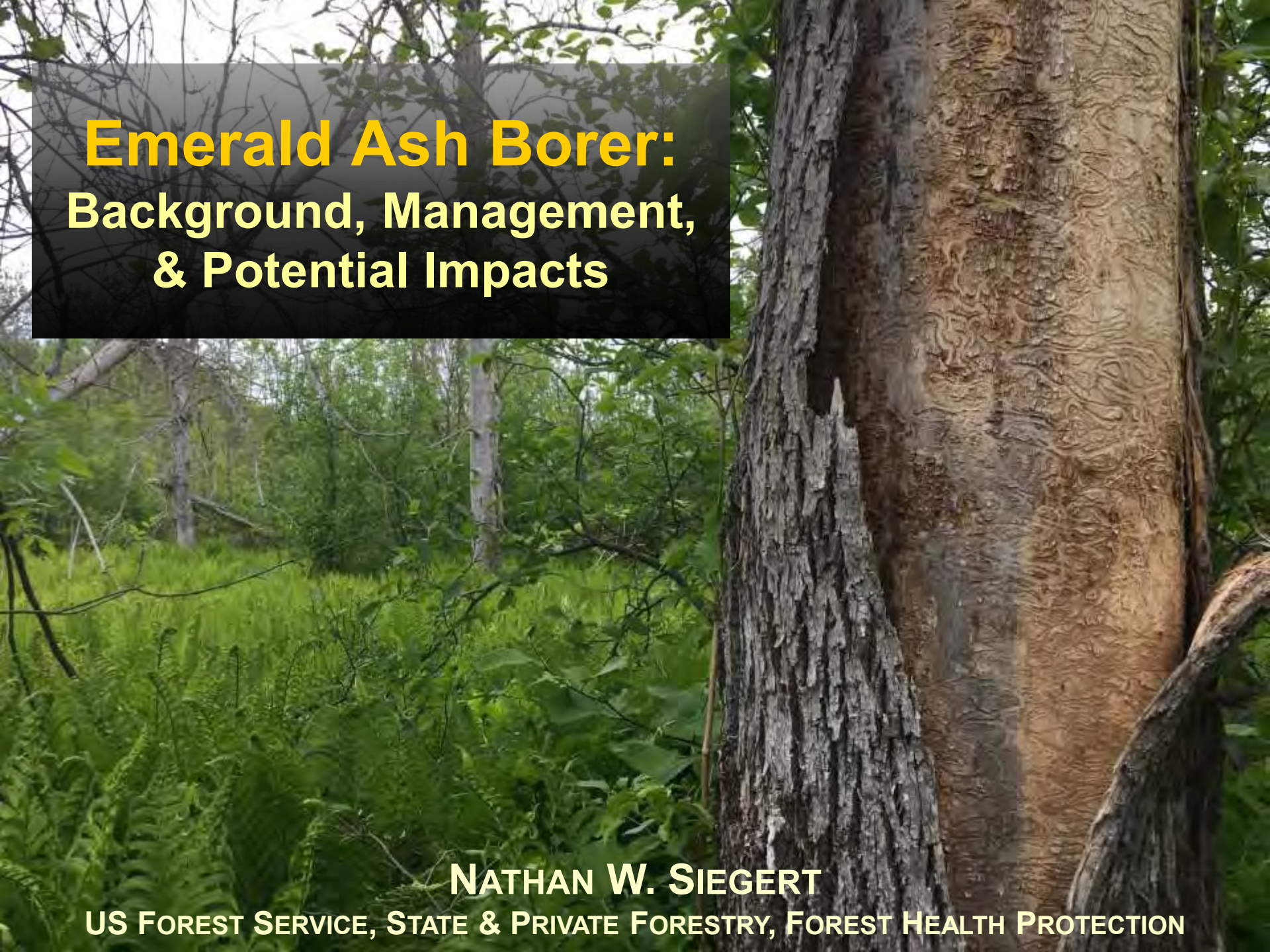
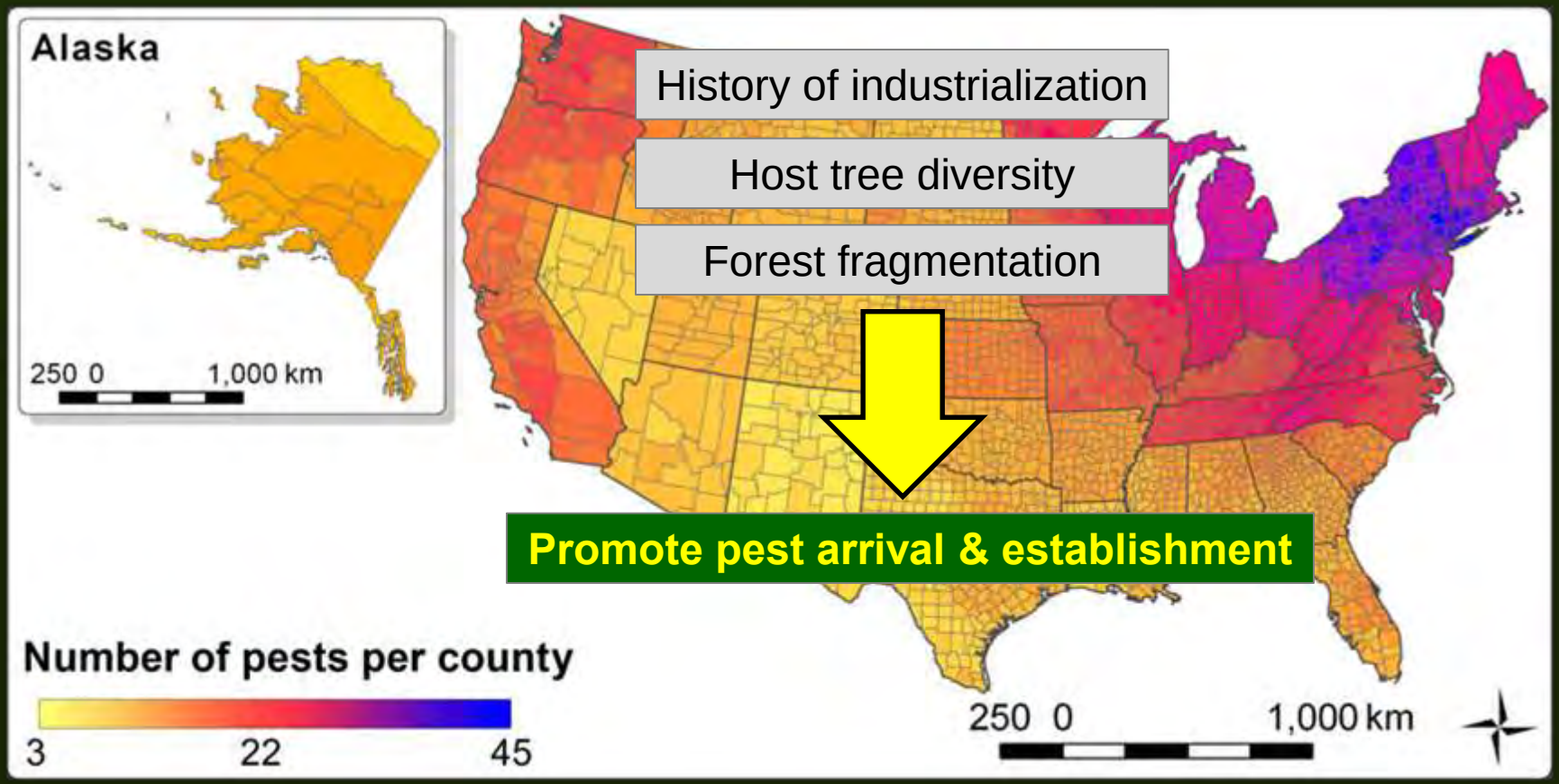


