanese tree lilac), a two-choice leaf-feeding bioassay, and evaluation of host preference at two woodlots containing white and blue ash trees.

Observations of the Within-tree Distribution of Emerald Ash Borer in Southern Ontario

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ABSTRACT

One of the greatest challenges facing the successful management of the emerald ash borer (EAB), *Agrilus planipennis*, is the ability to accurately detect its presence in a stand of trees. External symptoms of EAB infestation are often difficult to see and usually do not appear until after the beetle has already been present for some time. This research aims to address these problems in detection by identifying any patterns that may occur in the within-tree distribution of the larvae of the EAB. Previous research on a native beetle in the same genus, the bronze birch borer (*Agrilus anxius*), has indicated that the within-tree distribution of *Agrilus* spp. may be influenced by a combination of stem height, stem diameter, stem aspect, and bark thickness.

To assess what influence these variables might have on the distribution of EAB larval galleries, 93 ash trees from plantations in Essex County, Ontario, were cut and stripped of their bark entirely. Measurements of height, diameter, cardinal direction, and bark thickness were made on all EAB feeding galleries found in the trees. Preliminary analysis shows a directional preference for the southwest, or sunny, side of the trees at all sites (Rayleigh Test Z=337.809, $p<0.000001$, Oriana Version 2.02a, © 1994-2004 Kovach Computing Services). Feeding galleries were also found to be clustered within a specific range of bark thicknesses and tree diameters within the total range available within the trees. Further analysis is being carried out to clarify these results. It is our objective to use the conclusions of this research in the development of an improved sampling program for the EAB.

Effects of Colored Objects and Purple Background on Emerald Ash Borer Trapping

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During 2003, male EAB searching for mates landed on and attempted to copulate with both live and dead EAB of both sexes. This strongly suggests that they use visual cues to locate mates. In addition, a 12-day-old female beetle was observed to perform a display that ended in her spreading her green elytra and exposing her magenta abdomen. At the 2003 EAB Research Symposium, Jason Oliver reported that many species of buprestid beetles are attracted to purple panels. We sought to improve EAB trapping and survey efficacy by incorporating green- and magenta-colored objects (ovals and stripes) onto purple panels.

Onto each black Corraplast panel (1 ft^2) we affixed nine purple vinyl panels, each 8.9 cm x 8.9 cm and surrounded by a black border. Treatments were randomly assigned to these vinyl squares: stripes (four stripes 5.5 mm wide by 8.9 cm long in green, magenta, or green and magenta), ovals (six ovals with dimensions 16 mm long x 6 mm wide in green, magenta, or green and magenta), metallic ovals (same dimensions; green or magenta), and control (no objects). The panels were stapled onto the south sides of ash tree trunks or onto nearby posts with the tops of the panels at a height of 5.5 ft (1.68 m), then coated with Pestick sticky adhesive. We placed eight traps (half on trees, half on posts) at each of six sites in western Essex Co., Ontario (n=48 traps). Emerald ash borers had been detected at all six sites in 2003 by inspection crews of the Canadian Food Inspection Agency. Trapping was conducted over eight weeks (11 June to 6 August). Beetles were removed every two to three days (on M/W/F). Statistical analyses are preliminary, not final.

Over the entire study, we collected 1,027 beetles (248 males, 779 females). Numbers of beetles trapped were significantly affected by site ($P<0.01$) and setting (~7X more beetles on panels on trees compared to panels on posts; $P<0.01$). Treatment effects were not statistically significant. However, numerically more beetles landed on vinyl squares with stripes than those with ovals (perhaps because of greater amount of edge created by stripes), and more beetles were attracted to a combination of magenta + green objects than to only magenta objects; in comparison, panels with only green objects attracted the fewest beetles. Metallic ovals did not attract more beetles in total but may have attracted proportionately more males (31-37 percent male EAB to metallic ovals compared to 19-25 percent male EAB to non-metallic ovals). (Note: the metallic ovals were not identical in color to the non-metallic ovals).

Although EAB were abundant at some sites, trapping success in Experiment 1 was low (0.38 beetle/1 ft^2 panel/day). Consequently, we decided to compare trapping success with our Avery Graphics purple vinyl vs. the purple Corraplast used in trapping studies conducted by others in 2004. The three treatments in Experiment 2 consisted of three adjacent bands (15" wide x 8" high; 38.1 cm wide x 20.3 cm high) one above the other (order randomly assigned) on ash trees. The band treatments were purple vinyl, purple Corraplast, or clear polypropylene plastic, coated with Pestick. There were 24 replicates (eight sites with three trees/site). We caught 956 beetles in total (17.7 percent males) from 30 June–3 August (34 days). EAB captures did not differ significantly by treatment (purple vinyl, n=372; purple Corraplast, n=197; clear [control], n=387). Our results suggest that low beetle numbers in Experiment 1 were not due to the color of our vinyl: neither purple trap material was more attractive than clear plastic. Most of the beetles were trapped on the lowest band.

We conclude that the difference between EAB captures on tree traps vs. post traps indicates that beetles orient towards and land on trees preferentially over purple traps. Although magenta and green objects may have marginally enhanced EAB trapping success, our data suggest that purple traps are not effective for surveying for EAB or monitoring EAB populations.

Interspecific Variation in Ash Resistance to Emerald Ash Borer

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ABSTRACT

Emerald ash borer (EAB) is an aggressive killer of even healthy ash in North America. However, reports suggest that EAB does not devastate ash in Asia, but rather that isolated outbreaks occur in response to stresses such as drought. Thus, emerald ash borer seems to behave in Asia much as its close native buprestid relatives do in North America, colonizing only stressed trees. This implies that Asian ash trees may be generally resistant, with weakened trees preferentially colonized. Native trees may be more resistant to native pests because of natural defenses that have developed over their long coevolutionary history. This hypothesis is supported by a 20-year study of birch resistance to bronze birch borer conducted in Ohio where birches native to North America were found to be highly resistant to bronze birch borer, while European and Asian species were extremely susceptible. To test the hypothesis in the case of ash resistance to EAB, a replicated common garden planting containing native, European, and Asian ashes was established in Novi, Michigan with the following objectives: 1) compare resistance of major North American, European, and Asian ash species to emerald ash borer, 2) identify mechanisms of resistance/susceptibility of ash species to EAB, and 3) determine the effects of drought and other stress on susceptibility of ash species to EAB, as well as North American ash borers. After one year, Manchurian ash (*F. mandshurica*), which shares an evolutionary history with EAB, had significantly fewer EAB exit holes and minimal EAB induced-dieback, relative to white (*Fraxinus americana)* and green ash (*F. pennsylvanica*) cultivars, as well as Northern Treasure ash (*F*. x ‘Northern Treasure’), which is a hybrid between native black ash (*F. nigra*) and Manchurian ash. These very preliminary results are consistent with the hypothesis that Manchurian ash is a source of resistance genes to EAB by virtue of their coevolutionary history. However, it remains to be seen if this pattern will hold over time. Work is underway to determine whether this pattern has a phytochemical basis.

EMERALD ASH BORER: CHEMICAL CONTROL

EVALUATION OF VARIOUS INSECTICIDES APPLIED TO THE BARK TO CONTROL EMERALD ASH BORER

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ABSTRACT

The emerald ash borer (EAB), *Agrilus planipennis* Fairmaire (Buprestidae), a native of Asia, was first discovered in the United States and Canada in 2002. Within the area that is generally infested with EAB, homeowners and communities are typically either removing infested trees or treating them with various insecticides to protect them from further EAB attack. In addition, questions have arisen as to whether various insecticides will kill within-tree EAB life stages if applied to the bark surface soon before adult emergence is to begin. We report here the results of two studies that tested one systemic insecticide and four topically applied insecticides.

In a 2003-2004 study, we tested the product D-20 by Perma Guard (Albuquerque, New Mexico), which is composed of diatomaceous earth and natural pyrethrins (0.2 percent a.i.). In this study, we moved 40 uninfested green ash trees, 4-5 m tall, to an area that was heavily infested with EAB near Ann Arbor, Michgan. 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 all trees. 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 two applications of 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, which was recommended by the owner of Perma Guard, Mr. Wallace Tharp. The first set of Mauget capsules were applied on 27 June, but because uptake was poor on a few trees, we treated all eight trees again on 14 July. In fall 2003, we felled and debarked half the trees. EAB had completely colonized the trunk of all control trees as well as all trees that had been treated with D-20. We found no live EAB larvae on any of the Imicide-treated trees, and except for a few EAB galleries that had terminated early, there was no other evidence of EAB attack. In the spring of 2004, all of the remaining Imicide-treated trees leafed out, but none of the control or D-20-treated trees produced any foliage. This study showed that D-20 did not protect the trunks of trees from EAB infestation, but a double dose of Imicide was highly effective.

