# Emerald Ash Borer:

# Strategies for Conserving Ash in the Urban Forest

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DAVEY

TREE FUND
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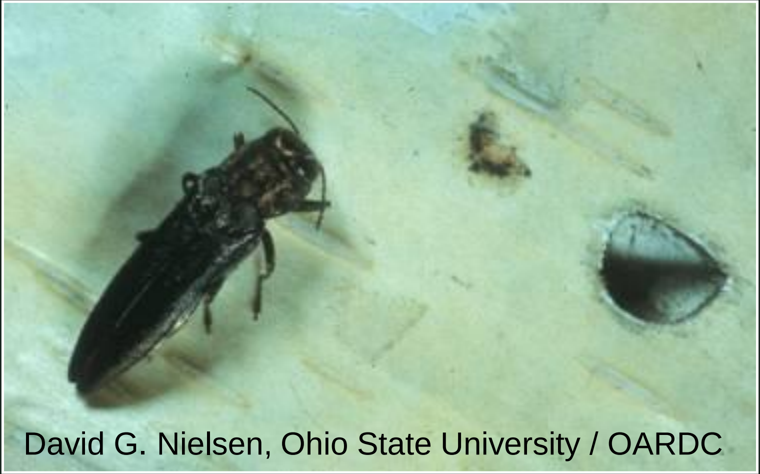
Emerald Ash Borer:

*Agrilus planipennis*

# Coleoptera: Buprestidae
## metallic wood-boring beetles

Emerald ash borer


David G. Nielsen, Ohio State University / OARDC

Bronze birch borer

Twolined chestnut borer


Robert A. Haack, USDA Forest Service, www.forestryimages.org

# Host Impact:

Larvae feed under bark; disrupt transport of water, nutrients, carbohydrates.

All major ash species are susceptible (and white fringetree).

Healthy trees killed within 1-3 years of first symptoms.

Trees of all size are colonized:
1/2 inch saplings to largest mature trees.

# Untold millions of dead ash trees (and increasing exponentially)

# Life cycle:  1-2 years / generation

Adults: June - August

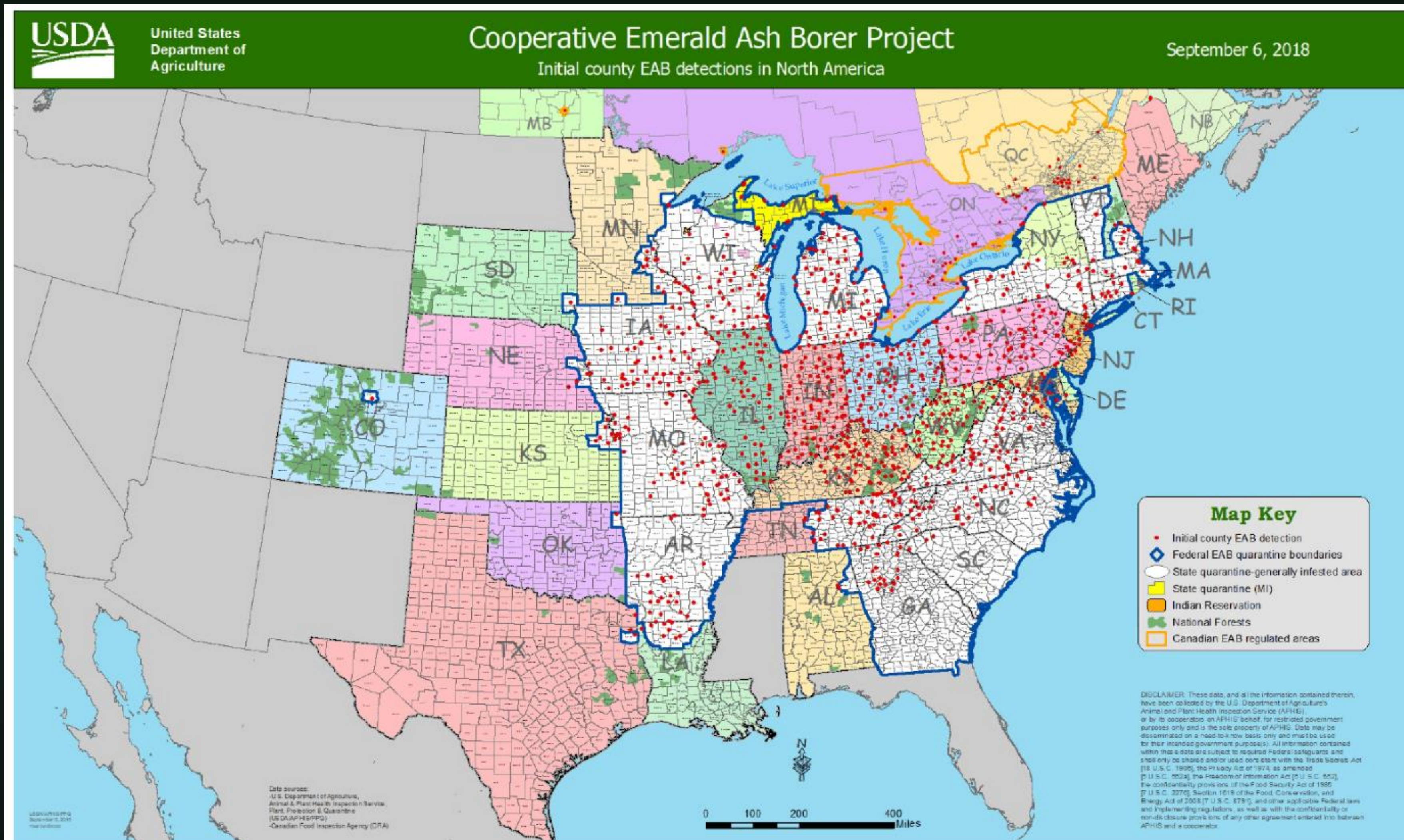
Larva:  July - Sept

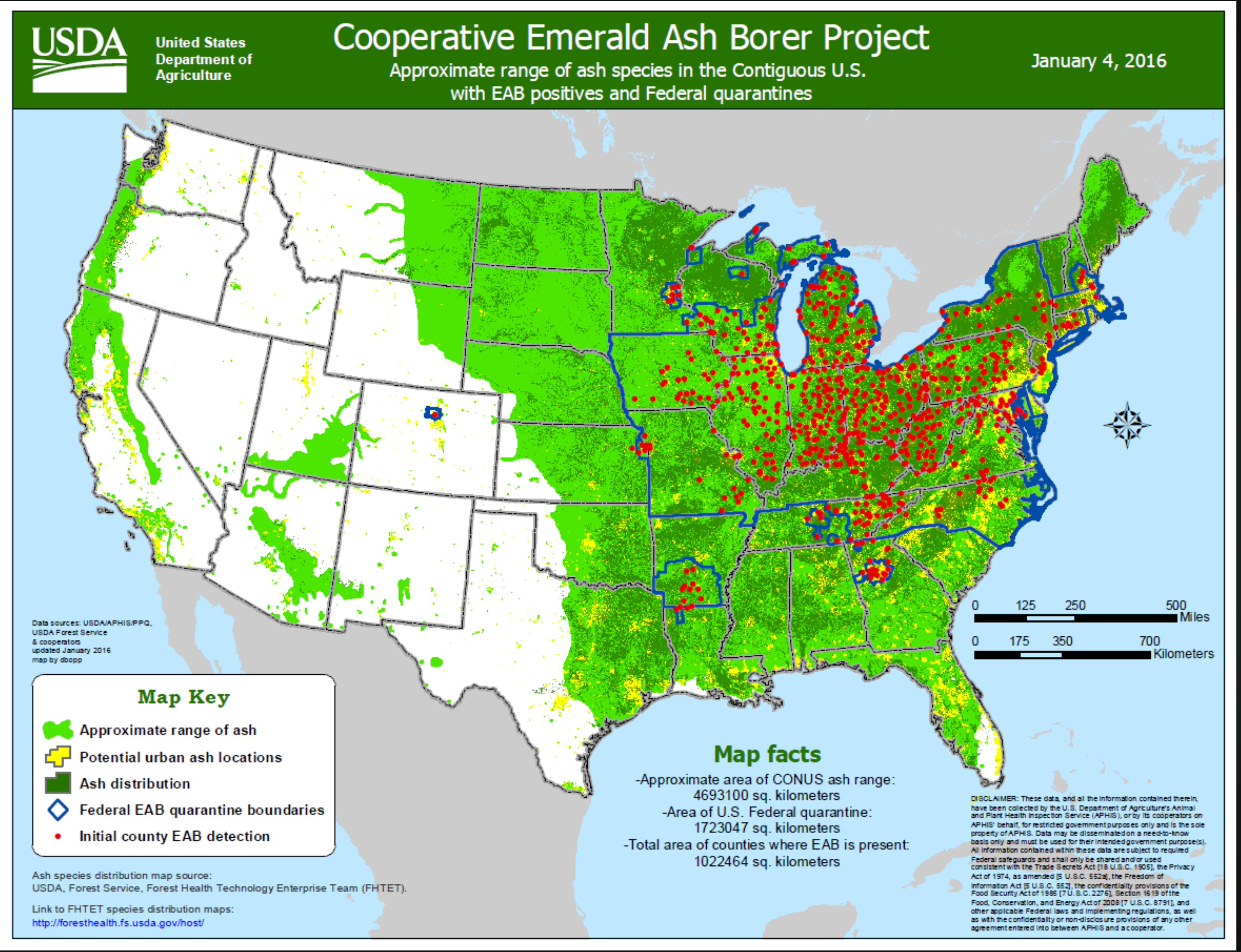
Prepupa:
Oct – April

Pupa: May –
June

Adults feed for 7-14 days before they mate and lay 50-200 eggs

# Known distribution of EAB in North America





USDA
United States Department of Agriculture
Cooperative Emerald Ash Borer Project
Approximate range of ash species in the Contiguous U.S. with EAB positives and Federal quarantines
January 4, 2016
0 125 250 500 Miles
0 175 350 700 Kilometers
Data sources: USDA/APHIS/PPQ, USDA Forest Service & cooperators
updated January 2016
map by dbopp
Map Key
Approximate range of ash
Potential urban ash locations
Ash distribution
Federal EAB quarantine boundaries
Initial county EAB detection
Map facts
-Approximate area of CONUS ash range: 4693100 sq. kilometers
-Area of U.S. Federal quarantine: 1723047 sq. kilometers
-Total area of counties where EAB is present: 1022464 sq. kilometers
Ash species distribution map source:
USDA, Forest Service, Forest Health Technology Enterprise Team (FHTET).
Link to FHTET species distribution maps:
http://foresthealth.fs.usda.gov/host/
DISCLAIMER: These data, and all the information contained therein, have been collected by the U.S. Department of Agriculture's Animal and Plant Health Inspection Service (APHIS), or by its cooperators on APHIS' behalf, for restricted government purposes only and is the sole property of APHIS. Data may be disseminated on a need-to-know basis only and must be used for their intended government purpose(s). All information contained within these data are subject to required Federal safeguards and shall only be shared and/or used consistent with the Trade Secrets Act [18 U.S.C. 1905], the Privacy Act of 1974, as amended [5 U.S.C. 552a], the Freedom of Information Act [5 U.S.C. 552], the confidentiality provisions of the Food Security Act of 1985 [7 U.S.C. 2276], Section 1619 of the Food, Conservation, and Energy Act of 2008 [7 U.S.C. 8791], and other applicable Federal laws and implementing regulations, as well as with the confidentiality or non-disclosure provisions of any other agreement entered into between APHIS and a cooperator.