Emerald Ash Borer:
Background, Management, & Potential Impacts

NATHAN W. SIEGERT

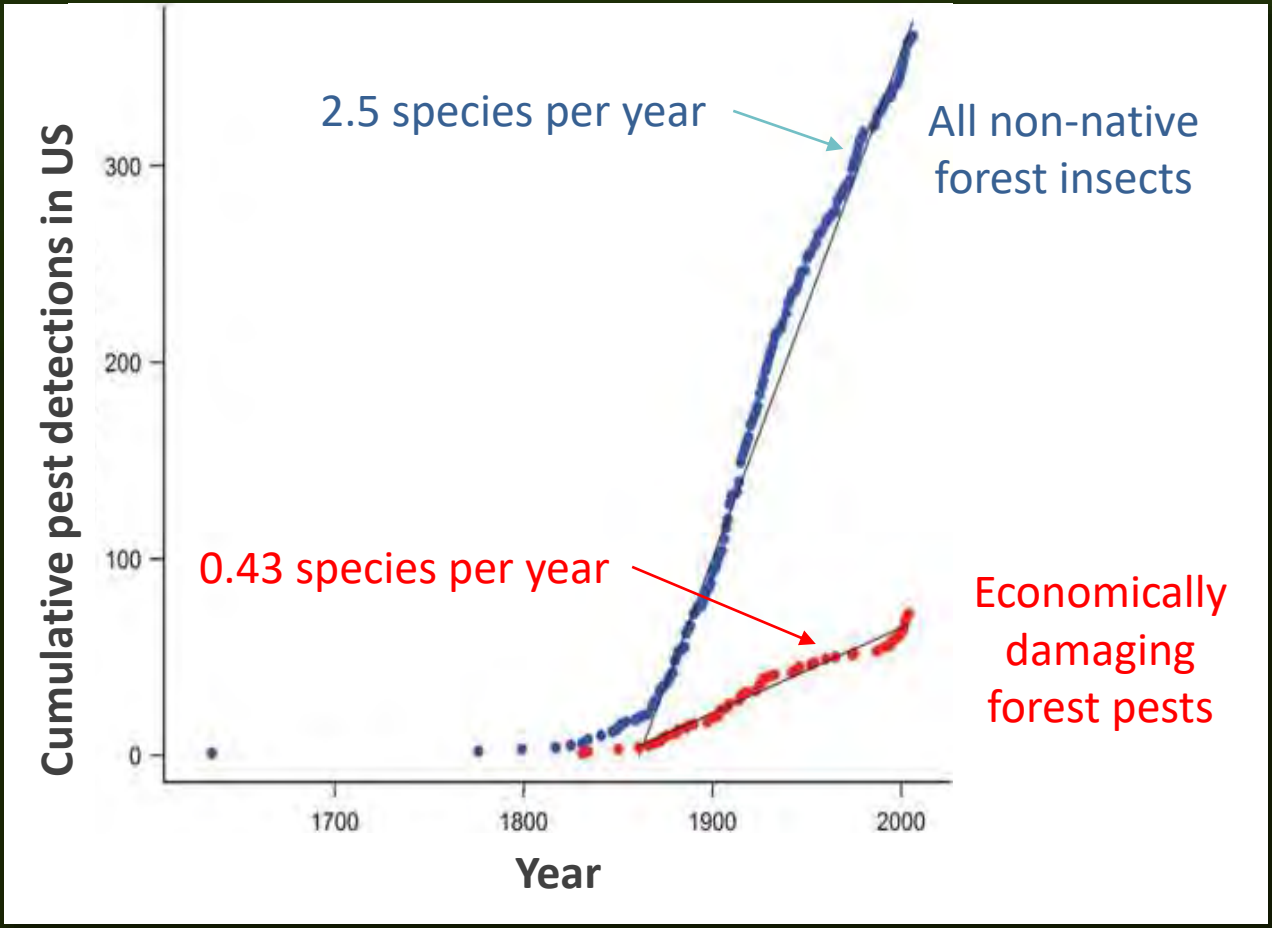
US FOREST SERVICE, STATE & PRIVATE FORESTRY, FOREST HEALTH PROTECTION

Number of Non-Native Forest Pests



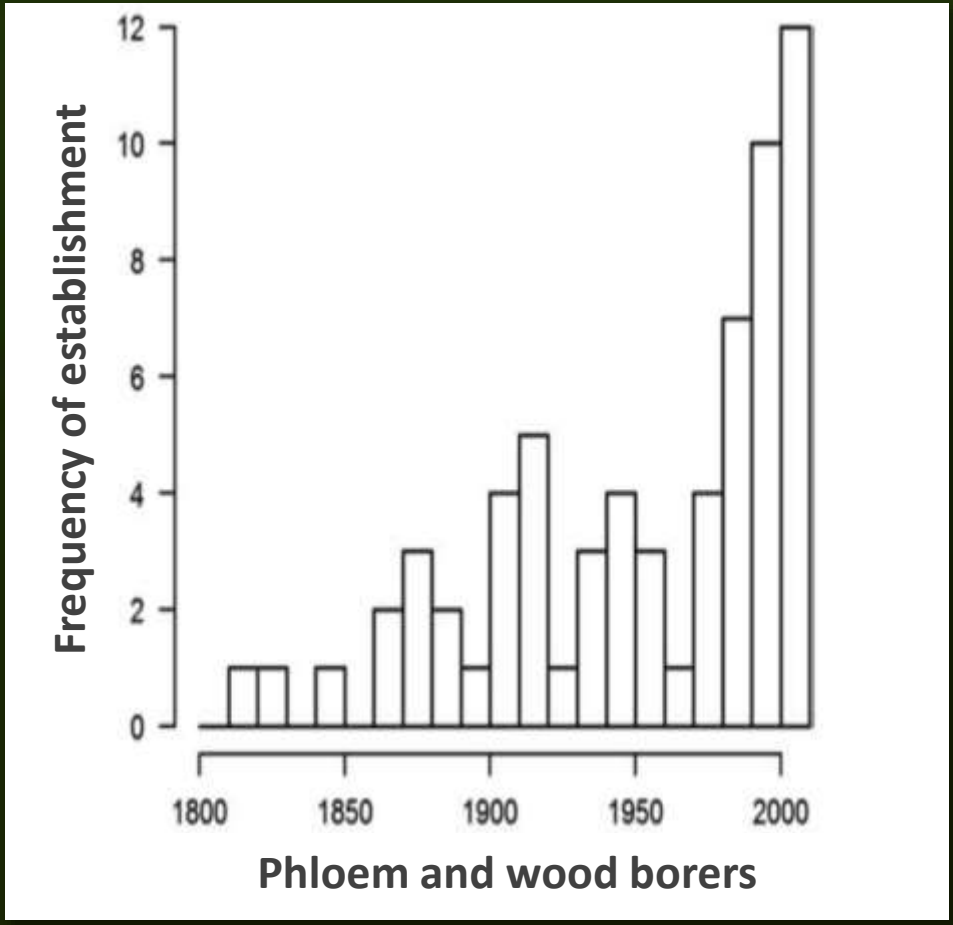
LIEBHOLD ET AL. (2013) A HIGHLY AGGREGATED GEOGRAPHICAL DISTRIBUTION OF FOREST PEST INVASIONS IN THE USA. *DIVERSITY & DISTRIBUTIONS*, 19:1208-1216.