In a 2004 study, we sprayed EAB-infested ash logs with one of three products: Astro (permethrin, a pyrethroid by FMC,) Onyx (bifenthrin, a pyrethroid by FMC), and Merit (imidacloprid, by Bayer). One set of logs was treated twice with Merit. We sprayed the outer

bark of all logs in mid-May or early June, and later placed the logs in rearing cages. Early estimates of EAB mortality range from 66 percent to 94 percent control. This study indicates that EAB life stages can be killed when the bark surface is treated with various insecticides.

Emerald Ash Borer Infestation of Ash Stumps

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ABSTRACT

The emerald ash borer (EAB), *Agrilus planipennis* Fairmaire (Buprestidae), was first found in North America in 2002. Eradication efforts are currently underway for this insect in both Canada and the United States. As part of the eradication program, thousands of ash trees are cut and chipped. Ash trees are known to produce stump sprouts, and therefore, herbicides are often applied to the cut surface of the stump to inhibit sprouting. In 2004, we initiated three studies in southern Michigan to evaluate the degree of stump sprouting and subsequent EAB infestation in relation to 1) time of felling, 2) stump height, 3) tree species, and 4) application of herbicide (Garlon).

In the first study, we cut green ash trees at three Michigan sites during April, June, and September 2004. The trees were cut at three different heights (0-5 cm, 10-15 cm, 20-25 cm) during each felling period. We cut 9-11 trees per stump height class and cut date. EAB adults were free to lay eggs on the stumps of trees cut in April and June. However, for the trees cut in September, we had screened the lower trunk of each tree throughout the summer months of 2004 to protect them against EAB colonization. In late summer 2005, we will record the degree of sprouting on all stumps and inspect them for EAB exit holes. We will also debark half the stumps and inspect them for EAB larvae. In 2006, we will determine EAB adult emergence from the remaining stumps.

In the second study, we focused on the degree of sprouting and subsequent EAB attack in relation to tree species. We felled three black ash, green ash, and white ash trees of similar size at one site during June 2004. The stump height for all trees was 20-25 cm. In 2005, we will record the degree of stump sprouting and EAB colonization.

In the third study, we will evaluate the effectiveness of Garlon 3A in inhibiting stump sprouting and the ability of EAB to colonize Garlon-treated stumps. In this study, we cut green ash trees at three sites during May and June 2004. The stumps were cut to a uniform height of 20-25 cm. Garlon was applied to the freshly cut surface of half the stumps. We will record the degree of stump sprouting and EAB colonization in 2005.

Evaluation of Trunk Injections for Control of Emerald Ash Borer

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ABSTRACT

In 2003, we evaluated trunk injections of imidacloprid for control of emerald ash borer (*Agrilus planipennis* Fairmaire) (EAB). Results were variable and indicated that efficacy could be affected by injection timing and method and by tree size and vigor. In 2004, we continued studies to assess the optimal timing for imidacloprid trunk injections and the persistence and translocation of imidacloprid in ash trees.

One project involved a two-year evaluation of two popular trunk injection methods on street trees growing in two subdivisions in Ann Arbor. In May 2003, we randomly assigned 30 green ash trees at Site 1 (average of 42 cm dbh) to one of five treatments: untreated Control, Imicide (10 percent, 3 ml Mauget capsules, 1 capsule per inch dbh/2), Pointer (12 percent in 2003, 5 percent in 2004, wedgle, 1 ml per 10.2 cm basal circum), an early Bidrin treatment or a late Bidrin treatment (12 percent, 2 ml Mauget capsules, 1 capsule per inch dbh/2). Imidacloprid (Imicide or Pointer) was injected on 21 May 2003. Bidrin was injected on either 2 June or 14 July in 2003. Trees were injected with imidacloprid (Imicide or Pointer) again on 19 May 2004 or with Bidrin on 15 June 2004. At Site 2, we injected and monitored 18 green ash (16 cm dbh) and 18 white ash (13 cm dbh) trees. These trees were randomly assigned to treatments in May 2003 and were injected with either Imicide or Pointer on 21 May 2003 and on 19 May 2004.

Canopy condition of each tree was estimated periodically in 2003 and 2004. The number of exit holes per m^2 was determined in September 2004 on five sections (each 3800 cm^2) of each tree to estimate the density of EAB adults emerging in 2004. Density of larval EAB was quantified in three to four bark windows (each approximately 300 cm^2) excavated on each tree.

At Site 1, canopy dieback on untreated Control trees jumped from an average of roughly 20 percent in June 2003 to an average of 50 percent in September 2004. Pre-treatment canopy dieback on all injected trees ranged from 15-19 percent in June 2003 and dieback remained low, averaging 25 to 30 percent in September 2004. On average, about 10 EAB adults per m^2 emerged from Control trees in 2004, but an average of 80 larvae per m^2 were feeding in those trees in September. Significantly more EAB adults emerged from untreated Control trees in 2004 than from any of the injected trees. Larval density on all injected trees was 82-96 percent lower than on the Control trees.

At Site 2, canopy dieback progressed from roughly 10 percent in June 2003 to over 60 percent in September 2004 on the green ash Control trees. On the white ash Control trees, average dieback remained below 10 percent in 2004. On the green ash Control trees, an average of roughly 35 adult beetles emerged in 2004, while larval density averaged 80 per m^2. Green ash trees injected with either Imicide or Pointer had significantly lower adult emergence than Control trees. Larval density on green ash trees was roughly 89 percent lower in Imicide trees and 45 percent lower in Pointer trees than in the Control trees (with various applications—all treatments differed significantly from each other). On the white ash trees, density of emerged adults and larvae was consistently low.

Additional trunk injection studies were initiated in 2004 at two different sites in Ann Arbor to evaluate relative levels of imidacloprid residues in xylem sap, foliage and phloem (using ELISA) over the growing season. Trees were injected with imidacloprid via Arborjet micro-infusion, Arborjet micro-injection, or Mauget capsules. Rates of imidacloprid included 0.15 g AI per injection port (Imicide), 0.20 g AI per injection port (Arborjet – small trees), or 0.4 g AI per injection port (Arborjet – large trees). Number of injection ports per tree was equal to dbh divided by 2. Half of the trees were injected on 21 May 2004; the other trees were injected on 19 July 2004. Preliminary samples from trees injected in May suggest that imidacloprid residues in the Imicide trees peaked about 4 weeks after injection at roughly 45-50 ppb. Residues in trees injected with either Arborjet device peaked about two weeks after injection at over 300 ppb. Results from six-day bioassays conducted with adult EAB indicated that beetle mortality was related to imidacloprid residues. Imidacloprid residue in xylem sap decreased in all trees during the summer, a pattern consistent with 2003 results. Processing of tissue samples for residue analysis and larval density sampling is continuing.

Imidacloprid Residue Levels from Soil-injected Street Trees

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ABSTRACT

Soil injection of Merit products (imidacloprid) is a common technique used by the asian longhorn beetle eradication program to treat at-risk trees that are in proximity to areas where trees have been removed due to beetle infestation. Similar applications may be used to protect trees and control populations of the emerald ash borer (EAB). An earlier presentation by Deb McCullough demonstrated that greater than 80 percent adult EAB mortality was seen for trees averaging 100 ppb imidacloprid residue in xylem sap.

Street trees in Chicago were injected in a circular pattern at the maximum labeled rate at three times, pre-leaf drop (October), post-leaf drop (December), and spring (April / May). For analysis, maple and ash trees were grouped by diameter at breast height (dbh). Small trees averaged 8” and medium sized trees averaged 12”. Xylem sap from treated trees was collected in May, July and September of 2004. One group of trees was treated once; a second group of trees was treated twice over a two year period. Imidacloprid residue was assessed using an ELISA assay from a commercially available kit (Envirologix).

Results demonstrated that residue levels in both ash and maple generally increased between the sampling periods in May and July. For trees treated only once, the two fall treatments were generally not as effective as the spring treatment for new treatment areas; small trees of both species had significantly more residue in spring than in pre-leaf drop treatments, while residue in medium sized trees did not differ between treatments. Trees treated over two consecutive years had similar residue levels between all treatments, and were higher than those trees that were treated only one time.

2004 Update on Studies of BotaniGard® for Control of Emerald Ash Borer Adults and Larvae

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ABSTRACT

The emerald ash borer (EAB), *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), native to northeastern Asia, was identified as the cause of ash (*Fraxinus* spp.) mortality in southeastern Michigan and southern Ontario in 2002. Subsequent infestations were found in Ohio, Indiana, Maryland, and Virginia due to transport of infested nursery stock, firewood, timber, and natural spread. Programs designed by regulatory agencies to eradicate localized infestations of EAB involve detection and removal of infested ash trees (*Fraxinus* spp.) and creation of an ash-free zone around each epicenter to prevent EAB spread. Conventional insecticides are being tested to aid in the eradication effort and to protect landscape ash trees; however, methods are also needed to manage EAB in more environmentally sensitive areas such as forests and riparian areas. To this end, we are studying the efficacy of BotaniGard®, a biopesticide formulated with the insect-pathogenic fungus *Beauveria bassiana* var. GHA.