Outlier infestations result from movement of infested ash trees and wood.

# How fast do EAB infestations spread?

- Flight mill lab studies:  EAB can fly several miles / day
- Transect studies and field analyses found that small infestations spread less than ½ mile per year.
- Infestations spread faster as they grow and  peripheral populations coalesce
- Zone of ash decline in SE Michigan and NW Ohio spread about 15-20 miles / yr.

Dave Shetlar, Ohio State University

# Symptoms of EAB: dieback and decline

Epicormic branching

Thinning canopy

Suckering from roots

# Diagnosing emerald ash borer: 3 key signs

1. Small (1/8”) D-shaped exit holes

2. Serpentine galleries just under the bark

3. Flat, tapeworm-like larvae with bell-shaped segments.

# Early warning: unusual woodpecker activity

Joseph Kosack

# Early warning:  bark splitting

# Native borers are extremely common.

Clearwing borers (stressed trees):

- Banded ash clearwing borer
- Ash / lilac borer

Roundheaded borers (dieing / dead trees):

- Redheaded ash borer
- Banded ash borer
- Ash and privet borer

Bark beetles (dieing / dead trees):

- Eastern ash bark beetle

# Banded Ash Clearwing Borer

David G. Nielsen, Ohio State University / OARDC

# Distinguishing exit holes of ash borers:


## Emerald ash borer

Shape: D-shaped

Width: 3 mm (1/8”)


## Banded ash clearwing borer

Shape: Round

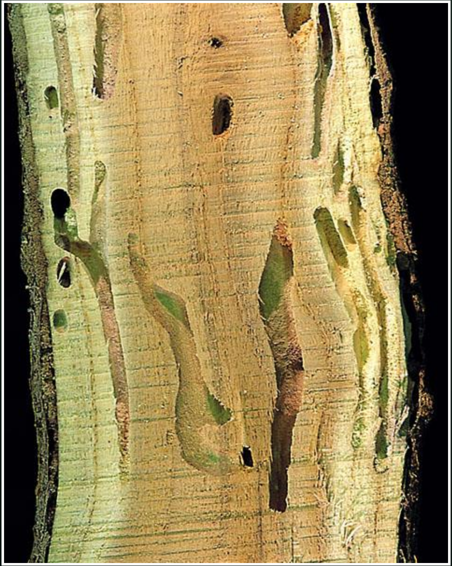
Width: 6 mm (1/4”)


## Redheaded ash borer

Shape: oval - round

Width: 6 mm (1/4”)

# Redheaded Ash Borer



G Csoka, Hungary For Res Inst.,
www.forestryimages.com

# Eastern Ash Bark Beetle

Images: J Solomon, USDA Forest Service, www.bugwood.org

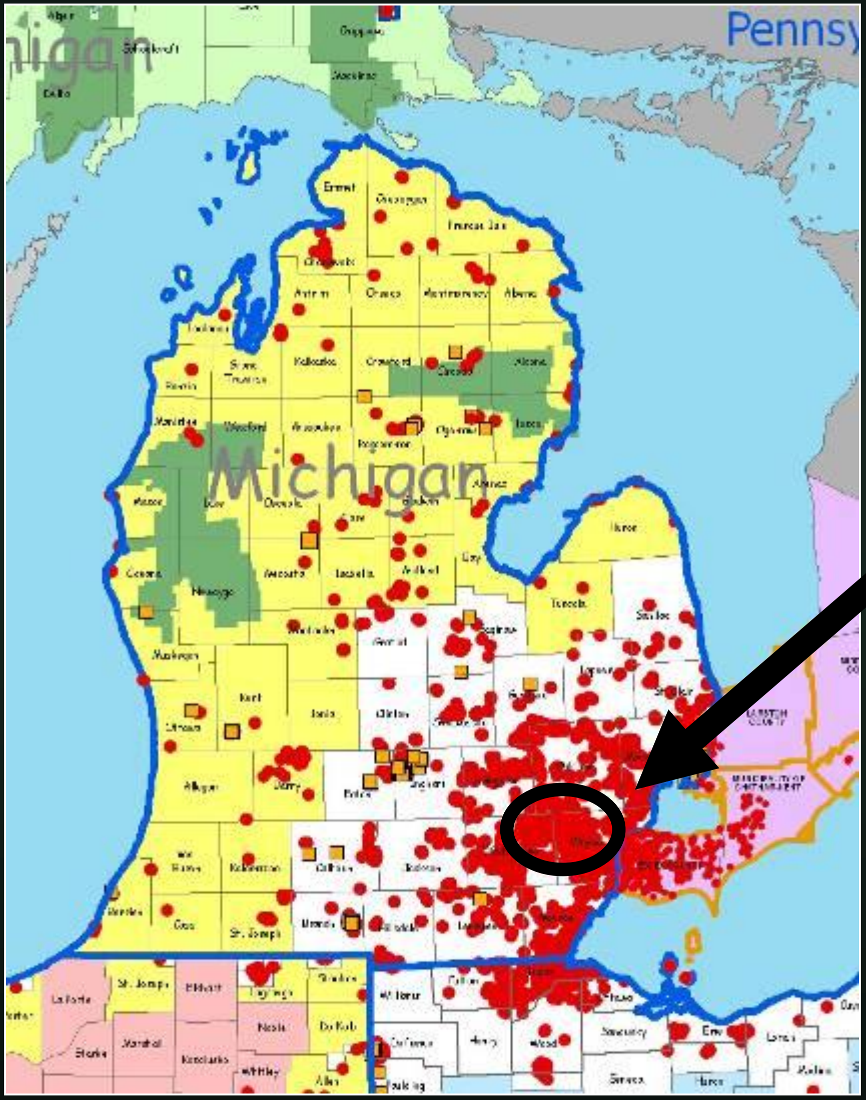
# Rapid ash mortality in the urban forest