Non-Native Forest Insect Establishment



AUKEMA ET AL. (2010) HISTORICAL ACCUMULATION OF NONINDIGENOUS FOREST PESTS IN THE CONTINENTAL UNITED STATES. *BIOSCIENCE*, 60:886-897.

Establishment of Phloem & Wood Borers



AUKEMA ET AL. (2010) HISTORICAL ACCUMULATION OF NONINDIGENOUS FOREST PESTS IN THE CONTINENTAL UNITED STATES. *BIOSCIENCE*, 60:886-897.

Emerald Ash Borer

First Detected in Detroit

- EAB was first detected in the US in Detroit, MI in 2002.
- Many thousands of ash trees were already dying.

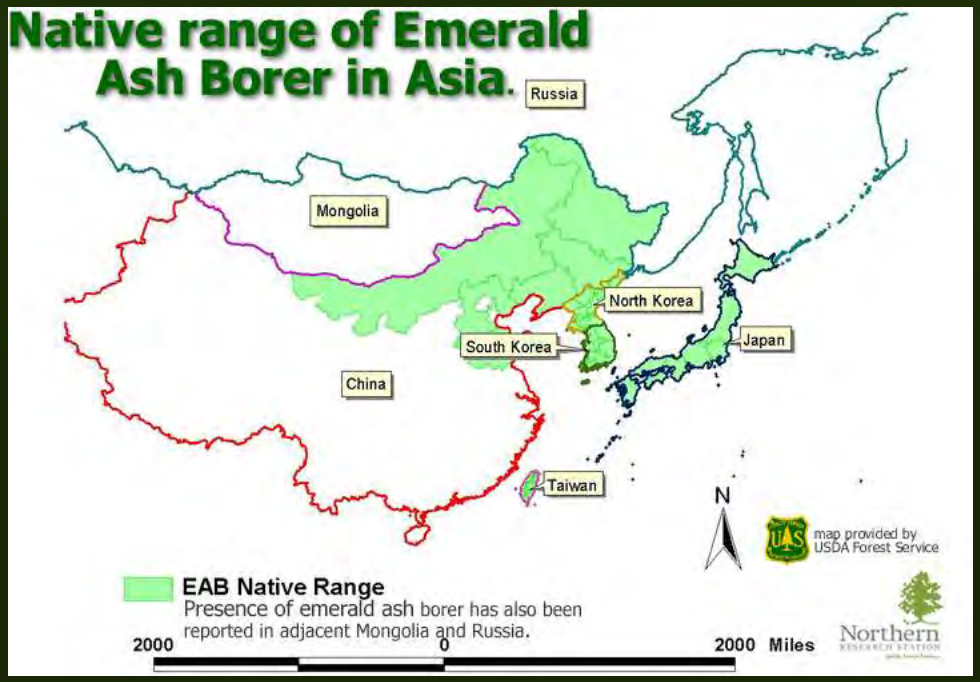
- The Port of Detroit receives significant international shipping.

EAB is the most destructive forest insect in North America

EAB has killed millions of ash trees in North America.

Transported to new areas in infested firewood, timber and nursery stock.

Native Range of EAB



- EAB is a destructive wood-boring beetle introduced from Asia.

- It is rare in its native range with little known about EAB globally at the time of its detection in the US.

Invasion History

2002
2003
2004
2005
2006
2007
2008
2009
2010

Michigan
Ontario CA
Indiana
Ohio
Illinois
Maryland
Pennsylvania
West Virginia
Wisconsin
Missouri
Virginia
Quebec CA
Kentucky
Minnesota
New York
Iowa
Tennessee

Invasion History

2002
2003
2004
2005
2006
2007
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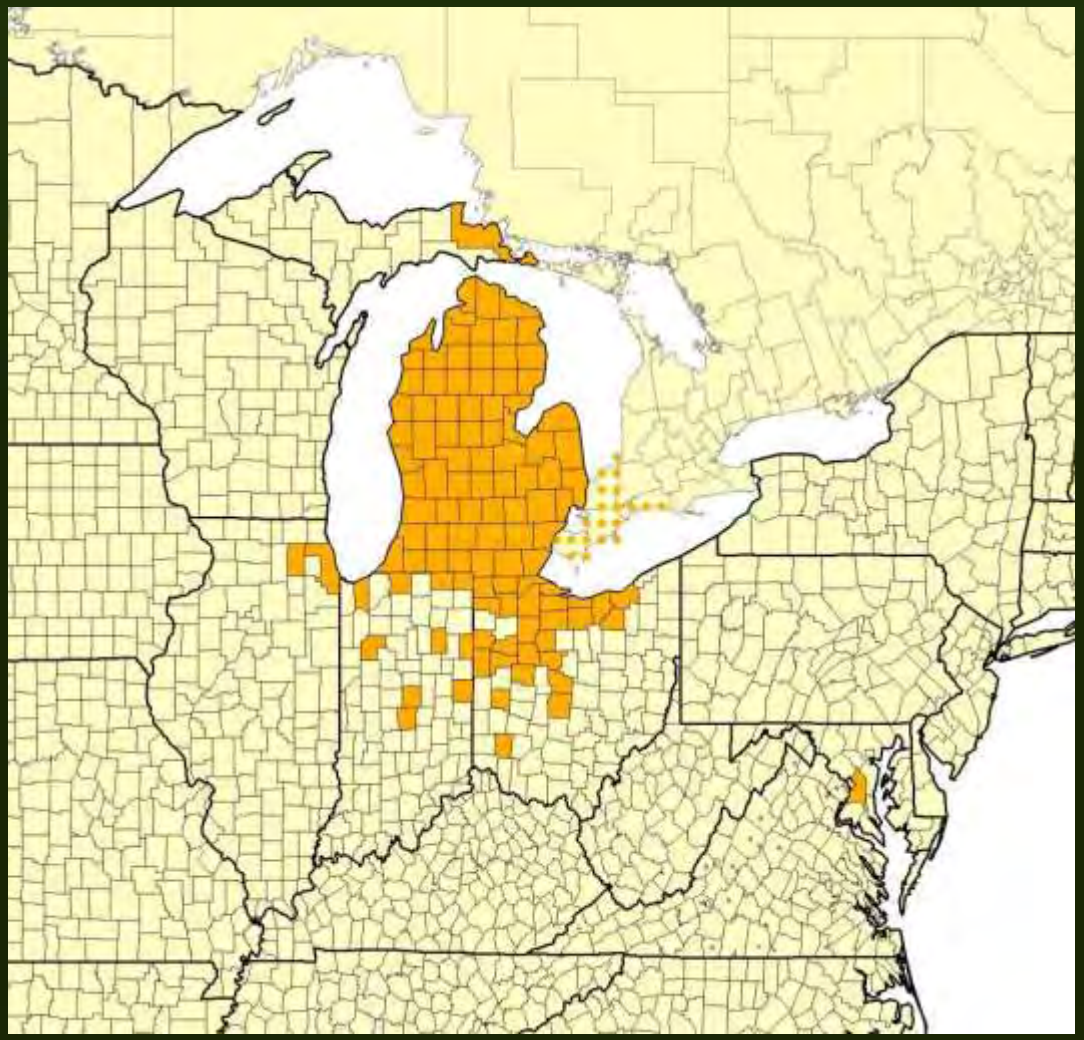
2009
2010



