Beyond Eradication: Managing EAB to Slow Ash Mortality (SLAM)



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Hundreds of millions of ash trees in landscapes & forests have been killed by EAB in the US.



But… can we use what we have learned to do better?

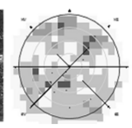
"Truths About EAB"
Knowledge relevant for management

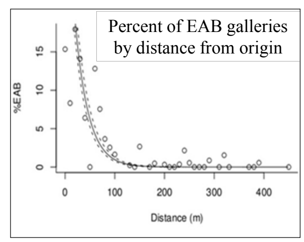
1. Early detection of EAB is rarely "early"

Early detection provides time to acquire resources, conduct outreach, treat priority trees, etc.

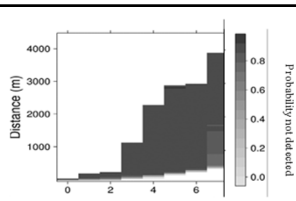
Challenge: Detection is complicated by EAB dispersal, behavior & effectiveness of baited traps.

EAB Dispersal: Large field studies showed most adult females lay eggs within 100 m of their emergence point.
A small portion of females disperse 400 to 800 m.
A few females go further – maybe 3 to 5 km?



McCullough et al. 2011, 2015; Mercader et al. 2009, 2011, 2012, 2016; Siegert et al. 2010



Long distance EAB dispersal: It occurs but we know little about why or how often or how far EAB females go.

Actual EAB distribution is likely 2+ miles or more beyond detection threshold, even 6 years after establishment.
New satellite populations usually "simmer" for ≥ 4 years before symptoms & tree decline become apparent.

Mercader et al. 2012

EAB detection remains difficult

•No long range pheromones.
•EAB traps & lures are not highly effective.
•Regulatory surveys typically end when EAB is detected.
Local EAB distribution or density are rarely known.

Purple canopy trap (APHIS)

Green canopy trap (Canada)

Double-decker trap (MSU)

McCullough & Poland 2017; McCullough et al. 2011
Mercader et al. 2013; Poland et al. 2011, 2014

- In healthy ash trees with low EAB densities, a 2-year EAB life cycle is common.
- Upper canopies are usually colonized first. External signs & symptoms can be difficult to see on large trees.
- External symptoms rarely apparent until EAB density builds to moderate levels within a tree.

1-year gallery; overwintering PP

Overwintering 2nd instar larvae

EAB exit hole

Ash dieback

Cappaert et al. 2005, Siegert et al. 2010; Tluczek et al. 2011

"Truths About EAB"
Knowledge relevant for management

1. Early detection of EAB is rarely "early"

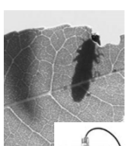
Detection is complicated by EAB dispersal, behavior & effectiveness of baited traps.

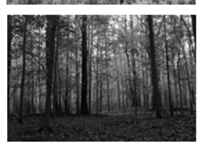
2. All ash trees are not the same.

Location, stress & species can affect EAB attraction & host preference, impacts & our management options.

Open-grown trees are highly preferred EAB hosts

Adult EAB beetles like hot & sunny conditions. Beetles are strongly attracted to light. Beetle activity is greater on trees fully exposed to sun than on edge trees. Edge trees are more attractive to EAB than shaded trees.



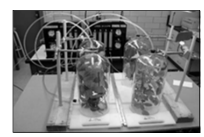


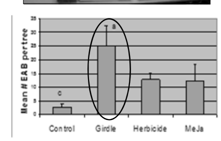
McCullough et al. 2009a, 2009b; Yu 1992

EAB adults preferentially colonize stressed trees

Trees stressed by injury, flooding, droughty soil, etc. emit volatile compounds that attract EAB adults.

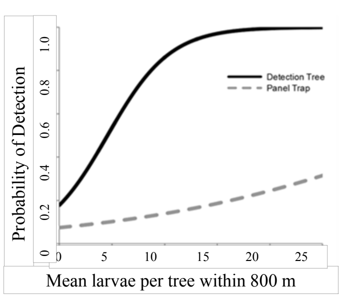
Girdled ash trees are especially attractive to EAB.

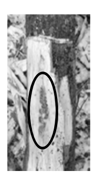




McCullough et al. 2009a, 2009b; Mercader et al. 2011; Rodriguez-Sanoa et al. 2006; Siegert et al. 2010, Tluczek et al. 2011

Girdling (in spring) then debarking ash trees (in fall) to locate EAB larvae is **<u>the</u>** most effective detection method.