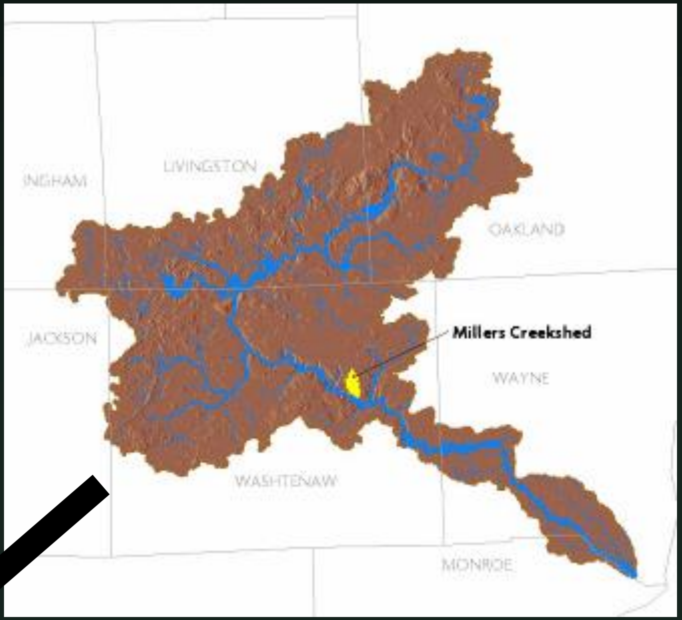
June 2006

August 2009

# Patterns of ash mortality in forests near the epicenter of the North American invasion

# Upper Huron River Watershed






- 38 forested stands
- 3 plots (0.1 ha) / stand

# Huron River Watershed

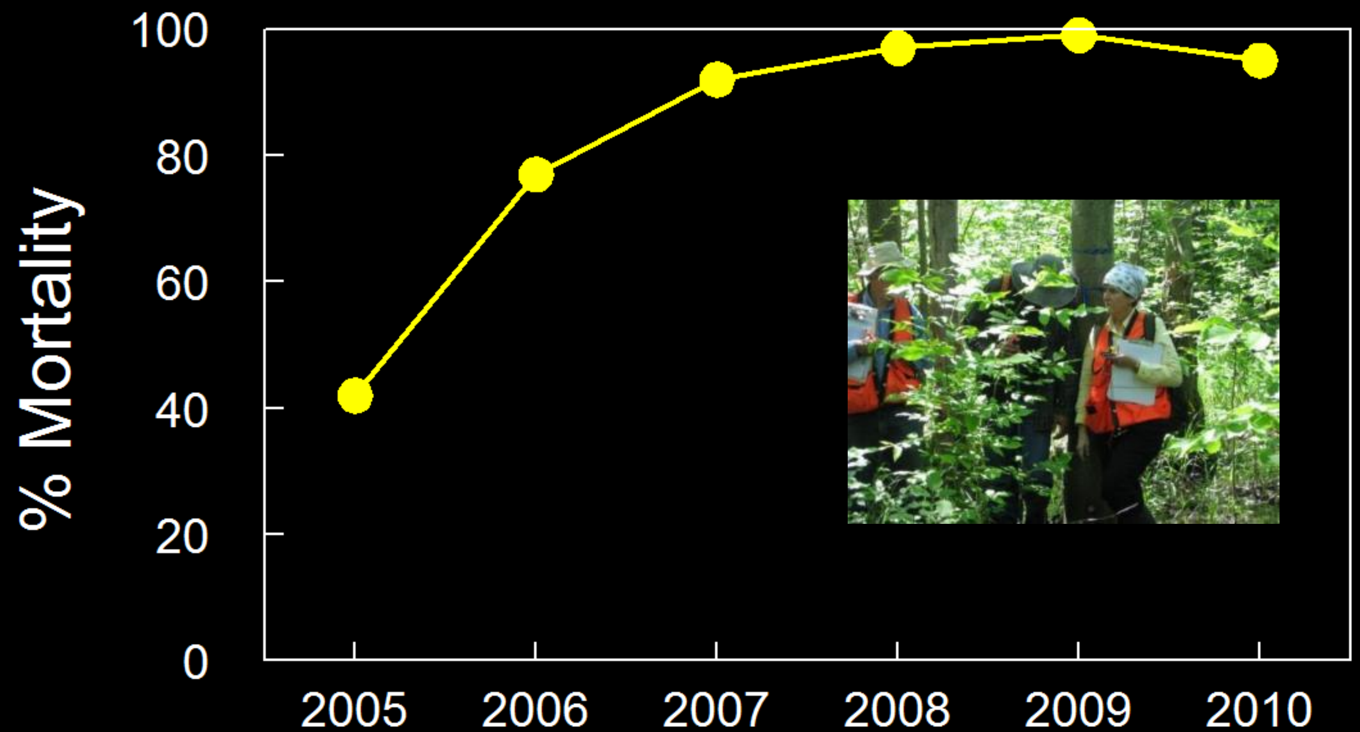
**White Ash** **Green Ash** **Black Ash**

>50% Species Dominance

**Increasing Moisture Gradient**

**Smith (2006)**

# Percent Ash Mortality (> 2.5 cm dbh)



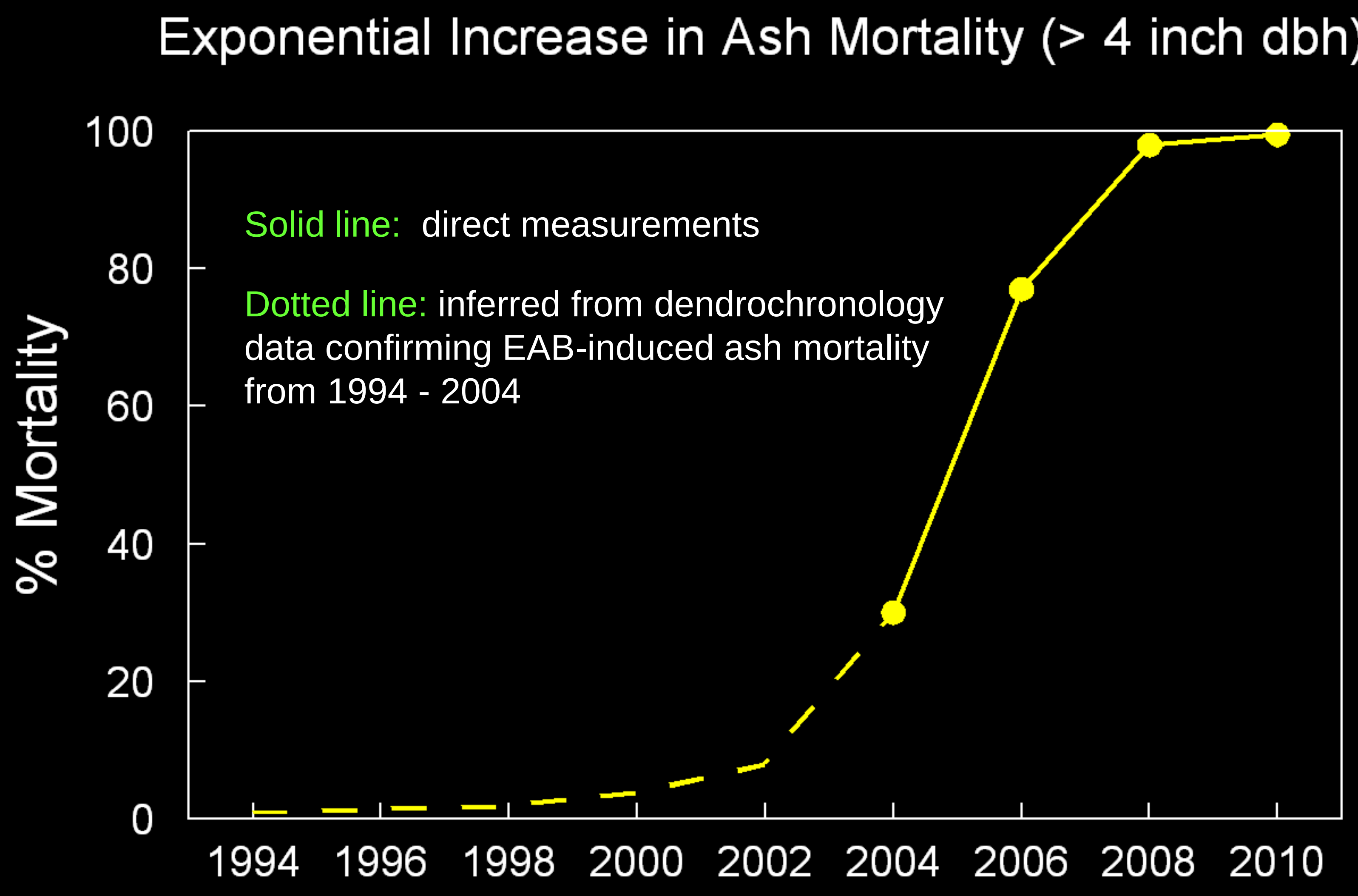

Biol Invasions
DOI 10.1007/s10530-013-0543-7

ORIGINAL PAPER

**Ash (*Fraxinus* spp.) mortality, regeneration, and seed bank dynamics in mixed hardwood forests following invasion by emerald ash borer (*Agrilus planipennis*)**

**Wendy S. Klooster · Daniel A. Herms · Kathleen S. Knight · Catherine P. Herms · Deborah G. McCullough · Annemarie Smith · Kamal J. K. Gandhi · John Cardina**

# EAB-Induced Ash Mortality in the Upper Huron River Watershed, SE Michigan



# Classical biological control:

Asian parasitoids discovered and released by USDA APHIS and US Forest Service:

## Larval parasitoids

*Tetrastichus planipennisi*

*Spathius agrili*

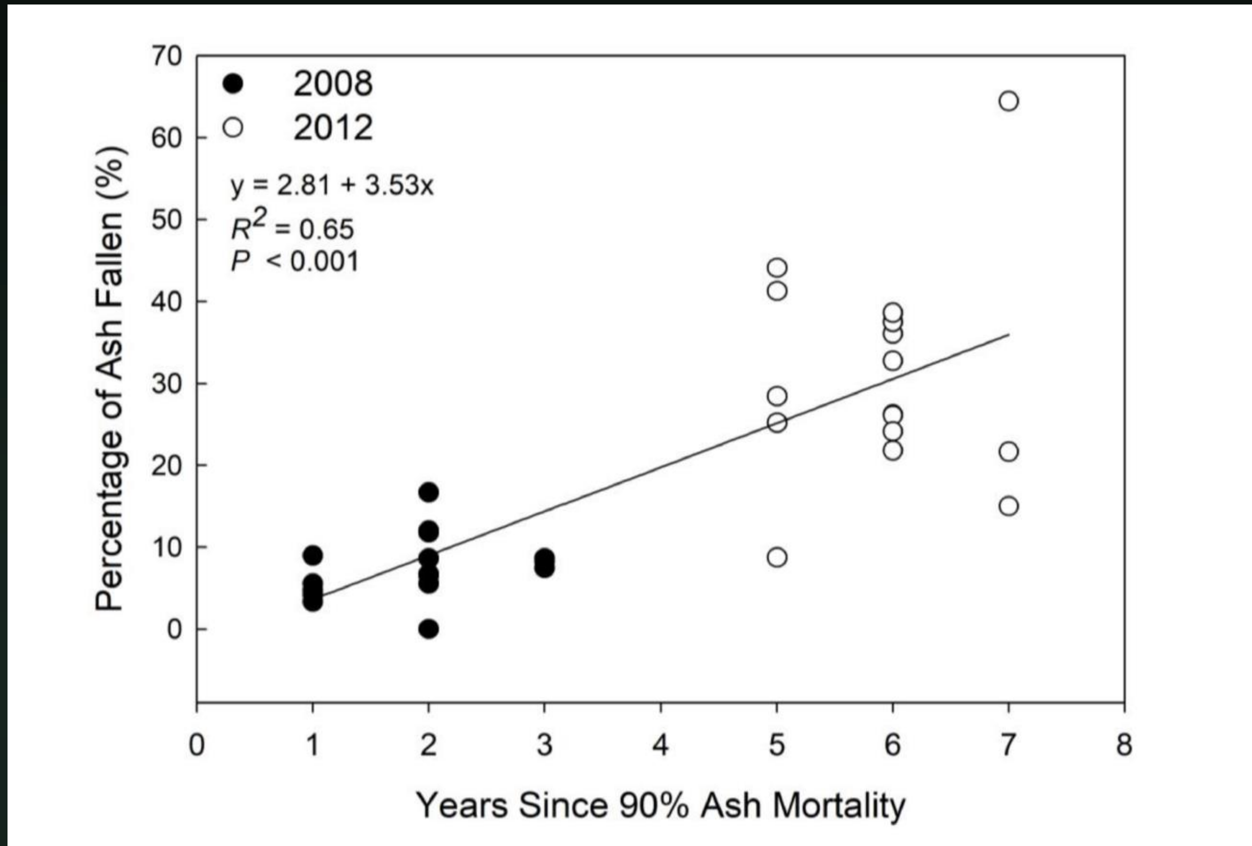
*Spathius galinae*


## Egg parasitoid

*Oobius agrili* (egg parasitoid)