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Indiana
Ohio
Illinois
Maryland
Pennsylvania
West Virginia
Wisconsin
Missouri
Virginia
Quebec CA
Kentucky
Minnesota
New York
Iowa
Tennessee

Invasion History

2002
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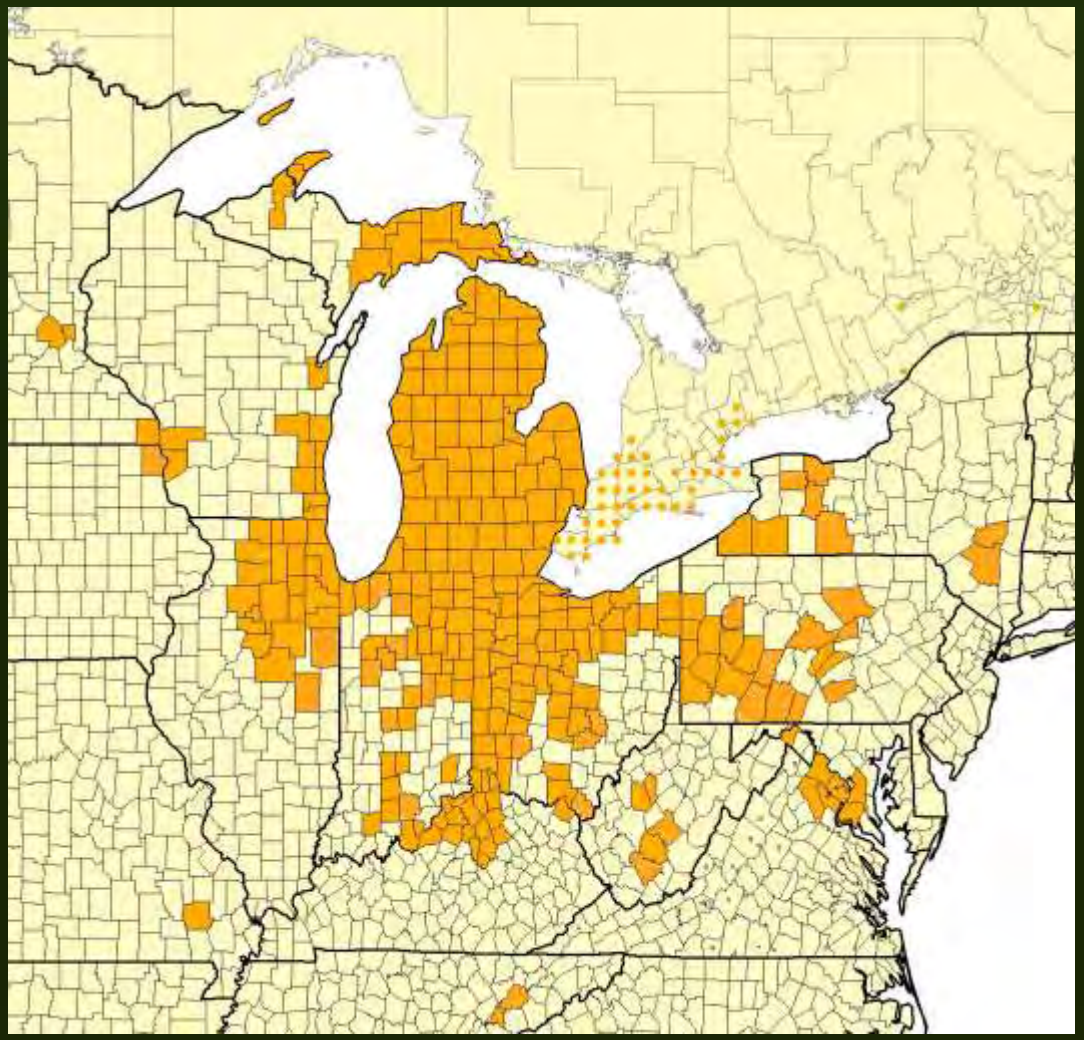

Michigan
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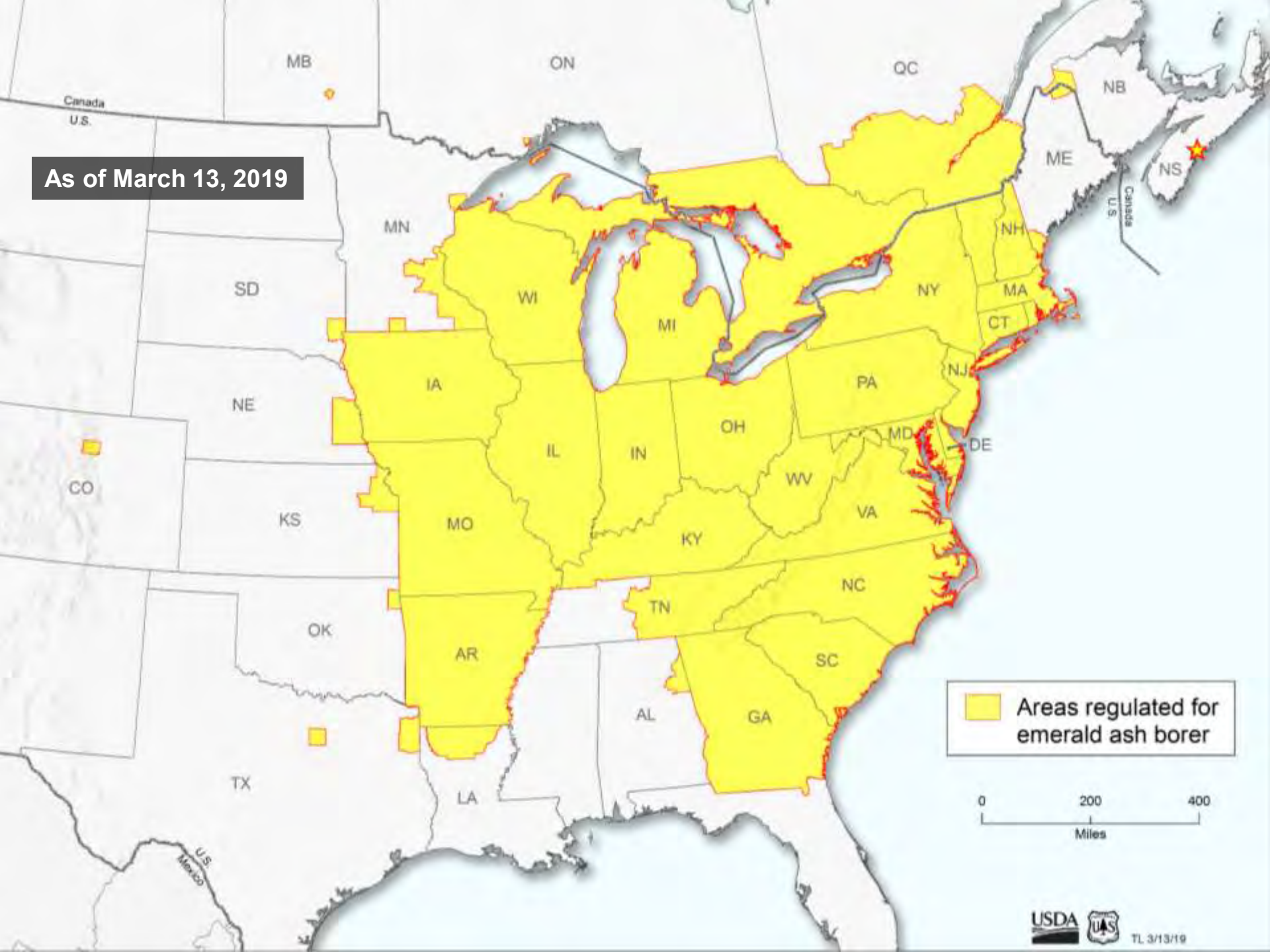
Tennessee