In 2002-2003, we began studying the natural enemy complex of EAB in Michigan. We found insect-pathogenic fungi were the most prevalent natural enemy of immature EAB (approximately 2 percent). Thus, we began laboratory and greenhouse studies of BotaniGard®, a registered biopesticide for control of insect pests of forests, shade trees, and agriculture. To summarize, we found both BotaniGard ES (petroleum based) and BotaniGard O (vegetable-oil based) were highly virulent against EAB in standardized laboratory studies. Subsequent studies of caged EAB-infested trees in the field demonstrated >80 percent adult mortality due to *B. bassiana* infection when BotaniGard® was applied before EAB emergence (pre-emergent trunk sprays). The application of BotaniGard® to EAB-infested tree trunks in the fall resulted in 10-20 percent larval mortality due to *B. bassiana* infection.

This spring, we initiated two field trials of BotaniGard® in Ann Arbor, Michigan:

1. In a 20-year-old ash plantation, a commercial applicator sprayed 73 ash trees with BotaniGard ES at the rate of 6 qts/100 gallons of water every two weeks from June 23 to August 3, 2004. Prior to application, levels of EAB infestation were ranked as low, moderate, or high for each tree. To achieve good coverage on these relatively large trees (approximately 20 feet tall), two to three gallons of BotaniGard® suspension was needed to spray the crown and trunk of each tree to drip point. The trees are being felled and dissected to evaluate the efficacy of this treatment.

2. In a separate study, uninfested ash trees, transplanted from a nursery apparently outside the infestation during the previous summer, were sprayed with BotaniGard ES using a CO_2 backpack sprayer every two weeks from June 25 to August 5, 2004. The canopies of these trees were small, and 600-ml of BotaniGard® suspension was sprayed to drip point on leaves, branches, and trunk of each tree at the rate of 6 qts/100 gallons of water. A gallon of fungal suspension can treat as many as six trees of this size. We evaluated the persistence of *B. bassiana* spores on ash foliage in full sun by exposing EAB adults for 72 hours to ash leaves harvested 0, 4, 7, and 11 days after BotaniGard application. After 7 days, EAB mortality due to *B. bassiana* infection was 100, 96, 88, and 78 percent, respectively. This is good persistence for a biopesticide, and the addition of UV protectants to the BotaniGard® tank mix may improve these results. The ash trees are being felled and dissected to evaluate efficacy of BotaniGard® in reducing EAB infestation.

Systemic Trunk Injections of Imidacloprid and Azadirachtin: A Control Option for Emerald Ash Borer Larvae

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ABSTRACT

The emerald ash borer (EAB), *Agrilus planipennis*, was discovered in Windsor, Ontario, in the summer of 2002. Since its detection, EAB has caused the death of more than 200,000 ash trees (*Fraxinus* spp.) in Essex County. In this study, small potted green ash trees (average dbh = 2.2cm, sd = 0.31) in Windsor were injected with either imidacloprid or azadirachtin to evaluate potential larval EAB control. Imidacloprid trunk injections provided complete control of EAB attack in trees treated with concentrations e•0.03g a.i./tree. Azadirachtin trunk injections provided control of adult emerging beetles at a concentration e•0.0075g a.i./tree, but did not control larval beetle or gallery development below the second instar stage. These indicate that both imidacloprid and azadirachtin have excellent potential for EAB larval control. These results are complemented by several additional trials involving injection of medium-sized ash trees with imidacloprid. Collectively, our results indicate that systemic trunk injections of imidacloprid have very high efficacy in controlling EAB infestations.

Using Tempo to Control Emerald Ash Borer: A Comparison of Trunk and Foliage Sprays

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ABSTRACT

Insecticide sprays may provide arborists, landscapers, and regulatory officials with a useful option to control emerald ash borer (EAB) in some situations. In our 2003 studies, we found that two applications of Tempo (a pyrethroid insecticide) significantly reduced the density of EAB larvae relative to unsprayed trees. It was not clear, however, whether this control reflected mortality of adult EAB that fed on sprayed foliage or mortality of newly eclosed larvae chewing through the bark. In 2004, we set up a study to determine if EAB could be controlled by spraying only the foliage or only the trunk and large branches of trees. We also compared larval density between trees that received one spray with those that received two sprays.

We selected 40 green ash street trees in Ann Arbor and randomly assigned them to one of five treatments: 1) Control (no spray), 2) Foliage-only spray (twice), 3) Trunk-only spray (twice), 4) Trunk & Foliage spray (twice), 5) Trunk & Foliage spray (once). A private contractor applied Tempo SC Ultra (160 ml per 378 l) on 10 June and again on 2 July for trees that were sprayed twice. During sprays, the trunk and large branches of Foliage-only trees (Treatment 2) were wrapped with plastic wrap and the ends sealed with clay to ensure that the spray did not contact the bark. On average, Trunk only trees (Treatment 3) received 1.1 gal of spray compared with 4.3 gal of spray applied to Foliage only trees and 5.3 gal applied to Trunk & Foliage trees. Similarly-aged adult EAB were caged with bark or with a leaf from each treated tree on July 7 (27 days post-spray) for five days. Mortality of beetles in the bioassay was recorded daily. In September, bark was removed from three to four windows (ca 400 cm^2) on the trunk and three to four windows in the canopy to estimate larval density.

Bioassay results showed that Tempo remained toxic to EAB adults for at least 27-30 days post-spray. More than 80 percent of beetles had died by Day 3 of the bioassay when they were caged with either bark or foliage that had been sprayed. During the same period, average mortality of beetles caged with unsprayed trees, unsprayed bark or unsprayed foliage was less than 20 percent.

Density of young EAB larvae (L1 to L3) feeding on tree trunks was reduced by 88 percent compared with Control trees when only the foliage or the trunk and foliage had been sprayed, and by 40 percent when the only the trunk had been sprayed. Density of young larvae feeding in the canopy was reduced by 66 percent to 90 percent when only the foliage or both trunk and foliage were sprayed, but only by 14 percent when only the trunk was sprayed. Efficacy did not significantly differ between trees that were sprayed only in June and those sprayed in June and July.

We also noted that some of the late instar larvae (L4) feeding on trees in September were actually two-year-old larvae—i.e., they began feeding in 2003, overwintered as immature larvae, and were still feeding in 2004. These larvae could be distinguished from the current-year L4 larvae by the dark, discolored appearance of the oldest part of the gallery and the presence of wood and callus tissue formed by the tree over the early part of the gallery. Obviously, cover sprays will have no effect on larvae that are already feeding below the bark when sprays are applied. Preliminary data indicated that roughly 60-70 percent of L4 larvae on unsprayed trees were two-year-old larvae while at least 90 percent of the L4s on twice-sprayed trees were two-year-old larvae. Additional sampling is planned to refine estimates of the density of one-year and two-year L4 larvae.

Distribution and Metabolism of 14C Imidacloprid in *Fraxinus spp*. and Effects of Imidacloprid on Adults of the Emerald Ash Borer

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ABSTRACT

Trunk or soil injection of systemic insecticides is often a preferred method for controlling insect pests in landscapes because it minimizes potential spray drift, applicator exposure and impacts on non-target organisms. Recent field trials and anecdotal evidence indicate that imidacloprid, applied as either a soil drench or trunk injection, can significantly reduce emerald ash borer (EAB), *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), populations in ash trees and canopy dieback associated with EAB. The persistence and translocation of imidacloprid in ash trees, however, is not well understood. In this study we used radiolabeled 14C imidacloprid to assess the distribution, persistence, and movement of imidacloprid in green ash and white ash trees following trunk injection. We also determined EAB mortality and LD50 in bioassays of adult beetles fed leaves from trunk-injected trees and the LD50 of adults of EAB treated in topical bioassays.

The specific objectives of the study were to:

1. Determine the translocation and persistence of 14C imidacloprid over time in trunk-injected white and green ash trees,
2. Determine the effects of water availability on imidacloprid translocation and distribution,
3. Determine the mortality and knockdown of EAB adults fed leaves from injected trees,

4. Determine the LD50 of adults of EAB, and
5. Identify the major the metabolites of imidacloprid in ash trees.

On June 14, 2004 we injected twenty container-grown green ash (*Fraxinus pennsylvanica*) trees (7.6 cm dbh) and twenty white ash (*F. americana*) trees (10.1 cm dbh) with 6 ml of imidacloprid (10 percent a.i.). The trunks of the trees were injected at 15 cm above ground level via two injection ports on opposite sides of the tree. Each tree received 25 mCi of 14C-imidicloprid in a ratio of 1:2400 (labeled:non-labeled imidacloprid). After injection, half of the trees were kept well watered (3.8 cm irrigation week^{-1}) and half were subjected to water stress (1 cm irrigation week^{-1}). Imposition of water stress was verified with periodic measurements of soil water content and leaf gas exchange. We collected leaf, twig, trunk, and root samples 0, 2, 7, 21, 60,105, and 150 days after treatments (DAT). After 105 DAT five trees from each species were covered with netting to collect litterfall samples. All samples were brought to the lab, oven dried, ground, weighed, and oxidized in biological tissue oxidizer. The resultant $14CO_2$ was trapped in scintillation cocktail and radioactivity was determined by scintillation counting.