# Biocontrol of EAB and the fate of the orphaned cohort?


# Ash snap: dead ash trees are hazards




*forests*

MDPI

*Article*

**Downed Coarse Woody Debris Dynamics in Ash (*Fraxinus* spp.) Stands Invaded by Emerald Ash Borer (*Agrilus planipennis* Fairmaire)**

Kayla I. Perry [1,*], Daniel A. Herms [1,2], Wendy S. Klooster [3], Annemarie Smith [1], Diane M. Hartzler [1], David R. Coyle [4,5] and Kamal J. K. Gandhi [4]

## EAB management options:

1. Do nothing, let nature take its course.

2. Removal, replacement (tree inventories are critical for planning / preparation).

3. Sustained insecticide treatments.

4. Integration of all of the above.

# Multi-year evaluation of systemic insecticides for control of EAB on street trees

- Soil treatments: Imidacloprid and Dinotefuran

- Trunk injections: Imidacloprid, Emamectin Benzoate, Azadirachtin

- Systemic basal trunk sprays: Dinotefuran

# Trunk Injections vs. Soil Treatments

Trunk injections:

Less environmental exposure.
Faster uptake and distribution in tree.
Some products more effective on larger trees.
Rate of uptake is weather dependent.
Distribution in tree may not be uniform.
Invasive:  wounding and compartmentalization.

Soil treatments:

Non-invasive.
More uniform distribution in the tree.
Can be applied under diverse environmental conditions.
Can be applied during dormant season.
Don’t require specialized equipment.
Slower uptake.
No way to know how much uptake.

## Key questions:

Will systemic treatments work on larger trees?

What are optimal application rates?

Are fall treatments effective?

How long will treatments remain effective?

How do various products compare?


Canopy decline (thinning) rating scale: 0-100%

Smitley et al. 2008. *J. Econ. Entomol.* 101:1643-1650

# Treatment evaluation:

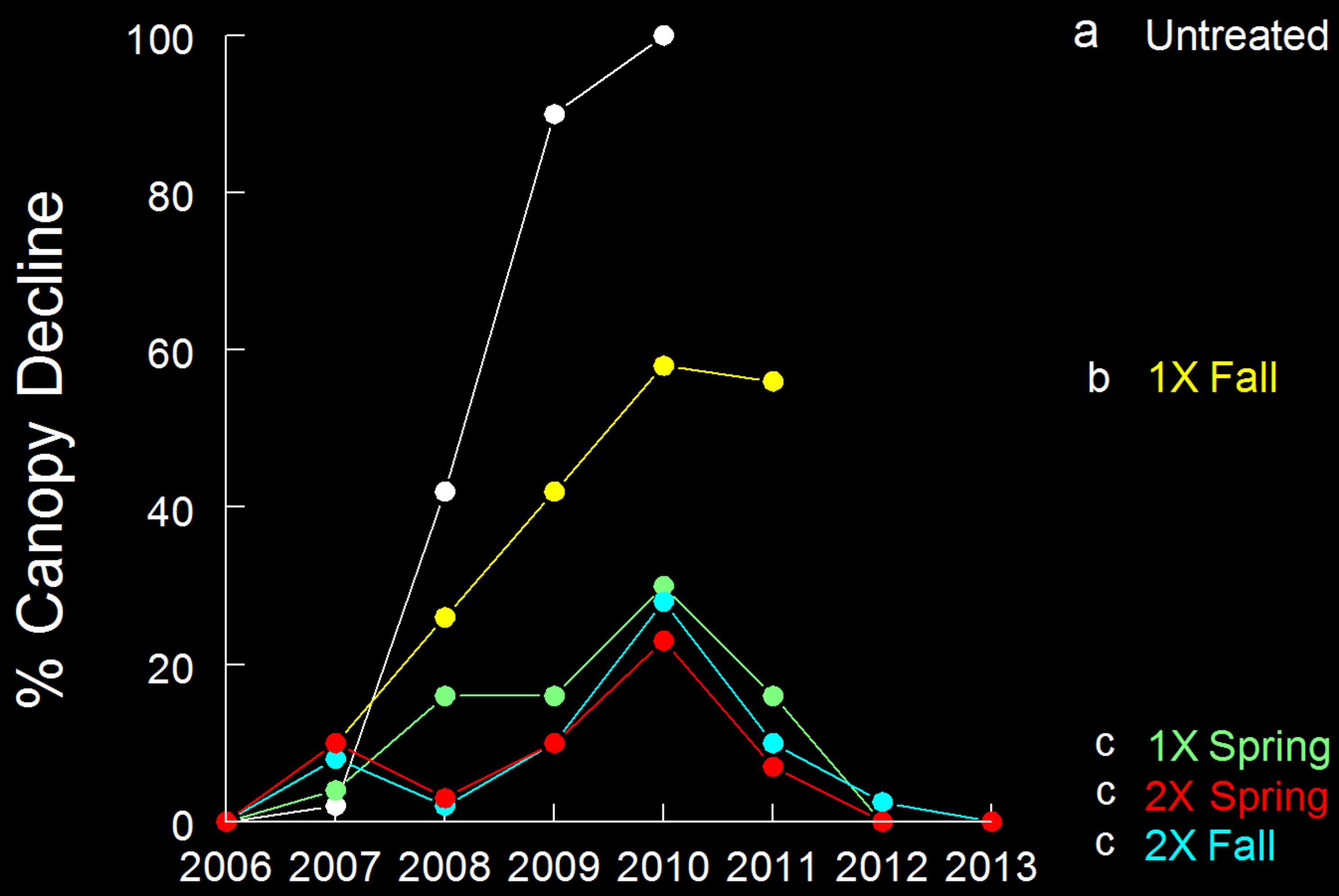
- Canopy decline rating using photographic scale (Smitley et al. 2008. *J. Econ. Entomol.* 101:1643-1650)

- Exit hole density in canopy branches.

# Imidacloprid Soil Drenches

| | |
|---|---|
| 1X rate (1.4 g ai / inch DBH) | spring |
| 1X rate (1.4 g ai / inch DBH) | fall |
| 2X rate (2.8 g ai / inch DBH) | spring |
| 2x rate (2.8 g ai / inch DBH) | fall |

# Imidacloprid Soil Drenches
## (16-23 inch DBH)



2006

2009

# Implications for long-term management of EAB

Reduced treatment intensity:

1. Treat annually 2006-2011.

2. Treat 2/3 of trees on rotating basis 2012-2014

3. No treatment 2015-2016

2013

# Implications for long-term management of EAB??

August 2016

Placement? Fine root density is highest adjacent to the trunk.

# Emamectin Benzoate: duration of control at different rates (DBH: 20-25”)

## Emamectin benzoate (Tree-äge)

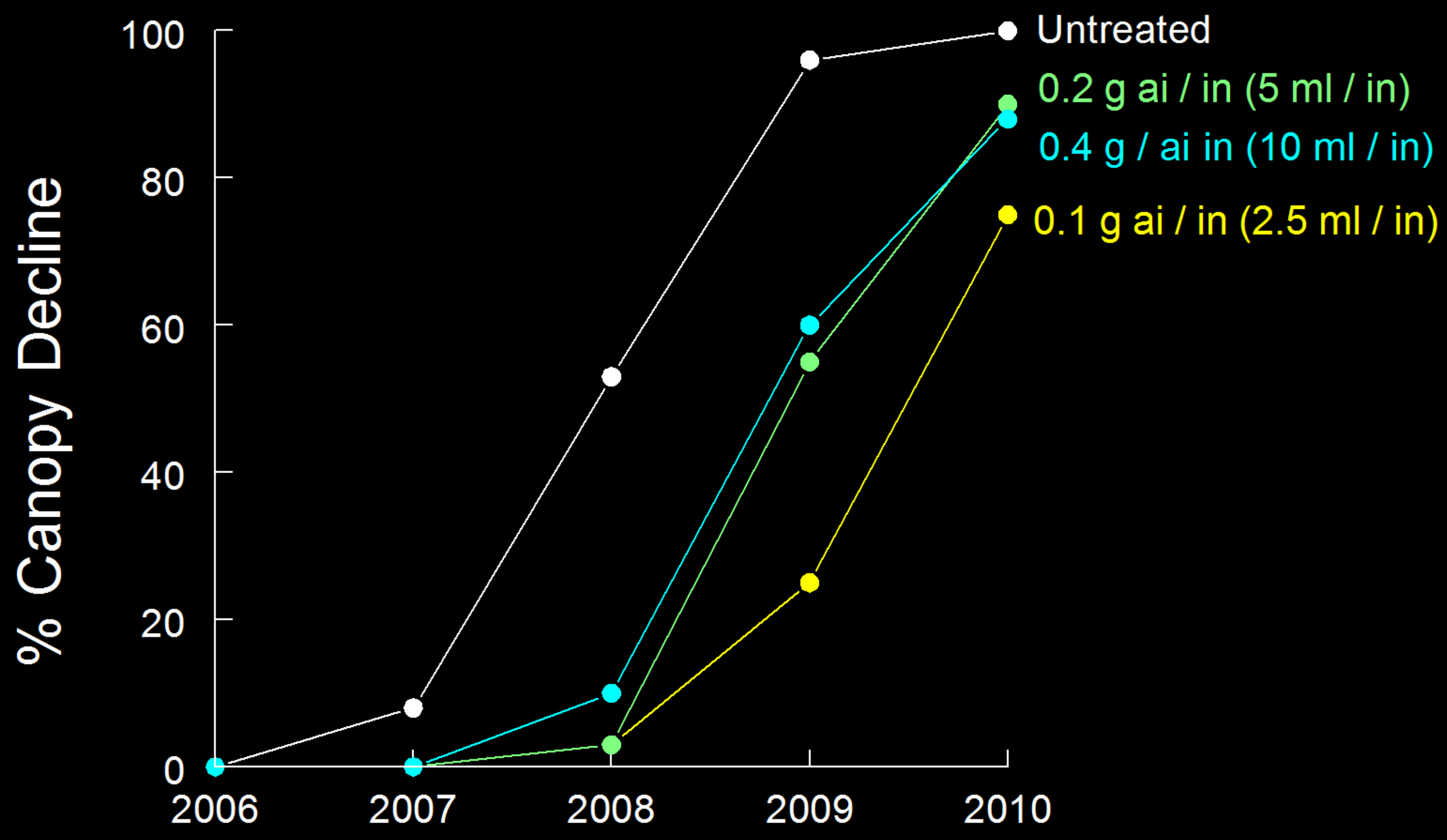
0.1 g ai / inch DBH (2.5 ml / inch - low)

0.2 g ai / inch DBH (5 ml / inch – med)

0.4 g ai / inch DBH (10 ml / inch – med / high)

Treat in 2006 and see how long they work.