As of March 13, 2019
MB
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WV
VA
CO
KS
MO
KY
NC
TN
OK
AR
SC
AL
GA
TX
LA
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Mexico
Areas regulated for emerald ash borer
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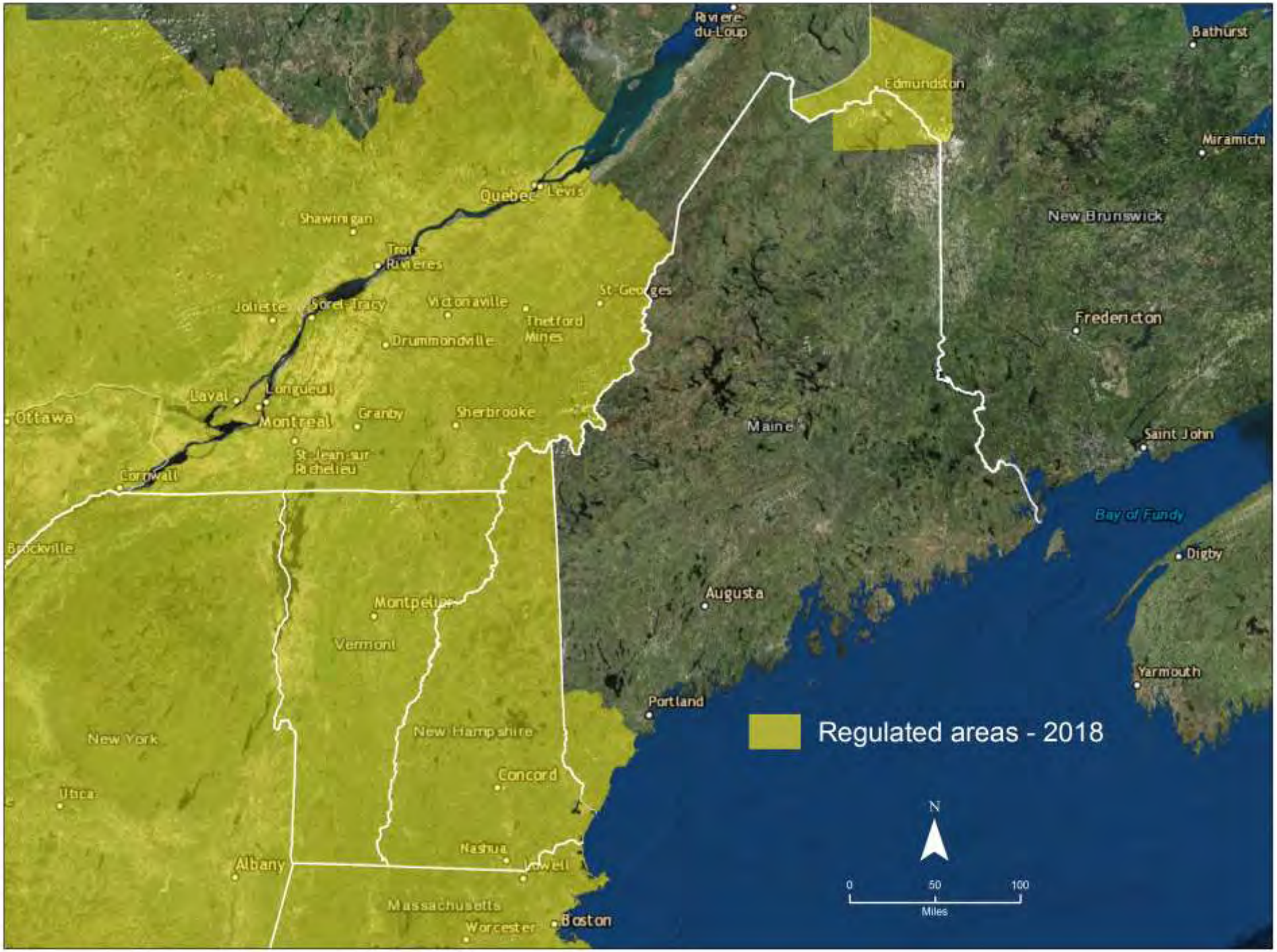
Miles
USDA
TL 3/13/19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Edmundston
Miramichi
Quebec
Levis
Shawinigan
New Brunswick
Trois-Rivieres
St-Georges
Joliette
Sorel-Tracy
Victoriaville
Thetford Mines
Fredericton
Drummondville
Laval
Longueuil
Ottawa
Granby
Sherbrooke
Montreal
Maine
Saint John
St-Jean-sur-Richelieu
Cornwall
Bay of Fundy
Brockville
Digby
Augusta
Montpelier
Vermont
Yarmouth
Portland
New York
New Hampshire
Concord
Utica
Nashua
Albany
Lowell
Massachusetts
Worcester
Boston
Regulated areas - 2018
N
0
50
100
Miles

What's at Risk?

- EAB has killed nearly 100% of ash trees ≥2 inch diam in SE Michigan forests.
- Ash mortality not related to site, stand or tree traits.
- At least 16 native North American ash species are at risk.

Host Susceptibility

Average survivorship of EAB is greater on North American ash species (63.3 ± 7.2%) compared to ash species with European (51.4 ± 17.0%) or Asian (26.6 ± 10.5%) origins.

Siegert et al. (2014) Susceptibility of Selected Asian, European, & North American Ash Species to Emerald Ash Borer: Preliminary Results of No-Choice Bioassays. *National EAB Research & Technology Development Meeting*.