A subsample of fresh leaves was collected 21 and 45 DAT for bioassays on adult EAB. Single leaves were put in a vial with distilled water placed in a cup. Four beetles (10 days old) were introduced in the cups. The beetles were kept at 28°C, 50 percent relative humidity, photoperiod of 16:8 (L:D) while inside the cups. Mortality and "knockdown" were assessed at 24, 48 and 72 hours. Beetles that were unable to stand on their legs and walk a distance equal to their own body length were counted as knocked down.

For topical bioassays, technical grade insecticide was diluted with acetone. Five doses that resulted in more than 0 percent and less than 100 percent mortality based on preliminary assays were used. Four beetles (about 10 days old) were treated with 1 ml of solution on the ventral area of the abdomen with a 50 ml microsyringe connected to a microapplicator. The control beetles were treated with 1 ml of acetone only. Three to five replications per concentration were performed. After treatment, beetles were placed in cups and fed ash leaves and kept at 28°C, 50 percent relative humidity, photoperiod of 16:8 (L:D). Mortality and knockdown were assessed at 24, 48, and 72 hours after treatment.

Radioactivity in leaves increased steadily from 2 DAT to DAT 60. Through 21 DAT radioactivity in twigs and roots was not significantly different from zero. Radioactivity in leaves collected after leaf-fall was as high or higher than samples collected at 60 DAT, indicating little re-translocation of imidacloprid or imidacloprid metabolites from leaves before leaf-fall. Specific activity (cpm g^{-1}) was somewhat lower in white ash than green ash, reflecting a dilution in the larger trees. Initial results did not indicate a significant effect of water stress on 14C imidacloprid movement. We are continuing processing and analysis of later sample dates and trunk tissues.

In the bioassays, a high percentage of knockdown in EAB adults was observed 24 hours after treatment (40 percent at 20 days and 36 percent at 45 days). Beetle mortality was less than knockdown (11 percent at 20 days and 17 percent at 45 days). However, three days after exposing the adults to the foliage, the mortality increased. Translocation of labeled and unlabeled imidacloprid was effective to control adults of EAB. The percent of knock down plus dead beetles was 71 percent at 20 days after treatment and 77 percent at 45 days after treatment.

Other sublethal effects, including reduced feeding, and slowed movement were also observed. These effects may severely affect the fitness of surviving beetles. The LD50 for the adults of EAB was 7.1 ng/beetle, which confirms that EAB is very susceptible to imidacloprid in comparison to other insect species.

EMERALD ASH BORER: SURVEY

PROGRESS ON REMOTE SENSING APPLICATIONS FOR AN EMERALD ASH BORER SURVEY IN 2004

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ABSTRACT

We have made considerable progress in remote sensing surveys for emerald ash borer (EAB) survey in our second season (Summer 2004). We continue to pursue two nested objectives: to develop maps of the distribution of ash trees over areas potentially infested by EAB and, further, to develop maps of the distribution of EAB-infested trees that include multiple levels of decline. Our primary remote sensing approach continues to be hyperspectral imagery. Imagery was acquired in 2004 by SpecTIR Inc. using their HyperSpecTIR instrument, which simultaneously records reflectance of electromagnetic radiation from ground features over 227 narrow spectral bands ranging from the visible spectrum through the middle infrared. As in last year's work, four basic activities are necessary to meet our objectives: image acquisition, collection of spectral signatures for ash trees and other tree species (which is treated in another abstract in this volume by D. Bartels), collection of ground truth information (including precise locations) of ash trees and other vegetation recorded in the imagery, and image analysis and map development.

Images were acquired over three long flight lines in southern Michigan and three flight lines in northwestern Ohio. Individual flight lines covered areas about 2 km in width and 15-40 km in length. Imagery was collected over all the areas at two times during the summer: midsummer (9 July 2004) and late summer (22-23 August 2004). These times were chosen to represent periods of relatively low stress due to beetle activity and water availability and of relatively high stress, respectively. The spatial resolution of sample pixels on the ground was 1 m for the longest flight line and 2 m for the remaining lines. The quality of imagery collected in

2004 was vastly superior to that in 2003 in terms of its high resolution, low spatial distortion, and greater precision of georeferencing. Ground truth data were collected during several periods in the growing season. Precise locations were obtained for almost 300 ash trees in various states of decline and over 400 trees of other species in the images using both GPS and identification directly on hard copies of the digital images. Analysis of the imagery is underway as of this writing (October 2004). It is being carried out by a group of scientists with considerable expertise in hyperspectral analysis, including personnel from Clark University, ITT Aerospace, and the USDA Forest Service.

The Feasibility of Using Hyperspectral Remote Sensing for Differentiating Hardwood Tree Species and Stressed Ash Trees

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ABSTRACT

Emergency response programs for agents such as emerald ash borer (EAB) could benefit greatly from vegetation mapping to locate susceptible tree species and stressed trees within urban and rural environments. Currently, detection surveys rely on visual identification of beetles and/or visible damage. Visual surveys are often inefficient and labor-intensive with surveyors first identifying susceptible tree species and then examining individual trees for signs of beetles. The goal of this project is look at hyperspectral remote sensing tools to enhance the survey and detection methods for EAB. Working with a hand-held spectrometer, the project focuses on two main questions: Can hyperspectral imagery be used to separate ash trees from other hardwood species and can it separate stressed ash trees from healthy ash trees? By building a spectral library of different hardwood tree species at different stages of phenology over the growing season, the project will be able to determine the feasibility of distinguishing tree species using spectral characteristics. The project will also contribute to a spectral library of ash trees with a range of EAB infestation as well as trees stressed by manual girdling and herbicide injections.

Preliminary data was collected in 2003 using an ASD FieldSpec Pro full range spectrometer and included bands from the visible spectrum to shortwave infrared (SWIR). Analysis indicates that, based on leaf signatures, tree species including oak, walnut, maple, and cherry were distinguishable from ash a high percentage of the time. Ash trees that had been girdled or treated with herbicide were also distinguishable from "healthy" ash trees at the leaf level.

During 2004, leaf-level data collections were made in replicated experimental plots set up by MSU and USDA Forest Service to look at stressed ash trees. Data was collected four times during the growing season from June to September. A large number of spectral signatures were also collected from over 15 trees species at multiple sites in Michigan during the growing season. Data will be analyzed this winter and used to help in classifying the airborne hyperspectral imagery collected by David Williams and the CPHST group at Otis, MA. Additional data sets were also collected over tree crowns using a bucket truck to provide ground truthing information for the airborne imagery.

Progress Toward Developing Trapping Techniques for the Emerald Ash Borer

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ABSTRACT

Since the 2002 discovery of emerald ash borer (EAB), *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), in southeastern Michigan and Windsor, Ontario, the distribution of this exotic insect has continued to expand. The primary infestation in Michigan currently includes 13 counties, with small isolated pockets in at least 13 other counties. Accurate delimitation of the infested area and detection of new outlier infestations is critical for regulatory officials who must establish the quarantine boundaries and implement eradication and control measures. Trapping and detection techniques would greatly enhance survey efforts to delineate the distribution of EAB and locate new infestations.

In 2003, we collected and analyzed ash leaf and bark volatiles. Electro-antennogram detection and walking bioassays were used to select candidate compounds that were tested both individually and in blends using four different trap types in the field. Trap trees (healthy, girdled, and herbicide-treated) and trap logs were also tested. Among trap trees, trap logs and baited traps tested, the girdled trees were found to be the most effective in capturing EAB.

In 2004, we identified additional potential attractants for EAB using coupled gas-chromatography electro-antennal detection of ash volatiles. Wind tunnel and walking olfactometer bioassays were used to select the most attractive compounds for field testing. Trapping experiments using a prototype purple-panel trap and other purple trap designs were conducted to compare several potential attractants. Purple panel traps baited with a blend of host volatiles captured significantly more EAB than traps baited with various individual compounds. Trap tree studies were conducted to compare girdled, wounded, healthy, and herbicide-treated ash trees; trap trees located along the edge of a stand, within a closed canopy stand, or in open canopy conditions; and healthy or girdled trap trees baited with attractants and/or colored

bands. The herbicide-treated trees were significantly more attractive than healthy ash trees; girdled and wounded trees were intermediate in attraction. Trap trees located in open canopy conditions were significantly more attractive than trap trees located along the edge of a stand or within a closed canopy stand. There were no significant differences in the number of EAB captured on trap trees with different colored bands or baited with blends of ash volatiles.