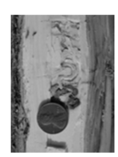


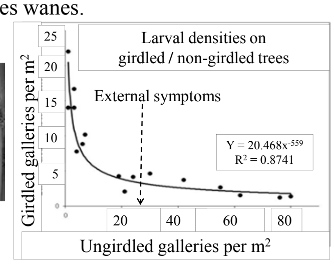


McCullough et al. 2011, 2015
Mercader et al. 2012, 2013

When EAB densities are low, girdled trees can be used for detection & as "trap trees" (if debarked, chipped, etc.).

But… as EAB density builds, many trees become stressed. Attraction to girdled trees wanes.





McCullough et al. 2009a,b, 2011, 2015; Mercader et al. 2011, 2013, 2016; Siegert et al. 2017; Tluczek et al. 2011

Interspecific differences in
EAB host preference & ash resistance

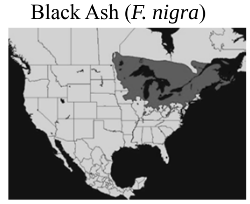
Continental US: 18 native ash species

EAB has encountered 4 major ash species to date:
Green, White, Black & Blue ash

Green Ash (*F. pennsylvanica*)

White Ash (*F. americana)*

Black Ash (*F. nigra*)



Blue Ash (*F. quadrangulata)*

Female beetles select hosts for leaf-feeding & oviposition.

Larvae must feed & develop on the host selected by the female beetles. *Female host preference is critical.*

Adult EAB host preference varies among ash species

Preferred & vulnerable - · - · - · - · - · - · - · - · - · -> Less preferred

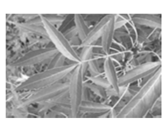
Black ash	Green ash	White ash	Blue ash

Anulewicz et al. 2007, 2008; Rebek et al. 2007; Tanis & McCullough 2012; Tanis & McCullough 2015; Robinett & McCullough 201X

Interspecific differences among European ash species?

F. excelsior

F. ornus



F. angustifolia

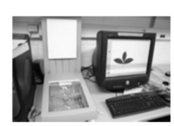
F. angustifolia oxycarpa (Rayburn ash) in Grand Rapids, MI parking lot in 2012.

Note dead green ash in the background.

Novel ash species – MSU study

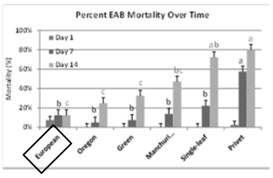
Ash plantation: Bare root trees were planted in randomized blocks in an irrigated plantation at MSU to monitor EAB attacks & canopy condition.

Leaf-feeding & longevity: Foliage + 3 beetles were caged for 14 days (12 plants per species). Leaves from the same plants were replaced & beetle mortality recorded every 2-3 days.

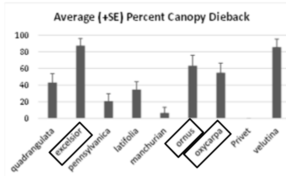


European ash species appear relatively attractive & vulnerable

EAB adult mortality
Leaf-feeding bioassay

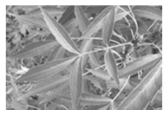


Percent canopy dieback




F. excelsior


F. ornus


F. angustifolia

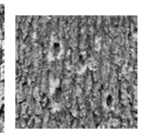
EAB detection & monitoring

Monitor vulnerable & attractive trees to detect EAB
Girdled > wounded or injured > poor sites
Open-grown > edge > shaded trees
Green or black ash > white ash > blue ash

Watch for woodpecks! Woodpeckers are great at finding EAB







"Truths About EAB"
Knowledge relevant for management

1. Early detection of EAB is rarely "early"

Detection is complicated by EAB dispersal, behavior & effectiveness of baited traps.

2. All ash trees are not the same.

Location, stress & species can affect EAB attraction & host preference, impacts & our management options.

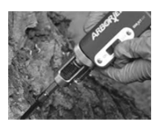
3. We can protect ash trees with systemic insecticides.

Ex: Emamectin benzoate provides 3 years of EAB control

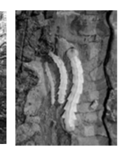
Systemic insecticides

Consider options for optimal use of emamectin benzoate or other systemic insecticides in specific areas.

- Protect seed trees to conserve some genetic diversity
- Integrate girdling & trunk injection to slow growth of EAB populations & ash mortality
- Integrate systemic insecticides & biocontrol







- Lethal trap trees (bait & kill)

Inject trees with emamectin benzoate then girdle trees 5-10 days later. Girdling attracts EAB adults but leaves are toxic. No need to chip, burn or otherwise destroy girdled tree.

McCullough et al. 2016

- Larger scale: Surround or intermix girdled trees with injected trees to increase chances that EAB adults will feed on toxic leaves. Remove or destroy girdled trees.