Susceptibility of Eastern North American Ash Species

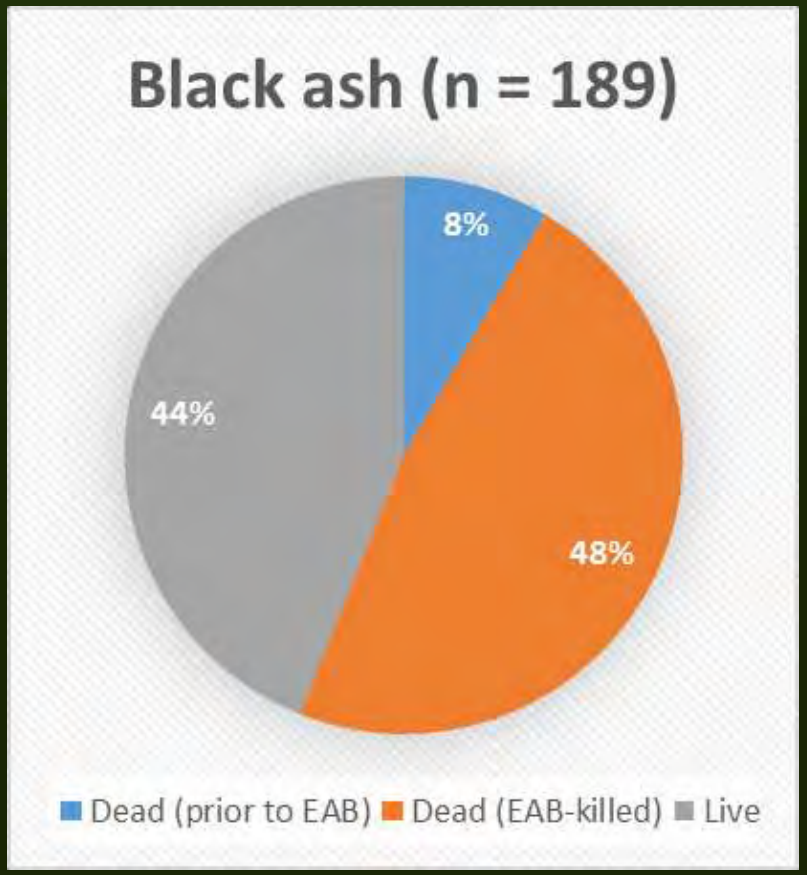
black ash > green ash > pumpkin ash > white ash > blue ash

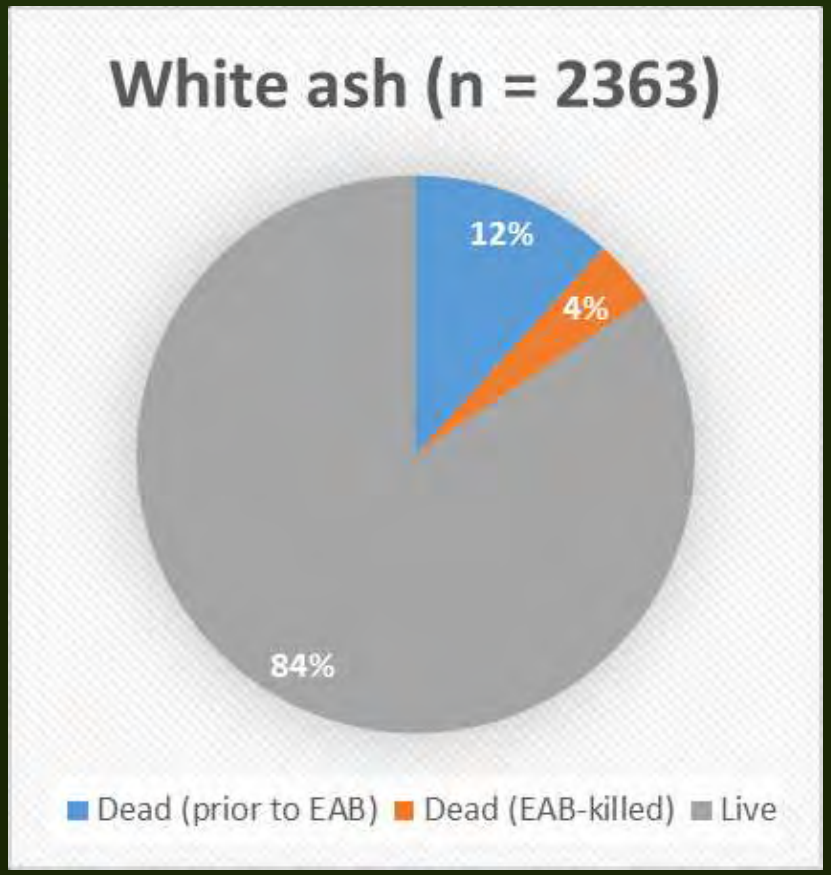
Most Preferred

Least Preferred

An estimated 1% of ash may exhibit greater levels of potential tolerance to emerald ash borer.

Susceptibility of Eastern North American Ash Species





EAB in New England

- Ash makes up 4-8% of hardwood forests in New England.
- Ash is not evenly spread across the region, but has a clumped distribution with some areas having much higher concentrations.
- Use of ash as a landscape tree varies as well.
- Some communities and developments are highly stocked with ash.

More Than Just a Loss of Timber

- Ecological effects – hydrology, biodiversity, other invasive species.

More Than Just a Loss of Timber

- Ecological effects – hydrology, biodiversity, other invasive species.
- Cultural significance – Native American basketmakers.
- $$$ Economic impacts $$$ – ecosystem services and developed US communities.

EAB Biology & Life Cycle

Adult beetles present from mid-May to August.

EAB Biology & Life Cycle

- Adults are roughly a half inch long and dark metallic green.
- Life cycle generally takes one year to complete.

- 2-yr development typical at newly established sites.
- More rapid development at high EAB densities and/or in stressed trees.

EAB Biology & Life Cycle

Larvae begin feeding in July and most finish by Oct-Nov.

EAB Biology & Life Cycle

Extensive galleries under the bark disrupt translocation of water and nutrients in the tree.

Tree Decline & Mortality

Foliage becomes thin, ragged and yellow.

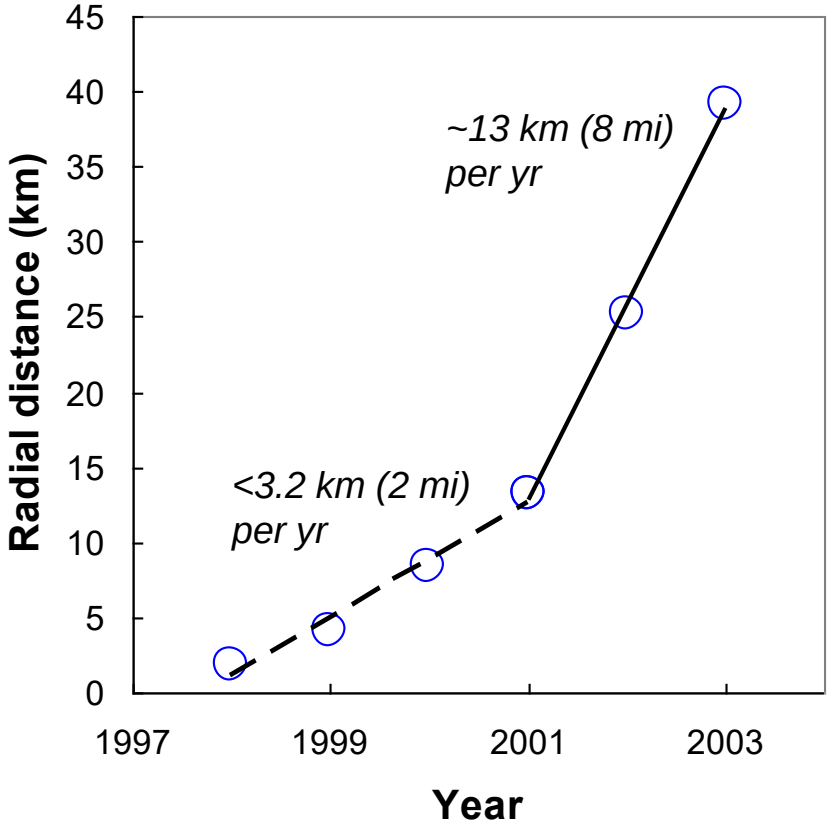
Canopy dieback progresses through the summer.