# Emamectin benzoate, applied June 2006: 3 yrs control (20-25 inch DBH)



# Emamectin Benzoate, applied June 2006

| Treatment | Exit Holes / $m^2$ 2008 (2 yrs) | Exit Holes / $m^2$ 2009 (3 yrs) |
|---|---|---|
| Untreated | 19.2 a | 24.6 a |
| 0.1 g ai / inch DBH | 0.2 b | 2.9 c |
| 0.2 g ai / inch DBH | 0.5 b | 10.1 ab |
| 0.4 g ai / inch DBH | 1.4 b | 3.3 c |

2006

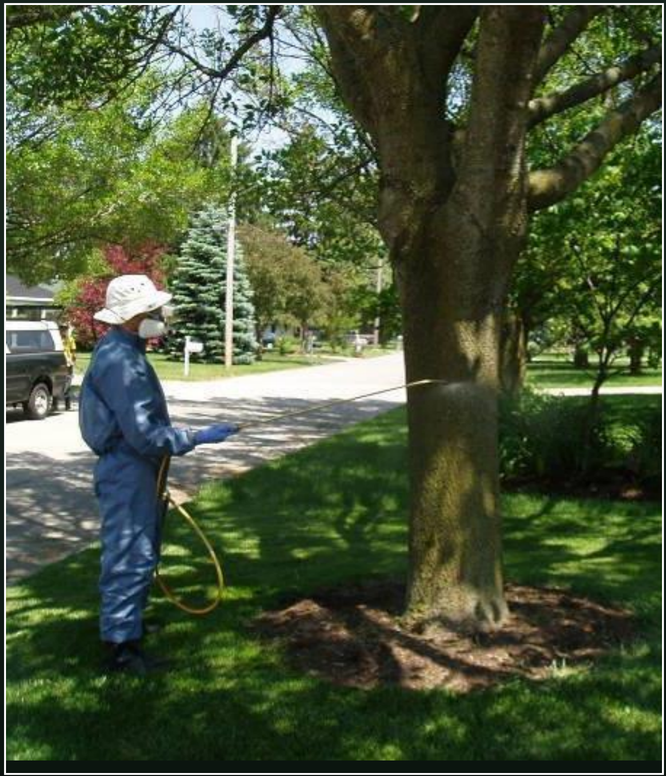
2009

# Emamectin Benzoate Comparison
## Treatments May 2012; Evaluated August 2014

| Treatment | Larvae / tree |
|---|---|
| Untreated | 52.0 b |
| Imidacloprid (1.4 g a.i. / inch) | 110.4 a |
| Tree-AGE (10 ml / inch) | 0.2 b |
| ArborMectin (10 ml / inch) | 6.6 ab |

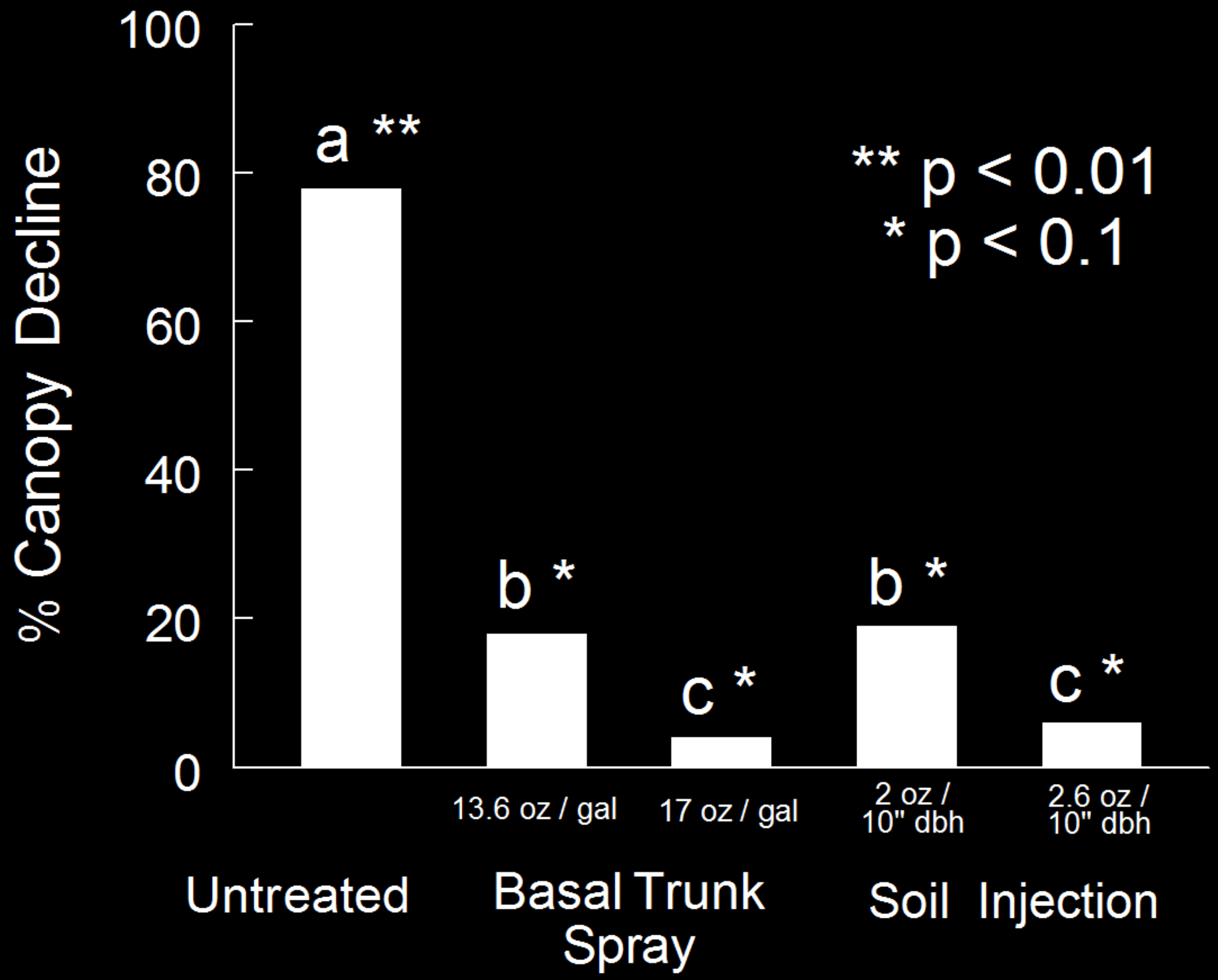
# Safari (Dinotefuran) Trials in Bowling Green