Chemical Ecology Studies on the Emerald Ash Borer

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ABSTRACT

The emerald ash borer (EAB), *Agrilus planipennis* Fairmaire (Buprestidae), a native of Asia, was discovered in the USA and Canada in 2002. This serious pest of ash trees (*Fraxinus sp.*) infests and quickly kills trees by mining the cambium area, disrupting the tree's nutrient transport system. As newly infested trees do not typically show distinctive external visual symptoms, there is a growing need to be able to trap adult beetles so that accurate surveying can be done. During the 2004 Michigan flight season of EAB, we collected bark and leaf volatiles from healthy and girdled ash trees using both Porapak-Q and Super-Q cartridges. We refined current collecting methods by using the very latest in 'micro-pump' technology. We also prepared ash leaf extracts by washing leaves in methanol and hexane. EAB adults were also aerated in chambers in an attempt to collect and identify possible sex/aggregation pheromones. Volatile components were screened for EAB antennal activity using coupled gas chromatographic electro-antennal detection (GC-EAD). Compounds that elicited antennal responses were identified by gas chromatography (GC) and mass spectrometry (MS) and tested in an olfactometer arena for behavioral activity.

Exploring the Use of Spatially-stratified Ash Host Distribution Maps for Improving Efficiency of Emerald Ash Borer Detection

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ABSTRACT

An accurate description of the host landscape pattern is critical for effective strategic management of the exotic insect pest the emerald ash borer (EAB), *Agrilus planipennis*, because population dynamics of EAB are a landscape-scale phenomenon and spatial variability in the ecological characteristics of ash host populations should define the context for the pests behavior. Strategic survey and sampling efforts to define the spatial extent of EAB infestations in southern lower Michigan have been made difficult because, like many exotic pests, EAB has been introduced into a complex, urbanizing landscape where forest inventory and health monitoring are especially difficult. Forests and other treed areas in urbanizing landscapes are fragmented and have a complex ownership patterns—which, in the case of privately owned lands, effects access and may add a public land bias to resource inventory. These landscapes also exhibit a high degree of spatial heterogeneity in species composition and forest structure, which makes it difficult to define a common sampling scheme or extrapolate forest inventory to the whole landscape (i.e., there is no "average" condition). In this analysis, potential methods for using host-weighted stratified sampling techniques to improve the efficiency of EAB detection are discussed in relation to preliminary results from the ASHMAP project. ASHMAP has the goal of defining the specific spatial distribution and abundance of ash species over the large complex landscape of southern lower Michigan where EAB is most prominent, as well as describing the general spatial ecological niche of ash in urbanized landscapes.

Environmental Spatial Distribution Patterns of Ash in Southern Michigan

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ABSTRACT

A critical step to controlling the spread of emerald ash borer is identifying the spatial distribution patterns of its host species. Ash species distribution is hypothesized to be influenced by a complex multi-faceted soil, climatological, and lake effect spatial conditions. During the summer of 2004, field crews established 1,010 plots (three sub-plots, each) across southern-lower Michigan for surveying ash at each plot. Each plot was georeferenced using a global position system that facilitated mapping the plot locations in a geographic information system (GIS). Using a preliminary sample (933 plot records), 133 tree species are included in 25,191 tree records. Approximately 24 species are present in at least 1 percent of the plots. Ash species (white 58.8 percent, green 29.9 percent, black 10.9 percent and blue 0.28 percent) were present at 31.8 percent of the plots. Soils and digital elevation models are included in the GIS in order to associate physical environmental factors with the spatial position of the plot records. Soil physical and geochemical properties derived from SURGO are spatially associated with the soil map and plot locations. Climatological data archived by NOAA provide regionalized precipitation, temperature, and cumulative growing-degree-day surface maps. Predictive models of ash tree species distribution patterns are being developed using General Linear Modeling techniques.

Dispersal of Emerald Ash Borer at Outlier Sites: Three Case Studies

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ABSTRACT

We worked with cooperators from several state and federal agencies in 2003 and 2004 to assess dispersal of emerald ash borer (EAB), *Agrilus planipennis* Fairmaire, from known source points in three outlier sites. In February 2003, we felled and sampled more than 200 ash trees at an outlier site near Tipton, Michigan, where one generation of adult beetles had emerged from firewood stacked near a drainage ditch in 2002. At least 70 percent of the EAB galleries occurred on trees growing along the ditch within 100 m of the firewood pile. Galleries were occasionally found on trees that were up to 750 m north from the firewood pile, but all infested trees were growing along the ditch. More than 80 woodlot trees that were roughly 400 m east of the ditch were sampled, but no galleries were found on any of these trees. The distribution of the infested trees suggested that the drainage ditch may have facilitated directional dispersal, perhaps extending the dispersal distance. The need to collect similar data at additional sites was noted.

In February 2004, we evaluated EAB dispersal at an outlier site near Shields, Michigan that resulted when a single generation of EAB adults emerged in 2003 from ten infested nursery trees. Cooperators from the Michigan Department of Agriculture randomly selected and marked one ash tree in each $^1/_{16}$-mile grid cell in a $^1/_2$-mile radius surrounding the point source of the infestation. Trees were felled and bark windows, each a minimum of 1,000 cm^2, were excavated on the upper surface of each tree. Number of bark windows sampled was based on the size of individual trees; four windows were evenly spaced from the base of the lower canopy to the upper canopy for each stem or major branch. The number of bark windows sampled ranged

from 4 to 24 windows per tree. The number and stage of EAB larvae and extent of feeding were recorded for each window. We sampled 147 ash trees and found 57 EAB larvae or galleries in eight trees. No infested tree was more than 0.38 miles from the point source. More than half of the EAB larvae were on a single declining tree.

We conducted a similar project in April 2004 at an outlier site in St. Joseph, Michigan, where two to three generations of EAB had emerged from infested nursery trees. One to two ash trees were felled and sampled per $^{1}/_{16}$-mile grid cell using methods developed at the Shields site. More than 200 trees were sampled and one or more infested trees were found in at least 14 grid cells. Trees with exit holes occurred in five grid cells, all within roughly 200 m of the point source. Trees with larvae or prepupae but no exit holes occurred in nine grid cells, located 200 to 600 m from the point source. Analysis of data from all three sites is continuing.

Studies to Develop an Emerald Ash Borer Survey Trap: I. Trap Design, Trap Location, and Tree Damage

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ABSTRACT

Current emerald ash borer (EAB), *Agrilus planipennis* Fairmaire, survey methods (e.g., tree damage surveys, trunk dissection for larvae, and trunk girdling in combination with sticky bands) are less than ideal for USDA Program surveys. To address survey issues, three trapping studies were performed from 20 June to the end of August 2004 at multiple replicated locations near the Townships of Salem, Ann Arbor and Northfield, Michigan. The objective of these studies was to develop an efficacious EAB trap that can be easily deployed for survey programs.

Test 1 – Trap Design. A trap design test evaluated multiple sizes, colors, and shapes of traps. Most traps were made from purple or black corrugated plastic covered in Pestick insect glue. In addition, two intercept flight traps, the Lindgren funnel and the IPM Tech Intercept Panel, were tested. Also included were girdled ash trees, banded with glue-coated plastic stretch wrap (30 cm width) (i.e., Michigan Department of Agriculture—MDA—Program trap). A new purple-colored elm bark beetle trap developed by Pherotech Inc. and a purple-colored wallpaper trap (3.75 cm wide) tested in 2003 were also tested. Total EAB collections among traps were low (58 EAB). The MDA Program trap had significantly higher EAB collections than other treatments (2.4 ± 0.7 [S.E.] adult EAB/trap/week) followed by the elm bark beetle trap (1.1 ± 0.6). All other trap treatments averaged < 0.3 EAB per trap per week. Unlike the other traps, the MDA Program and the elm

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bark beetle trap were both in association with ash trees. In general, traps with larger surface areas were the most effective. The Lindgren funnel and IPM Tech Panel traps, as well as another black-colored corrugated plastic trap, caught no EAB. Sticky traps were more effective than the flight intercept traps.

Test 2 – Trap Site. Traps were placed along the edge of a woodlot, 25 m into the woods, or 25 m from the woodlot in an open field. Location treatments were replicated four times. Each trap site had two Pestick–covered purple corrugated plastic strips (15 cm wide by 90 cm) that were attached to 1.3 cm rebar rod at heights of 0 to 0.9 and 2.1 to 3.0 m. Total EAB collections were very low (36 EAB). On two dates (25 June and 7 July), average EAB collections were significantly greater on traps located along the forest edge (2.1 and 1.0 EAB/trap, respectively) than in the open field or woods (³ 0.4 EAB/trap). No adult EAB were captured on traps in the wooded sites. Trap height did not significantly affect EAB capture. Although none of the traps in Test 2 were associated with ash trees, EAB collection on the forest edge traps was equivalent to the MDA Program trap in Test 1.