SL.ow Ash Mortality (SLAM) Pilot Project 2008-2012

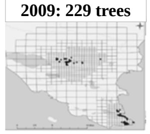
- Large scale SLAM project encompassed > 390 km^2 in Upper MI. Involved 6 agencies & 2 universities; ARRA funding
- SLAM Pilot Project included a mix of national, state & private forest lands, rural areas & small communities.
- Goal: Protect the ash resource by slowing EAB population growth & the rate of ash mortality *(SL.A.M - not SL.EAB)*

➢SLAM started ~ 5 years after EAB became established.

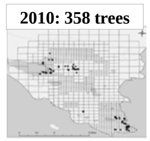
➢Grids of small girdled & debarked ash trees were used to monitor EAB density & distribution. Annually, 444 to 855 ash (8-15 cm DBH) were girdled from 2008 to 2011. Baited traps supplemented girdled trees.

➢A ***tiny*** proportion of ash trees (<0.1%) were treated with TREE-äge (EmBen). Distribution of treated trees was not optimal; mostly roadside trees.

2009: 229 trees



2010: 358 trees



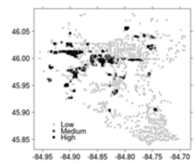
SL.ow Ash Mortality (SLAM) Pilot Project

➢Ash was inventoried & phloem area (m^2) estimated (grids).

➢Ash condition was evaluated in forest health plots.

➢Some ash harvesting occurred; mostly on private land.

➢Regulatory & public outreach activities focused on reducing transport of infested ash material into or beyond project area.

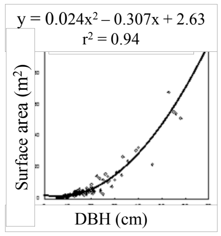


Potential EAB density in a given area depends on the area of ash phloem available for larvae. We can use DBH to estimate ash phloem area & potential adult EAB production.

DBH	EAB / m^2
3 - 14 cm	69 ± 6
15 - 25 cm	108 ± 10
26 - 45 cm	106 ± 10
46 - 60 cm	102 ± 9
> 60 cm	94 ± 11
Overall	89

McCullough & Siegert 2007
J. Econ. Entomol.

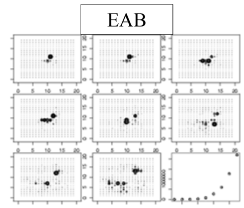
$y = 0.024x^2 – 0.307x + 2.63$
$r^2 = 0.94$



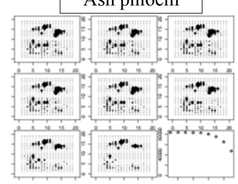
Y =ash phloem area (m^2)
X = DBH (cm)

Evaluation: Compared <u>observed</u> versus <u>predicted</u> EAB density & distribution to assess effects of insecticide & girdled trees.

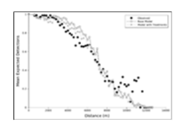
EAB



Ash phloem



1. EAB adults emerge
   (1-yr & 2-yr cohorts tracked)
2. Adults disperse
3. Population grows
4. Ash phloem consumed



Mercader et al. 2009, 2011a, 2011b

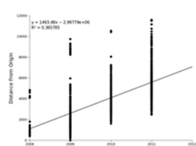
Results

Treating a very small portion of the ash trees with EmBen insecticide slowed EAB population growth (≥ 2 years) & rates of ash decline across the project area.

Number of treated trees was significant ($P = 0.009$)
Area of treated ash phloem was not ($P = 0.21$)

Girdled trees slowed EAB population growth (for 1 year) ($P = 0.015$) & retained local beetles (spill-over effect).

Annual EAB spread rate:
1.50 to 1.75 km



McCullough et al. 2015; Mercader et al. 2013; 2015; 2016

Lessons from SLAM Pilot Project

- Treat as many trees as possible with EmBen to slow EAB population growth (expect 3 years of efficacy).
- Treating *more* trees has a greater effect on slowing EAB population growth than selectively treating *large* trees.
- Insecticide treatments did not slow EAB spread.

- Girdled & debarked ash trees (8-15 cm DBH) were more effective at EAB detection than baited traps & also provided data on EAB density & development.
- Girdled trees had a small but significant effect on EAB spread.

Lessons from SLAM Pilot Project

✓Heavily infested ash trees should be removed, ideally before high densities of EAB adults can emerge.

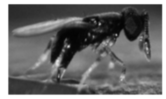
✓Ash utilization can provide value for landowners. Merchantable trees represent a small portion of the ash resource in forests but produce a high proportion of the EAB.

✓Simply removing ash trees, however, is **not** a SLAM strategy. Ash removal has less effect on EAB population growth than insecticides or girdling & will eventually increase EAB spread rates.

✓Combine ash removal with other tactics.