- Basal trunk sprays
- Low volume soil injection



# Dinotefuran (Safari) Treatments for EAB

Treated 2008-2012; evaluated 2013

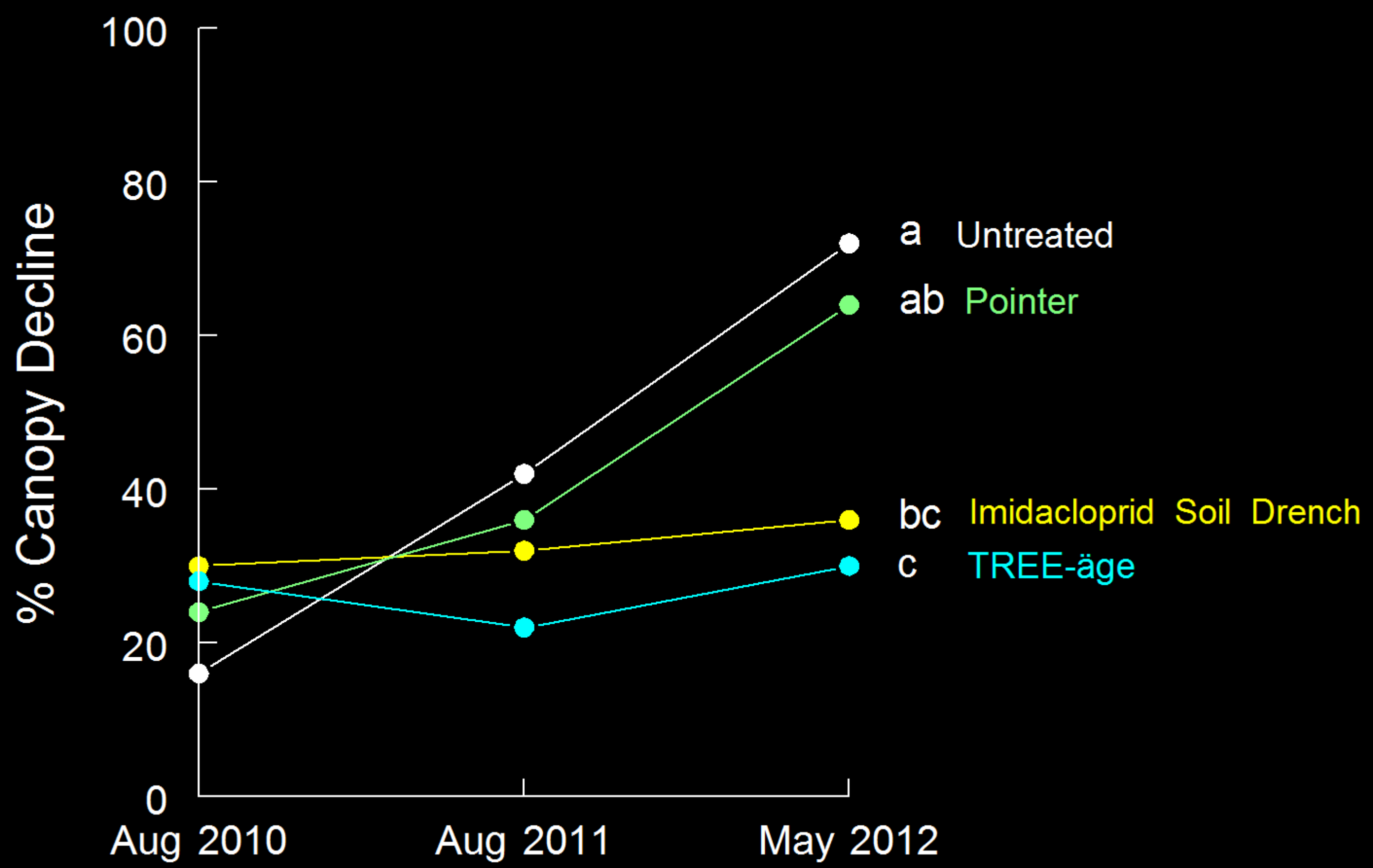


# Product Comparison: 2010-2012

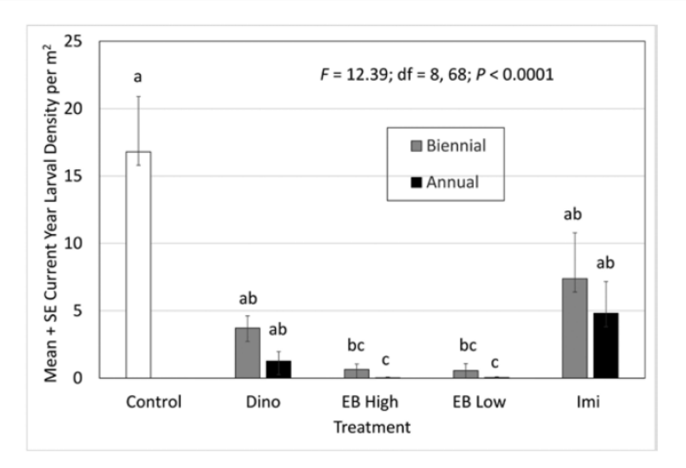
1. Untreated control
2. Pointer (labeled rate)
3. TREE-äge (med rate)
4. Imidacloprid soil drench (highest rate)

# Comparison of Systemic Insecticides for Control of EAB

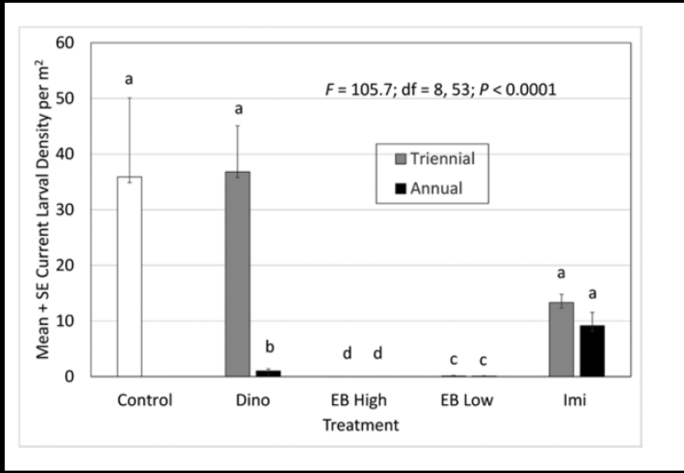
Imidacloprid applied 11 June 2010 and 9 June 2011;
TREE-äge applied in 2010 only



# Comparison of Systemic Insecticides (2008-2013; 8-12" DBH)




Treated every two years




Treated every three years

McCullough et al. (2018) *J. Econ. Entomol*. Doi:10.1093/jee/toy282

# Effect of Emamectin Benzoate for Control of EAB on big trees (32-47 inch DBH)

# Effect of Emamectin Benzoate for Control of EAB on big trees (32-51 inch DBH)

treated 2010, 2012, 2014

| Treatment | % Canopy Decline | | | | |
|---|---|---|---|---|---|
| | 2010 | 2011 | 2012 | 2013 | 2015 |
| 0.2 g ai / inch DBH (5 ml / in) | 10 | 13 | 6 | 1 | 1 |
| 0.4 g ai / inch DBH (10 ml / in) | 11 | 14 | 7 | 1 | 2 |

# Trunk Injections Wounds

## Tree IV

Smith & Lewis 2005

## Wedgle

Arboriculture & Urban Forestry 2011. 37(1): 6–12

## Tree Wound Responses Following Systemic Insecticide Trunk Injection Treatments in Green Ash (*Fraxinus pennsylvanica* Marsh.) as Determined by Destructive Autopsy

Joseph J. Doccola, David R. Smitley, Terrance W. Davis, John J. Aiken, and Peter M. Wild

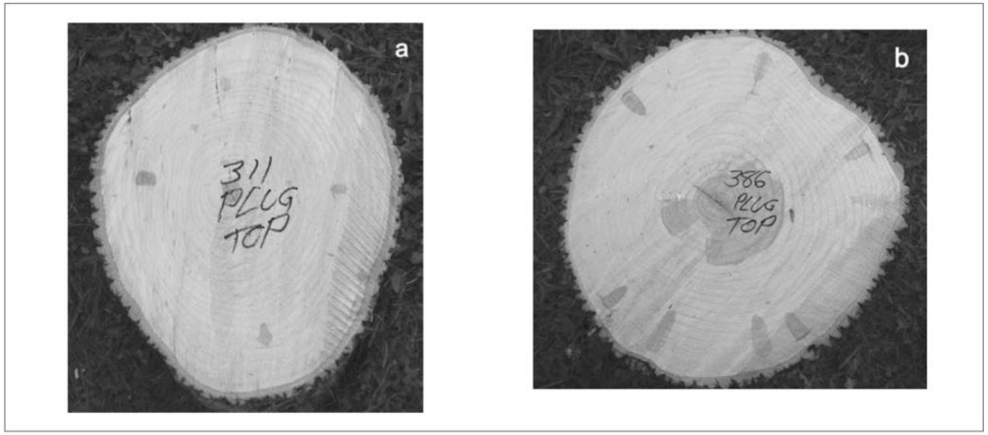


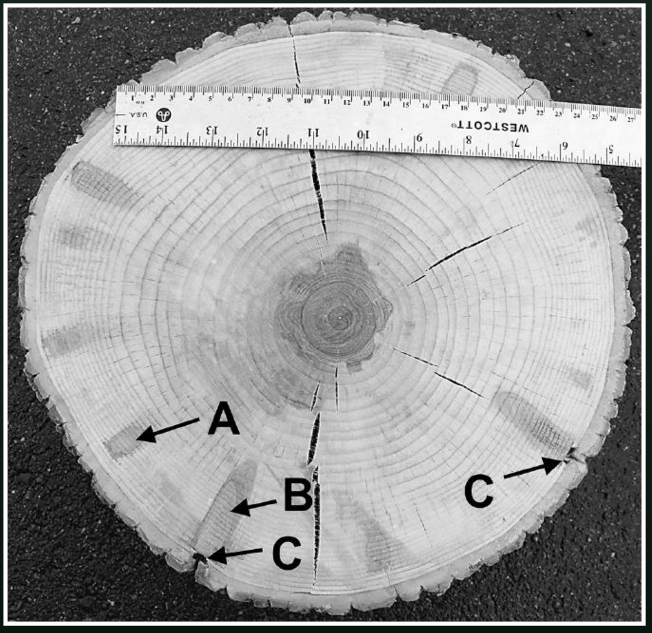

Figure 2. Cross-sections of tree trunks cut just below the injection sites. a) Trunk injections to this tree were made in autumn 2005 only, four injection sites with TREE-äge. b) Trunk injections to this tree were made in autumn 2006 and again in spring 2008, four injection sites per treatment. Discoloration columns due to trunk injections are still visible but there is no evidence of decay.

Arboriculture & Urban Forestry 42(6): November 2016 389

Arboriculture & Urban Forestry 2016. 42(6): 389–399

## Evaluation of Xylem Discoloration in Ash Trees Associated with Macroinjections of a Systemic Insecticide

Sara R. Tanis and Deborah G. McCullough



# Key Conclusions:

1. Insecticides are effective on large trees even under intense pest pressure.
2. Imidacloprid soil drenches most effective on large trees (>15 inch DBH) when applied at the 2X rate.
3. Fall imidacloprid soil drench requires higher rate than spring.
4. Dinotefuran soil and basal bark spray treatments providing good and equivalent control.
5. Emamectin benzoate provides 2 years of control on large trees even at lowest rate.
6. TREE-äge trunk injection and Imidacloprid soil drench were more effective than Pointer trunk injection.

# Ideal Timing of Treatments

- Soil treatments: in spring allowing time for uptake before adults begin feeding and eggs begin to hatch.

- Trunk injections: in spring just after the canopy has fully developed.

What about summer and fall treatments?