North American ash of all sizes typically die in 3-5 years.

Short- & Long-Distance Dispersal

Satellite populations of EAB increase the rate of spread.

Short- & Long-Distance Dispersal



Natural spread via adult flight is <3.2 km (2 mi) per yr.

Human-assisted spread results in disjunct satellite infestations.

Quarantines, outreach, and BMPs all help to reduce the frequency of long-distance dispersal events.

SIEGERT ET AL. (2014) DENDROCHRONOLOGICAL RECONSTRUCTION OF THE EPICENTRE & EARLY SPREAD OF EMERALD ASH BORER IN NORTH AMERICA. *DIVERSITY & DISTRIBUTIONS*, 20:847-858.

Influence of Satellite Infestations $$$

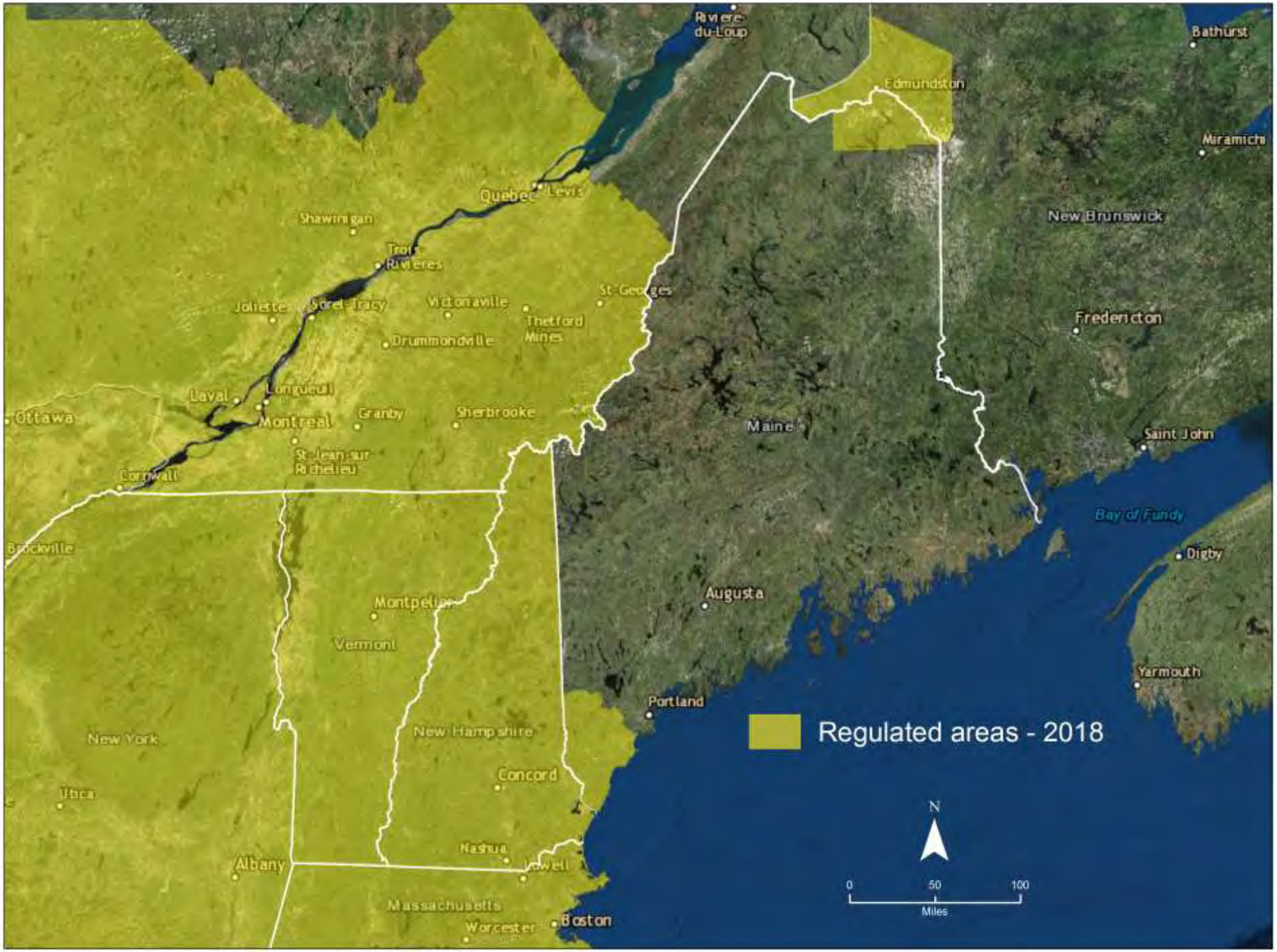
Economic analyses suggest that spending money to:

1) prevent establishment of new satellites; or

2) slow expansion of known existing EAB populations

can be cost-effective, long-term strategies for managing EAB infestations in urban and forested sites.