Can systemic insecticides be integrated with EAB biocontrol efforts?

Additive or even synergistic effects can occur if:
(1) Two tactics target different life stages of the pest.
(2) Insecticides do not interfere with natural enemies.
(3) Natural enemies engage in non-random searching for their prey or hosts.

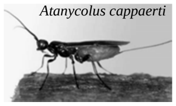

Tetrastichus planipennisi


Atanycolus cappaerti

Barclay & Li. 1991. Theor. Pop. Ecol; Berec et al. 2007. Trends Ecol. Evol; Sucking et al. 2012. Environ. Entomol.

Systemic insecticides are compatible with EAB natural enemies & biocontrol efforts

- ➢Egg & larval parasitoids of EAB are not exposed to systemic insecticides.
- ➢Woodpeckers & parasitoids will not attack dead EAB.
- ➢Treating some ash with effective systemic insecticides may even facilitate success of native & introduced parasitoids.

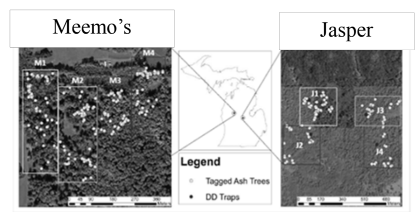

Atanycolus cappaerti


T. planipennisi

Evaluation of Area-Wide EAB Strategy: MSU & USDA ARS

Delineated 4 blocks, each 6 ha, in 2 forested sites in May 2016

Recorded coordinates, tagged & measured DBH of live ash trees, then estimated ash phloem area within each block.



March-April 2016 (pre-treatment)
Debarked 2 paired trees per block; one healthy & one declining

Treatments randomly assigned to each block at both sites

(1) EmBen (TREE-äge); applied May 2016 to ~ 10% ash phloem)
(2) *Tetrasticus planipennisi* parasitoids
Released 1000 wasps per block in 2016 & again in 2017
(3) EmBen + *T. planipennisi*
(4) Control

Selected 2 pairs of trees & girdled one in May 2016 & 2017

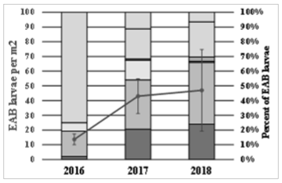
April 2017 & 2018: we debarked the pairs of girdled & healthy trees to quantify EAB larval density by life stage & condition.

Also monitored 2 baited double-decker traps per block
Conducted bioassay with adult EAB & leaves from EmBen trees

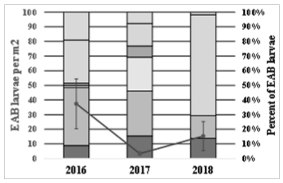
Jasper Site

Trees declining (2016) or Girdled (2017 & 2018)

No EmBen Blocks



EmBen Blocks



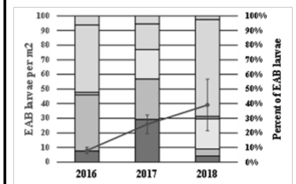
- Current-year larval density
- Live Prepupae + L4 (%)
- Woodpecker predation (%)
- *Atanycolus* parasitism (%)
- *Tetrastichus* parasitism (%)
- Live L2+L3 (%)
- Unknown (%)

EmBen applied in spring 2016
(n=4 trees per year)

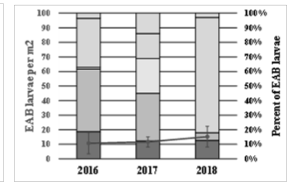
Meemo's Site

Trees declining (2016) or Girdled (2017 & 2018)

No EmBen Blocks



EmBen Blocks



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EmBen applied in spring 2016
(n=4 trees per year)

Area-Wide EAB Strategy: MSU & USDA ARS

Trapping showed EAB was present in all blocks at both sites. Bioassays in July 2016: 100% mortality of EAB adults caged with leaves from EmBen trees.

Healthy (non-girdled) trees had low EAB densities.

Girdled ash in blocks with EmBen-treated trees had lower EAB densities & higher proportions of overwintering 2-year larvae than blocks with no EmBen trees.

Woodpeckers preyed on L4 or prepupae in all blocks.

Native *Atanycolus* spp. & introduced *Tetrastichus planipennisi* parasitoids attacked EAB larvae in girdled trees in blocks with EmBen trees.

What are the options when EAB arrives?

A) Do nothing: Simple but major economic & ecological impacts

B) Management: Integrate available tactics into site-specific strategies. Not simple & costs will be incurred. Benefits should outweigh costs

C) Eradication: Is it possible with available tools? Could be substantial economic & ecological benefits…

A ← – – – – – – – – – B – – – – – – – – – → C

Acknowledgements

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