Test 3 – Tree Damage. The attraction of EAB to sticky traps placed on damaged and undamaged ash seedlings was investigated. Bare-root green ash (*Fraxinus pennsylvanica* Marshall) in three varieties (‘cimmaron’, ‘patmore’, and ‘urbanite’) ranging from 1.3 to 2.5 cm caliper were planted on 21 April at a site in South Lyon, Michigan. Trees were planted at 1.5-m intervals in rows by variety (completely randomized block design). Damage treatments consisted of severe root pruning (~30 percent) at planting, trunk scraping, crown decapitation, or girdling on 11 May 2004. Traps were purple corrugated plastic triangles (with each side 30 cm long x 15 cm wide) attached to the tree at 15 to 45 cm. Traps were covered in Pestick glue. Total EAB collections were low (153 EAB). Treatments did not significantly affect EAB collections. However, there was a trend towards more EAB being captured on girdled and trunk-scraped trees than other treatments and on the ‘urbanite’ variety.

Due to the low trap catch in these studies, it is difficult to make any definitive conclusions. The actual EAB populations in the trapping areas of these studies were unknown, so there is no estimate of the relationship between trap collection and population density. Therefore, it is unknown if low EAB trap recoveries were due to ineffective traps or low EAB populations at our trapping sites. However, it appears that traps located on the edges of woodlots performed better than traps located in open or wooded areas. The MDA Program trap was the most effective treatment among trap treatments placed solely within wooded sites. Light levels were much lower (40 to 60 times) in the wooded test sites than open or edge sites. Therefore, EAB may not distinguish trap colors in low light conditions. However, EAB may be able to locate the MDA Program trap trees in low light wooded areas due to the release of volatile attractants from girdle-damaged trees. The utilization of colored sticky traps and tree damage treatments to attract EAB may be more effective when traps are placed along the edges of woodlots, but further testing will be required to confirm this assumption.

Studies to Develop an Emerald Ash Borer Survey Trap: II. Comparison of Colors

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ABSTRACT

The objective of this study is to develop a trap for EAB that would improve the sensitivity and efficiency of EAB survey and aid the overall program in achieving its goals. A four panel 'hanging box' 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 Pestick 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 6.1). In 2003, over 500 beetles were caught in a three-week period. More beetles were caught on purple traps than on any other color. More beetles were caught on low traps than on high traps for all colors except black and yellow. In 2004, we deployed the hanging box traps in the same arrays, but only 149 beetles were caught throughout the study. Purple-colored traps caught significantly more beetles than all other colors except white. Unlike 2003, there was no difference between traps hung at the two heights. Traps containing logs did not catch more beetles than traps without logs. Additional studies were also conducted in 2004 using a cross-vane prototype trap. Nineteen colors (including colors produced by the plastic manufacturer, purple-colored glue, glue containing small metallic objects [purple and green], metallic foil, and paints reflecting in the 400-450 nm range) were tested. Beetle catch was low, with only 95 beetles caught throughout the study. Of the treatments, purple-colored glue caught the most beetles (21) followed by glue mixed with green glitter (11) and the manufacturer's purple (10), also used in the 'hanging box' study. The attraction of EAB adults to specific colors may enhance the performance of a trap baited with semiochemicals or be utilized in a control strategy.

Studies to Develop an Emerald Ash Borer Survey Trap: III. Tree Banding

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ABSTRACT

Attraction of emerald ash borer (EAB) to girdled ash trees has been demonstrated in prior trapping studies. Other studies have demonstrated its attraction to colors such as purple. We combined the two trapping methods using colored sticky bands (clear plastic and blue, purple, yellow and clear cellophane) on trap trees (unwounded, wounded by a half girdle, and, in a separate study, completely girdled). Trends in both of these studies indicate that clear sticky bands do better at capturing adult emerald ash borer than colored bands in trap trees. In the first study mentioned, wounded–clear cellophane trap trees caught the most EAB, followed by wounded–clear plastic, then unwounded–clear cellophane and wounded–purple. The clear–cellophane trap was the only one of the four mentioned to catch significantly more than the remaining trap tree types (both yellow and blue types and unwounded–purple.) However, it did not catch significantly more than the other top three trap tree types. The results from the study of girdled trap trees showed no significant differences between trap types, with clear cellophane catching the most, then blue, clear plastic, purple, and lastly, yellow.

Problematic Agrilus Identifications from Emerald Ash Borer Trap Tree Interceptions

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ABSTRACT

Initial trap tree studies conducted by EAB survey crews have captured many species of Agrilus. To facilitate correct species diagnosis, a protocol for cleaning and removing tanglefoot residue from specimens is provided. Seven *Agrilus* species are listed from Ohio and Michigan trap trees and visual characters are provided for diagnosis.

EMERALD ASH BORER: BIOLOGICAL CONTROL

Exploration for Natural Enemies of Emerald Ash Borer in South Korea during 2004

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ABSTRACT

We searched for emerald ash borer populations and associated natural enemies from June through August 2004 in the northern part of South Korea. Previous to our investigations, emerald ash borer was recorded in a single citation in a Korean forestry publication under the synonym *Agrilus marcopoli* Obenberger. Our approach to exploring for natural enemies is threefold: to locate areas with plentiful host trees of *A. marcopoli* (which we assumed to be *Fraxinus* spp.), to locate beetle populations in the host stands, and to rear insects from beetle-infested wood and identify potential natural enemies. The Korean ash, *Fraxinus rhynchophylla* Hance, is very abundant, particularly in riparian habitats along rocky mountain streams, and thus, we chose it as the focus of our investigations.

Our primary strategy for locating *A. marcopoli* populations was trapping using girdled host trees and purple plastic traps. We established nine trapping sites across the northern end of South Korea in riparian habitats. In all, 84 ash trees were partially girdled. Plastic food wrap was stapled above and below the girdle and coated with Pestick. A total of 20 purple plastic traps (also coated with Pestick) were placed near girdled trees. The traps were checked for *A. marcopoli* and other *Agrilus* species 2-3 times from mid June through mid August. In addition to trapping, we searched for adult beetles by sweeping and visual inspection of foliage and examined trees for signs of larval damage. Despite considerable effort, we did not find any adult beetles or evidence of larval damage on *F. rhynchophylla*.

We also sought out *Agrilus* specimens in museum collections and talked with beetle collectors. In doing so, we saw specimens of *A. marcopoli* collected from 1983-2003 from nine locations scattered throughout the country. Clearly, *A. marcopoli* is indigenous to South Korea, but it is apparently at very low population levels. Future research will address the causes of this apparent rarity, as well as the identity of hosts of *A. marcopoli*, which may include ash species other than *F. rhynchophylla*.

Foreign Exploration for Emerald Ash Borer and its Natural Enemies

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ABSTRACT

Two transpacific trips permitted further foreign exploration for the emerald ash borer (EAB), Agrilus planipennis (Coleoptera: Buprestidae), in Korea (June 21–July 3), Japan (July 4-11), and Mongolia (Aug. 5-27) in 2004. In no case, could I reconfirm the presence of EAB. In both Japan and Korea, the situation is much the same in that the most common species of *Fraxinus* (*mongolica* and *chinensis*, respectively). Oleaceae can be found quite readily, but careful examination of foliage for adult beetles and bark for both exit holes (D-shaped holes) or cracking, peeling bark, and sweepnetting failed to yield EAB. *Fraxinus* trees were usually found in riparian habitats, near streams, lakes, or other low, wet areas. I can now only postulate that perhaps EAB is more specific in its host range and may be more closely associated with some of the lesser known *Fraxinus* spp. (e.g., *apertisquamifera*, *spaethiana*, and *lanuginosa* in Japan or *sieboldiana* and *chiisanensis* in Korea) or even other tree taxa. One recent reported find was the presence of larvae and non-emerged adults of EAB under the bark of felled logs of *Pterocarya rhoifolia* (Juglandaceae) in Japan. Local entomological collections do contain enough material of EAB from these countries to suggest that EAB is widespread throughout Japan (found on all major islands) and Korea but populations remains at a low density. To illustrate how low: in Fukui Prefecture, Honshu, Japan, EAB is reported as "Red Listed" or endangered with only two collection locations recorded in that prefecture.

In Mongolia, the situation is somewhat different. Rather extensive travels (more than 4,000 km) via hired jeep and driver has failed to detect the presence of any *Fraxinus* spp. In a published listing of the vascular plants of Mongolia, no species under the Genus *Fraxinus* are listed (though a number of synonyms have yet to be checked). Furthermore, no EAB can be located in the National University collection, Ulaanbaatar, and neither *A. planipennis* nor its synonym, *A. marcopoli*, are given in a comprehensive listing of the known *Agrilus* spp. of Mongolia. In conclusion, the listing of EAB for Mongolia appears doubtful and just may be an error brought on by associating Mongolia with Inner Mongolia (a part of People's Republic of China), where EAB is reportedly present.