# EAB adult emergence begins when black locust blooms: 550 DD

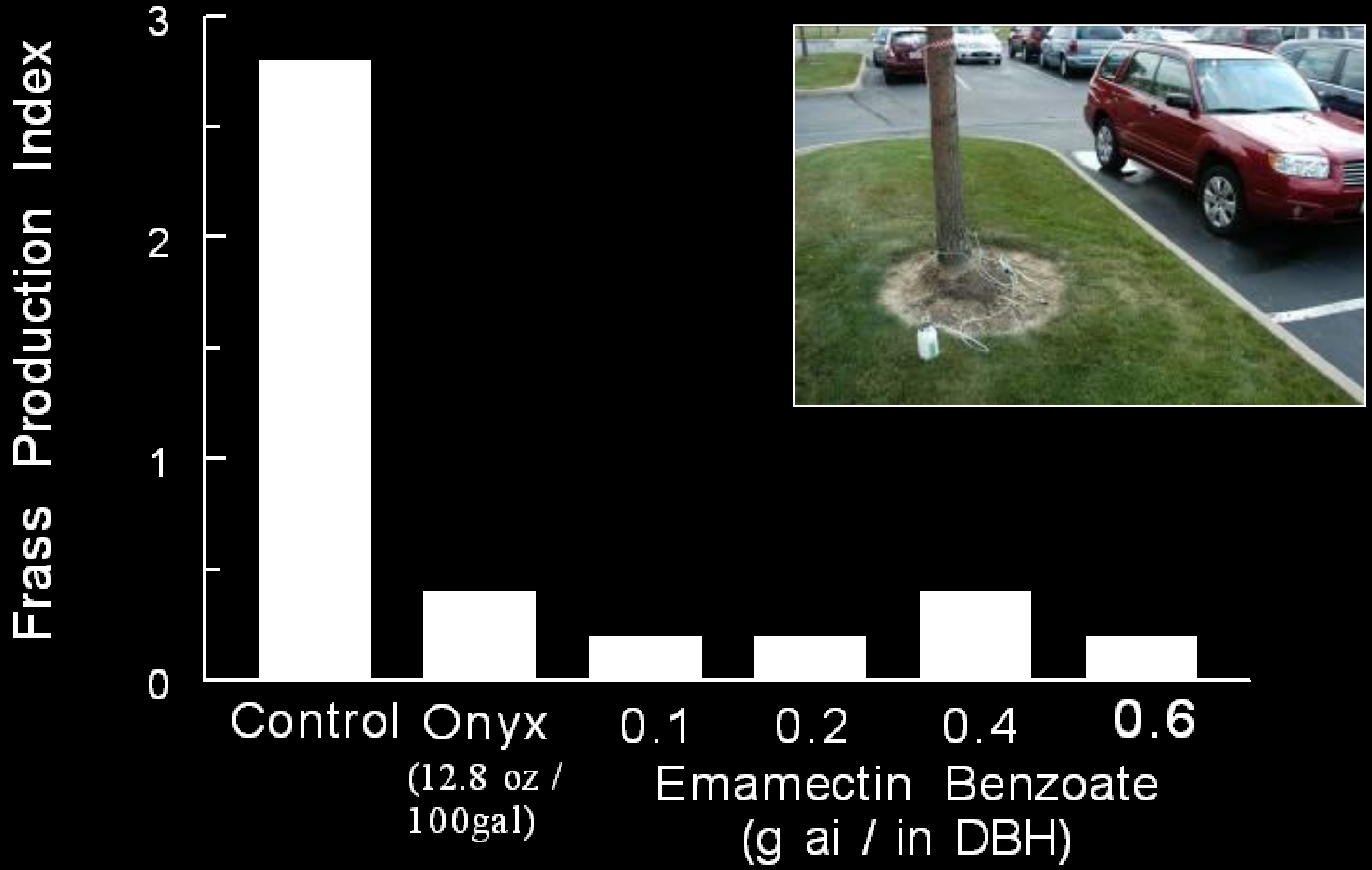
Black locust, *Robinia pseudoacacia*

# Banded Ash Clearwing Borer





# Emamectin Benzoate Controls Banded Ash Clearwing Borer



# Misconception: tree removal slows the spread of EAB

"…cutting them down is a sure pre-emptive strike. If that's what has to be done to prevent the spread of the emerald ash borer, then that's just what has to be done…"

"The city began cutting down trees on city property marked for removal on Thursday, the beginning of a six-week campaign to get rid of 700 trees and attempt to slow the spread of the insect."

"…are trying to slow the spread of the emerald ash borer, an invasive insect known for spreading like wildfire and killing ash trees. The trees here are not believed to be infested with EAB…"

Economic value of environmental services provided by trees increases exponentially with tree size.

The probability that a tree reaches a large size on urban streets is increasingly low.

Roman & Scatena (2011) Street tree survival rates: meta-analysis of previous studies and field survey in Philadelphia, PA, USA. *Urban Forestry & Urban Greening* 10:269-274.

Sydnor & Subburayalu (2011) Should we consider expected environmental benefits when planting larger or smaller tree species? *Arboriculture & Urban Forestry* 37:167-172.

## Economics of treatment vs. removal is dependent on many factors:

…urban ash conservation can be less costly than removal, especially when the significant environmental and economic benefits of established trees are considered…

Vannatta et al. (2012) Economic analysis of emerald ash borer (Coleoptera: Buprestidae) management options. *J. Econ. Entomol.* 105:196-206

# Economics of treatment vs. removal:



Arboriculture & Urban Forestry 2017. 43(1):15–26

ISA
International Society of Arboriculture

ARBORICULTURE & URBAN FORESTRY
Scientific Journal of the International Society of Arboriculture

## Tools for Staging and Managing Emerald Ash Borer in the Urban Forest

**Clifford S. Sadof, Gabriel P. Hughes, Adam R. Witte, Donnie J. Peterson, and Matthew D. Ginzel**

https://int.entm.purdue.edu/ext/treecomputer/files/Sadof_et_al_2017_Staging_EAB_Infestation.pdf

# Purdue EAB Cost Calculator:

http://extension.entm.purdue.edu/treecomputer/

EXTENSION ENTOMOLOGY | EAB IN INDIANA

Emerald Ash Borer
Cost Calculator

PURDUE UNIVERSITY

## Welcome to the Emerald Ash Borer Cost Calculator 3.0

Get the January 2017 article in Arboriculture and Urban Forestry that describes how this calculator shows why it is more economical to protect ash trees than to replace them. This version is driven by an EAB invasion wave model that assumes it takes 8 years from the time EAB is detected in your city until all the untreated ash can no longer be saved with a pesticide application. In this new version you can:

- Stage your response to an EAB invasion based on the percentage of ash trees that have lost more than 30% of their canopy.
- Evaluate management plans that reduce the frequency of ash treatment after the initial wave of EAB has passed through your forest.
- Compare the annual and cumulative costs and the size of the remaining forest over a 25 year period for ANY management strategy that includes a mixture of tree removal, replacement, and insecticide treatment.
- Generate and share electronic and printed reports of projected costs of up to 3 management strategies

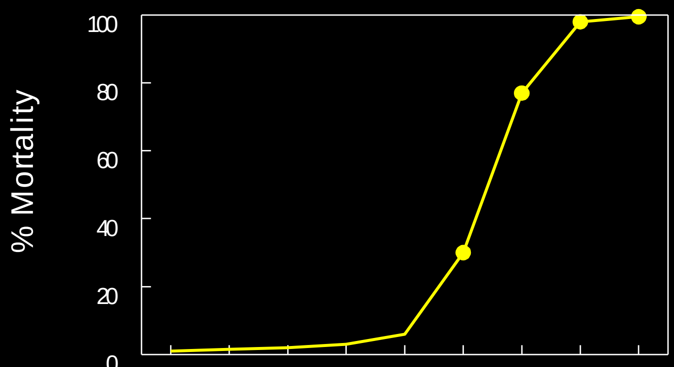
# Purdue EAB Cost Calculator:

http://extension.entm.purdue.edu/treecomputer/

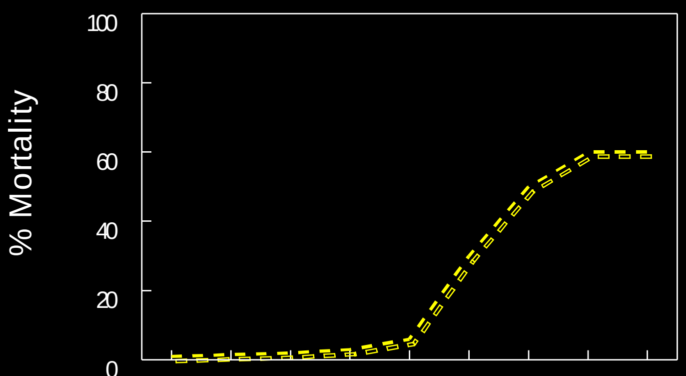
To run the calculator you will need:

- An inventory of the number and size of ash trees
- An estimate of costs for removing and treating trees based on the size of each tree.
- An estimate of costs for replacing each ash tree that is removed.

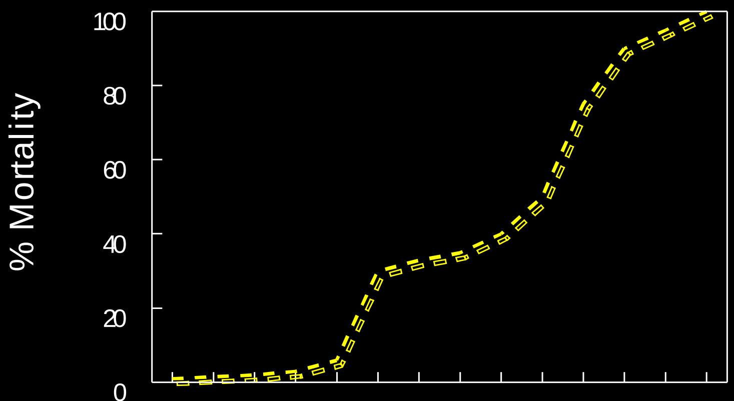
# Hypothetical Ash Mortality Trajectories as Manipulated by Insecticides