Elsewhere in Russia, our investigations have likewise failed to reconfirm recent EAB in that country. A listings of 36 *Agrilus* spp. represented in the collections at the Siberian Zoo-

logical Museum, Novosibirsk, does not list *A. planipennis (=marcopoli).* I am aware of only one known published Russian record: that of Alexeev (1979), who lists EAB from one location near the Russian-Korean border. This leaves China as the only other major area known to be part of the native range of EAB, and reports from China (found elsewhere in this compilation) indicate that populations are available there.

The Upside of the Emerald Ash Borer Catastrophe: A Feast for Woodpeckers

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ABSTRACT

Under the most favorable conditions, woodpeckers reduce larval EAB density as effectively as the best pesticides. Woodpeckers work over the entire core region for free and are always more popular than spray trucks.

In the course of trapping and pesticide trials, we have dissected multiple sections of several to several dozen trees at 24 sites in southeast Michigan. For each of these datasets, we recorded the density of successful emergence holes (exits) and of woodpecker attacks where those resulted in EAB mortality. The calculated woodpecker predation rate ranges from 9-95 percent (mean=44 percent). Preliminary analyses of these data considered two variables that might explain this variation. There was no correlation between site EAB density (R2=0.00; P=0.98) or any clear pattern of a density/predation relationship for trees within sites. Categorization of sites by habitat type (street tree, open park, forest) also revealed no relationship between habitat and predation rate (ANOVA, P=0.27), although the four sites with >65 percent predation were all in a forest setting.

Our datasets varied in many ways that we have not quantified (tree size, species, stand density, non-Fraxinus tree composition, etc.), so inferences at this stage are problematic. However, the magnitude of the predation rate at some sites suggests that woodpeckers may play an important role in EAB population dynamics. Furthermore, two features of avian predators make it likely that predation may be of increasing importance over time. First, vertebrates often exhibit a functional response as prey density increases. Thus, predation intensity may increase as EAB population increases. Second, any numerical response by woodpeckers responding to increased high-quality prey may require several years to manifest; and again, woodpecker predation may increase over time.

Because woodpeckers are at present the only EAB natural enemy documented to impose more than single-digit mortality and because woodpeckers are already-established native

species, we encourage researchers to examine those features of habitat and woodpecker biology that interact to identify the role and effectiveness of woodpeckers as biocontrols.

Update on Emerald Ash Borer Natural Enemy Surveys in Michigan and China

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ABSTRACT

We began research on natural enemies of emerald ash borer (EAB), *Agrilus planipennis* soon after its discovery in Michigan and Ontario in 2002. Regulatory agencies in the United States and Canada adopted a strategy of eradication for EAB in an effort to protect New World ash. Should eradication fail, however, conventional biological control will be needed to suppress populations of this invasive buprestid. To this end, we are studying the natural enemies of EAB in Michigan and in China.

In 2003, we reported results from our 2002-2003 study of EAB natural enemies in a woodlot in Livonia, Michigan. Briefly, the most prevalent natural enemies of immature EAB were five species of insect pathogenic fungi, causing mortality in approximately 2 percent of EAB.. Potential larval-pupal parasitoids of immature EAB causing mortality in approximately 0.05 percent of EAB were three braconids (*Atanycolus* sp., *Heterospilus* sp., and *Spathius simillimus*), one chalcid (*Phasgonophora sulcata*), and an exotic eupelmid (*Balcha* sp.). A eulophid wasp, *Pediobius* sp., parasitized approximately 0.3 percent of EAB eggs.

This year we expanded our study of EAB insect parasitoids by sampling infested trees throughout southeastern Michigan's EAB infestation. In early spring, we cut 2-3 trees into logs from each of 14 study sites, stored the logs in a coldroom, and placed logs in cardboard emergence tubes; all insects emerging from the logs were counted each day. During July, we collected approximately 6,000 EAB eggs on small bark flakes from infested ash trees in each study site; the eggs were returned to the laboratory, placed in petri dishes sealed with parafilm, and held until hatch and parasitoid emergence was complete. Many of the hymenopterans are tentatively identified to family, although we have not yet sent out specimens for identification. Besides the same potential larval-pupal parasitoids found last year, we found an additional four unknown ichnuemonids, three unknown braconids, one unknown pteromalid, and two other unknown species. *Pediobius* sp. was the most prevalent egg parasitoid. Other hymenopterans emerging from egg/bark flakes include one encyrtid, two mymarids (*Ooctonus* and an unknown specie), two scelionids, two trichogrammids, and one unknown specie; their status as EAB egg parasitoids is unknown.

We surveyed ash for EAB infestation at sites in Heilongjiang, Jilin, Liaoning, Hebei, Tianjin, and Shandong Provinces in October-November 2003 to locate study sites for EAB natural enemy research. Plantings of Korean ash (*F. rhynchophylla*), Chinese ash (*F. chinensis)*, Manchurian ash (*F. mandchurican*), green ash (*F. pennsylvanica*), and velvet ash (*F. velutina*) were dissected for EAB in urban and rural areas along roadsides and fields and in parks and woodlots. We also looked for EAB attacking Korean and Manchurian ash in natural forests in Heilongjiang, Jilin, and Lioaning Provinces. EAB was present in each Province except Shandong, where velvet ash, a neoarctic species, is extensively planted due to its tolerance of saline soils. We learned the neoarctic ash species planted in China require pest management for EAB due to high susceptibility, and early efforts to maintain white ash (*F. americana*) in China failed due to EAB (Liu 1966). In general, native ash species in China sustain greater EAB infestation when transplanted than when grown in a natural forest.

During our initial survey, we found *Spathius* sp. (Braconidae) parasitizing 1 to 50 percent of the EAB larvae at sites in Changchun (Jilin Province) and Guangang (Tianjin Province). We also discovered an unknown gregarious endoparasitoid of EAB larvae at sites in Benxi (Liaoning Province) and Changchun (Jilin Province) and with a parasitism rate of 2.7 to 50 percent. Mature larvae, pupae, and adults were collected and later identified as *Tetrastichus* sp. (Eulophidae).

Based on these results, we established our 2004 study sites in Jilin and Liaoning Provinces in cooperation with local foresters to determine the species composition and seasonal abundance of EAB natural enemies. Larval parasitoids were similar to those species found at these sites in 2003. In addition, egg parasitoids reared from EAB eggs were identified as the encyrtid *Avetianella* sp.

Liu, Yiguo. 1966. A Study on the Ash Buprestid Beetle, Agrilus sp., in Shenyang. Annual Report. Shenyang Municipal Institute of Gardening-Forestry Science, Shenyang, Liaoning Province, China http://www.ncrs.fs.fed.us/4501/eab/translations/

Initial Studies on the Laboratory Rearing of Emerald Ash Borer and Foreign Exploration for Natural Enemies

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ABSTRACT

Rearing: We tested the possibility of rearing more than one pair of emerald ash borers (EAB) per cage to reduce the space required for rearing. We found, however, that EAB adults laid significantly fewer eggs per female when three or five pairs were reared together. We tested the effect of humidity on egg hatch by rearing eggs in sealed plastic boxes over saturated salt solutions. Percent hatch was highest in boxes with 75 percent humidity (compared with 25 percent and 50 percent), which was created with a solution of sodium chloride. We tested the development and survival of EAB larvae on five artificial diets:

1. Commercial boll weevil diet with 50 percent water,
2. *Hylobius* diet with ground ash bark instead of purple loosestrife,
3. Melanie Keena's asian longhorned beetle diet,
4. Ogura longhorned beetle diet, and
5. Cottonwood borer diet.

For each diet, we tested survival on diet packed into Petri dishes and crumbled into the dishes. We collected larvae from logs in Michigan at the end of July and the beginning of August. The larvae varied in size and were randomly placed on the 10 types of diet. Survival after one month was highest on the *Hylobius* diet (50 percent), followed by boll weevil (19 percent), Ogura (10 percent), MK2 (6 percent), and cottonwood borer (0 percent). On the *Hylobius* diet, 67 percent of the larvae were still alive after one month on the packed diet; only 35 percent were still alive on the crumbled diet. We also tested neonate larvae hatched in the laboratory. We have only tested eight individuals per diet type so far. We found, however, that after four weeks, 75 percent of the neonates reared on the packed *Hylobius* diet had molted to the second instar and 63 percent were still alive. No neonates survived on the crumbled *Hylobius* diet of on any of the other artificial diets.

Creating populations of EAB by moving tree wrap: The EAB is typically difficult to find in China because it has a low population density. This complicates exploration for effective natural enemies. We decided to explore the possibility of using trap plants infested with EAB to

move into areas with low density EAB populations to attract natural enemies. We erected nine screen cages, placed oviposition substrates in them, and released adult EAB into the cages. We tested potted boles, logs, and potted trees (from a nursery). All three treatments proved to be heavy and cumbersome, so we decided to see whether the EAB would lay eggs on tree wrap wrapped around the trunks of the trees. The EAB readily laid eggs on the tree wrap on nursery trees but laid very few eggs on the potted boles and the potted logs. Eggs were laid on tree wrap wrapped around park and street trees in areas where there were many EAB adults flying. Prior to egg hatch, we moved the tree wrap to a site within the quarantine area but which did not yet have populations of EAB. Twenty-seven percent of the eggs on the tree wrap hatched, and 13 percent of the larvae produced galleries in the tree trunks. While the percentages on our first try were low, we feel that this validates the concept of creating populations of EAB larvae by moving tree wrap infested with EAB eggs.

Exploration for EAB Natural Enemies in China: In September 2004, Juli visited Dr. Yang Zhong-qi of the Chinese Academy of Forestry, who has been studying EAB and its natural enemies for several years. The first site visit was to Tianjin City, where there are plantings of *Fraxinus velutina* that are heavily attacked by EAB. There they found the braconid parasitoid *Spathius* parasitizing EAB larvae. This ecto-parasitoid has four generations per year and is well synchronized seasonally with the availability of its hosts, third and fourth instar EAB. The next field site was in Changchun, Jilin Province. Here they found a moderately heavy infestation of EAB on *Fraxinus mandshurica.* The most prevalent parasitoid at this site was a Eulophid in the genus *Tetrastichus,* but braconid pupae were also found. considerable time was spent looking for EAB in the Changbaishan Mountains near the Korean border. Most of the ash trees were very healthy and showed no signs of EAB attack. However, they did find four ash trees that had been girdled.

All four trees were heavily attacked by EAB, showing that this beetle is present in the area and will attack girdled trees. Dr. Yang has initiated host specificity testing. To date, he has tested eight species (mostly Lepidoptera) and has found no evidence of attack by *Spathius*. He plans to test *Agrilus mali* and *Agrilus citri* soon. Dr. Yang will ship *Spathius* to the U.S., where we will see if it attacks *Agrilus anxius, Agrilus bilineatus,* or other borers.

Taxonomic Status of Two Recently Discovered Natural Enemies of the Emerald Ash Borer Found in China

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Soon after the magnitude of the emerald ash borer (EAB) threat to North American ash was determined, a Sino-American program was developed to study the potential for biocontrol. During the natural enemies investigation in China, a species of *Spathius* Nees was discovered attacking EAB larvae by Yang Zhong-Qi of the Chinese Academy of Forestry in Beijing. With 300 species described world-wide and many undescribed species known to exist, a team of systematists led by Dr. Yang was formed to determine if this was a new species and facilitate publishing a description. Individuals involved include Paul M. Marsh (USA), Sergey A. Belokobylskij (Russia), C. van Achterberg (Netherlands), and John S. Strazanac (USA). Type material was examined in London, Washington, D.C., and Beijing. It was determined to be a new species, and a manuscript with its description and biological observations has been prepared for publication.

A second species was later found attacking EAB larvae by Dr. Yang's team. It is a *Tetrastichus* species (Eulophidae), and it also appears to be new to science. A manuscript by Dr. Yang with its description has been reviewed by chalcidoid systematists at AgCanada in Ottawa (John T. Huber and Gary A. P. Gibson) and USDA-ARS Systematics Laboratory (Michael W. Gates and Michael E. Schauff) in Washington, D.C.

EMERALD ASH BORER: REGULATORY TREATMENT

Emerald Ash Borer Survival in Firewood

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ABSTRACT

The emerald ash borer (EAB), *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), is native to Asia and was first discovered in Michigan and Ontario in 2002. As of October 2004, EAB was only found to breed in ash (*Fraxinus*) trees in North America. 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 EAB adults are present throughout the summer, larval development is not highly synchronized, and therefore, EAB life stages can be found beneath the bark of infested trees throughout the year. As is typical for *Agrilus*, early larval stages require living hosts. Therefore, if infested trees are cut early during larval development, the host tissues should dry and thus reduce *Agrilus* survival.

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 tracked the following treatment parameters: month of felling, sun vs. shade storage, split vs. whole bolts, and tarped vs. not tarped. Exit holes were counted in late summer 2004. Again, EAB were able to survive and emerge from all treatment combinations. However, survival was significantly lower on logs cut early during larval development (July and August) and lower on split wood, especially for wood cut and split in July. Direct sunlight reduced EAB survival, especially for the earliest cut logs. Tarping either had no apparent effect on EAB survival or enhanced it. Perhaps the tarps that we used reflected a great deal of sunlight and thus temperatures beneath the tarps did not reach lethal levels.

Results from these studies indicate that even converting infested trees to firewood in July is not early enough to stop all EAB larvae from completing development and emerging as

adults in the following year. We will monitor some of the firewood cut in 2003 to determine if any EAB adults emerge in 2005 (the second summer post-felling). If no adults emerge in 2005, this would indicate that firewood cut during summer of year 1 needs to be kept until at least the fall of year 2 before it could be safely moved.

Survival of Emerald Ash Borer in Chips

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ABSTRACT

The ability of emerald ash borer (EAB), *Agrilus planipennis* Fairmaire, to survive following chipping or grinding of infested ash trees remains a critical question for regulatory officials. In October 2002, we felled eight infested ash trees and sampled sections of the trunk and large branches from each tree to estimate EAB density. We estimated that at least 9,400 to 10,000 EAB, primarily in the prepupal stage, were present in the eight trees. Each tree was loaded into a grinder at a marshalling yard in southeast Michigan and processed; half of the wood of each tree passed through a screen with 1-inch diameter holes and the rest of the wood passed through a screen with 4-inch diameter holes. We intensively inspected samples of 1" and 4" chips for evidence of EAB survival. We also checked the relatively large chips in each pile to determine if they contained an EAB life stage. Material that passed through the 1" screen was ground to a fine, "chaff-like" consistency and we found no evidence that any EAB had survived the grinding process. In the pile of 4" chips, however, we found at least eight pieces of wood with intact prepupae.

We next investigated survival of EAB in chip piles over the winter. We prepared 45 sentinel chips by chiseling small sections of wood (approx. 6 x 3 x 1 cm) containing live overwintering prepupal or L4 larvae from infested ash logs and attaching a long section of nylon twine to each chip. In late October, we buried 22 sentinel chips 15 to 35 cm deep within the 1" chip pile (roughly 3.8 m^3 volume) and 23 sentinel chips in the 4" chip pile (2.9 m^3 volume). Temperature-recording dataloggers were used to monitor temperatures on and within each chip pile. Six infested ash logs (6 to 25 cm diam.), also cut in late October, were set next to the chip piles.

Sentinel chips were retrieved from the chip piles and examined on 29 April 2003. Live EAB were held to monitor survival to the adult stage. On 4 May 2003, the chip piles were moved into screen tents and ten sticky cards were suspended in each tent to capture any adult beetles that emerged from the piles. Logs that had been placed near the chip piles were dissected in early May to estimate overwintering survival.

Six of the EAB prepupae in the 45 sentinel chips (13.3 percent) survived the winter. In comparison, 32 of the 35 prepupae (91 percent) in the logs stacked adjacent to the chip piles survived the winter. Temperatures within the chip piles ranged from -18 to 39C (-2 to 102F) between October 2002 and May 2003. Temperatures in the chip piles tracked ambient temperatures closely, indicating that little heat was generated from decomposition in our relatively small chip piles. No EAB adults were captured in the screen tents.

To further evaluate the effects of temperature on EAB survival, we chiseled 56 bark sentinel chips and 56 wood sentinel chips from infested logs on 1-7 April 2004. Each chip contained a live EAB prepupae. We filled 28 plastic boxes, each 30 x 22 x 12 cm, with ash chips collected at a marshalling yard. We placed four bark sentinel chips or four wood sentinel chips in each box of ash chips and held all boxes in growth chambers at 25°C for 3 days to allow the EAB prepupae to acclimate.

On 10 April, two boxes with bark sentinel chips and two boxes with wood sentinel chips were assigned to a temperature and time treatment which included exposure to 40°C for 8, 24 or 48 hours or exposure to 60°C for 8, 24, or 48 hours. Four additional boxes (two with bark sentinel chips and two with wood sentinel chips) were left at a constant 25°C. After exposure to the designated temperature and time treatments, boxes were returned to 25°C and held until 15 June. Sentinel chips were checked daily from 1 May to 15 June and adult emergence or observations of dead EAB were recorded. All sentinel chips were dissected on June 15.

Five of the eight EAB prepupae in the bark sentinel chips and seven of the eight EAB in wood sentinel chips that were exposed to constant 25°C survived. When bark sentinel chips were held at 40°C, a total of four, three, and three of the original eight EAB survived exposure for 8, 24, and 48 hours, respectively. A total of seven, eight, and six EAB survived in the wood chips exposed to 40°C for 8, 24, and 48 hours, respectively. No EAB survived exposure to 60°C in any of the bark or wood chips, regardless of the duration of exposure. Further assessments of EAB survival at temperatures between 40 and 55°C are planned.

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