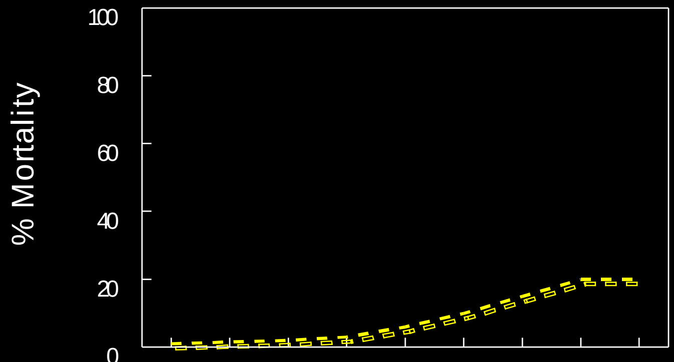

Do Nothing




Stabilize Mortality




Delay Mortality




Prevent Mortality

# Ash is pollinated by wind, not bees

http://www.cas.vanderbilt.edu/bioimages/biohires/f/hfram2-flmale18150.JPG

© 2002 Steve Baskauf

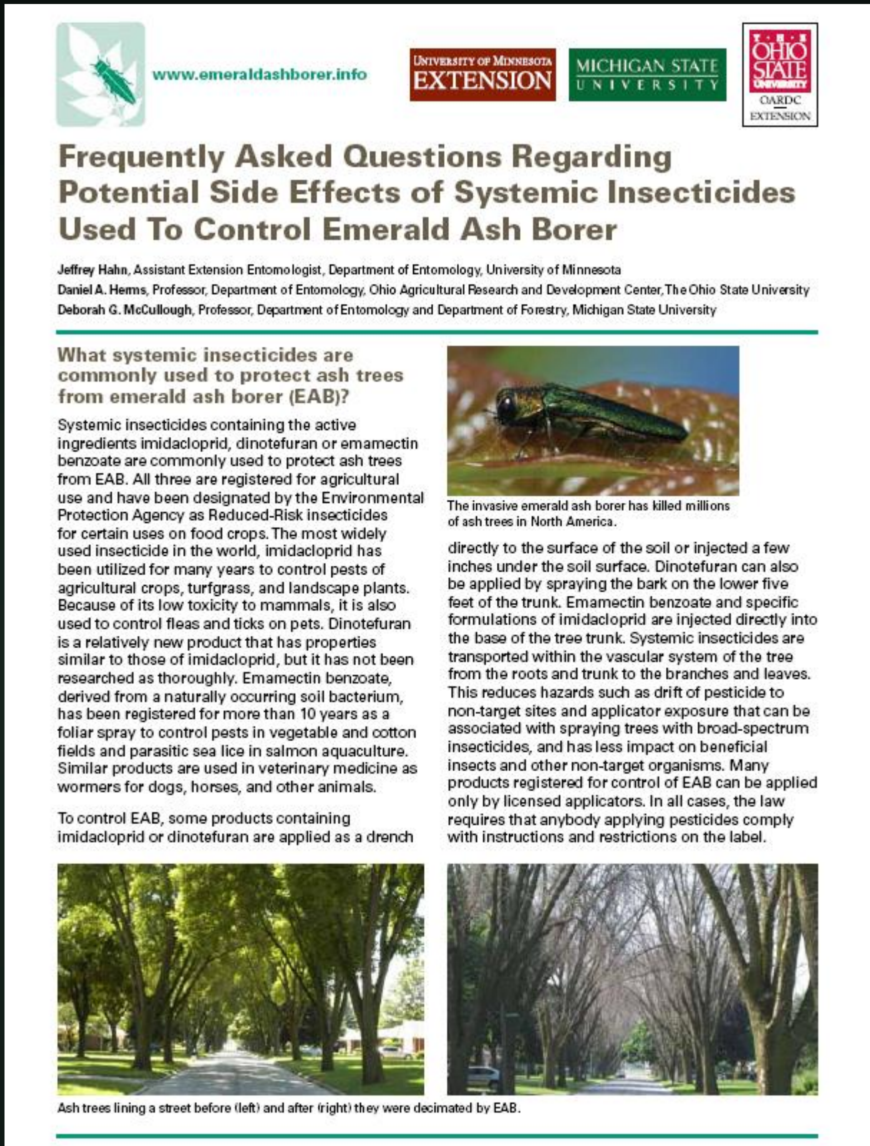
# We have never observed a bee visiting ash.

High diversity of bee-pollinated plants that bloom with ash: crabapples, cherries, pears, redbud, viburnums, azaleas, rhododendrons, dandelions, numerous herbaceous perennials and wildflowers

# All treatments made after flowering was complete:

18 May 2006, 13 June 2007, 23 May 2008, 10 May 2009,
24 May 2010, 3 May 2011, 28 April 2012

Toledo, August 2013



www.emeraldashborer.info

University of Minnesota EXTENSION

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# Frequently Asked Questions Regarding Potential Side Effects of Systemic Insecticides Used To Control Emerald Ash Borer

**Jeffrey Hahn**, Assistant Extension Entomologist, Department of Entomology, University of Minnesota
**Daniel A. Herms**, Professor, Department of Entomology, Ohio Agricultural Research and Development Center, The Ohio State University
**Deborah G. McCullough**, Professor, Department of Entomology and Department of Forestry, Michigan State University

## What systemic insecticides are commonly used to protect ash trees from emerald ash borer (EAB)?

Systemic insecticides containing the active ingredients imidacloprid, dinotefuran or emamectin benzoate are commonly used to protect ash trees from EAB. All three are registered for agricultural use and have been designated by the Environmental Protection Agency as Reduced-Risk insecticides for certain uses on food crops. The most widely used insecticide in the world, imidacloprid has been utilized for many years to control pests of agricultural crops, turfgrass, and landscape plants. Because of its low toxicity to mammals, it is also used to control fleas and ticks on pets. Dinotefuran is a relatively new product that has properties similar to those of imidacloprid, but it has not been researched as thoroughly. Emamectin benzoate, derived from a naturally occurring soil bacterium, has been registered for more than 10 years as a foliar spray to control pests in vegetable and cotton fields and parasitic sea lice in salmon aquaculture. Similar products are used in veterinary medicine as wormers for dogs, horses, and other animals.

To control EAB, some products containing imidacloprid or dinotefuran are applied as a drench directly to the surface of the soil or injected a few inches under the soil surface. Dinotefuran can also be applied by spraying the bark on the lower five feet of the trunk. Emamectin benzoate and specific formulations of imidacloprid are injected directly into the base of the tree trunk. Systemic insecticides are transported within the vascular system of the tree from the roots and trunk to the branches and leaves. This reduces hazards such as drift of pesticide to non-target sites and applicator exposure that can be associated with spraying trees with broad-spectrum insecticides, and has less impact on beneficial insects and other non-target organisms. Many products registered for control of EAB can be applied only by licensed applicators. In all cases, the law requires that anybody applying pesticides comply with instructions and restrictions on the label.

The invasive emerald ash borer has killed millions of ash trees in North America.

Ash trees lining a street before (left) and after (right) they were decimated by EAB.

Will they impact ground and surface water?

Will they impact aquatic organisms?

What about residues in leaves that fall in autumn?

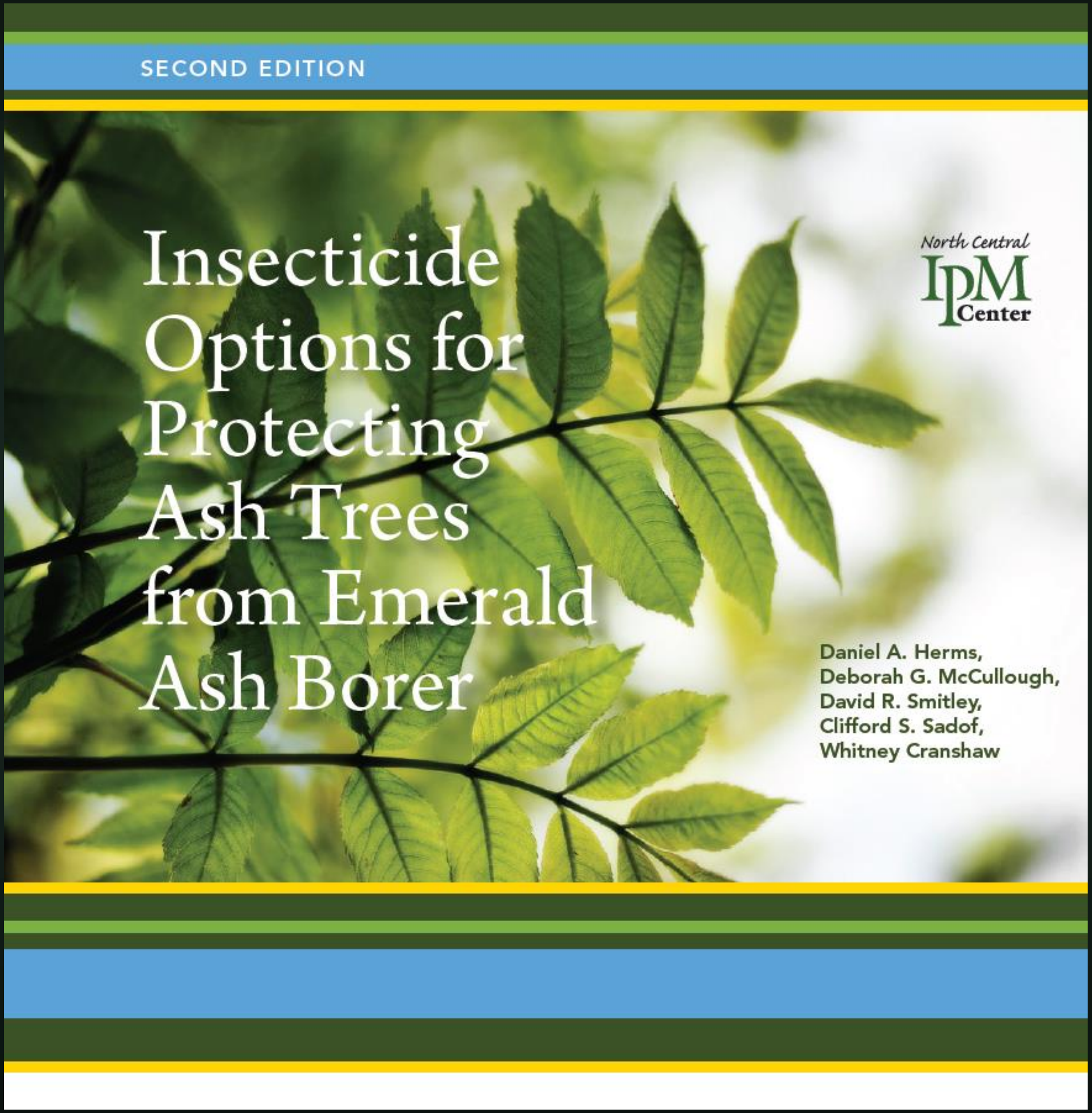
Will they harm honey bees? Other insects? Woodpeckers?

Will injection wounds harm the tree?

Will EAB evolve insecticide resistance?

emeraldashborer.info

# emeraldashborer.info



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