Kovacs et al. (2011) The Influence of Satellite Populations of Emerald Ash Borer on Projected Economic Costs in U.S. Communities, 2010-2020. *Journal of Environmental Management*, 92:2170-2181.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Shawinigan
New Brunswick
Trois-Rivieres
St-Georges
Joliette
Sorel-Tracy
Victoriaville
Thetford Mines
Fredericton
Drummondville
Laval
Longueuil
Ottawa
Granby
Sherbrooke
Montreal
Maine
Saint John
St-Jean-sur-Richelieu
Cornwall
Bay of Fundy
Brockville
Digby
Augusta
Montpelier
Vermont
Yarmouth
Portland
New York
New Hampshire
Concord
Utica
Nashua
Albany
Lowell
Massachusetts
Worcester
Boston
Regulated areas - 2018
N
0
50
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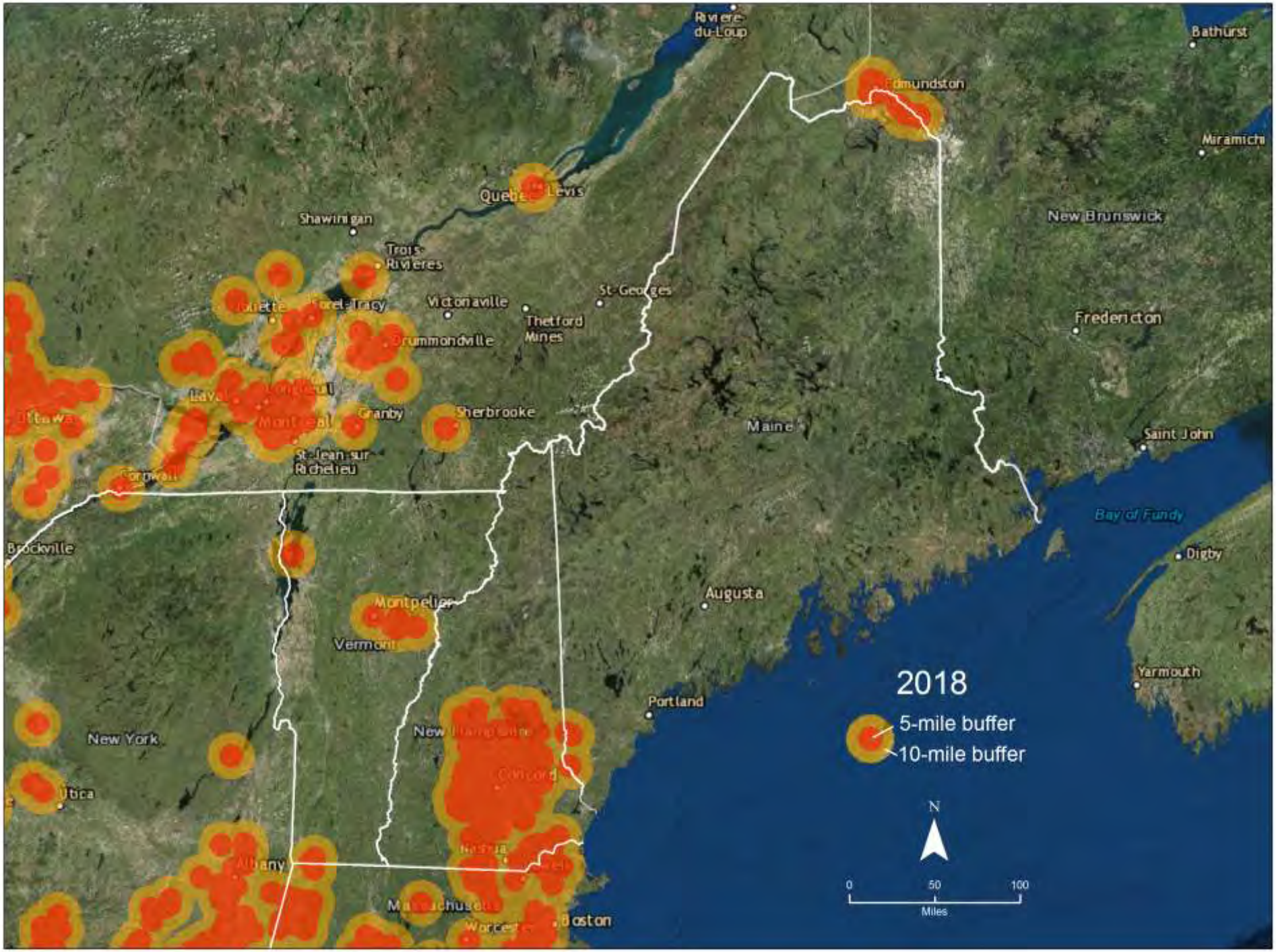
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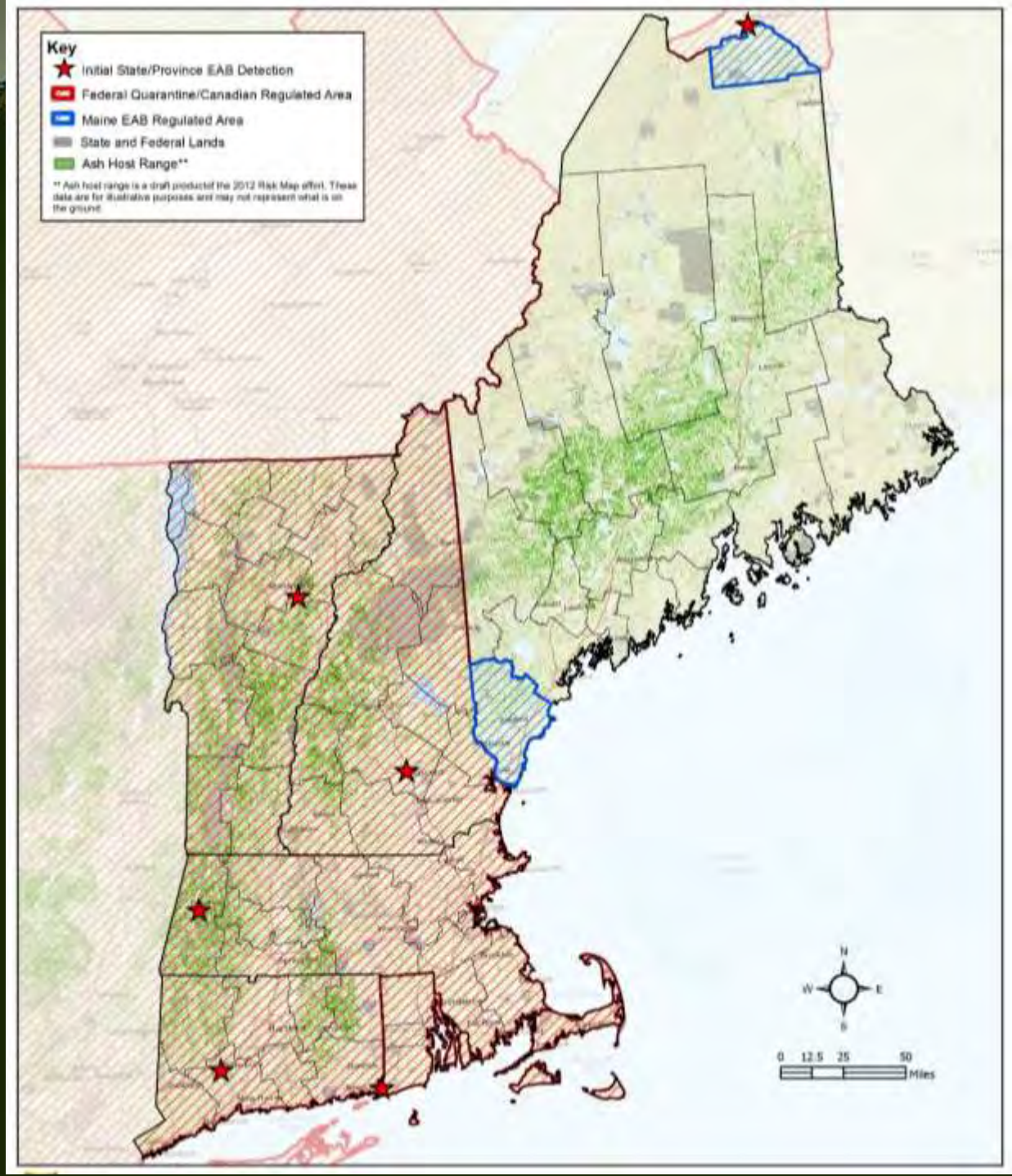
Victoriaville
St-Georges
Thetford Mines
Fredericton
Drummondville
Granby
Sherbrooke
Maine
Saint John
St-Jean-sur-Richelieu
Bay of Fundy
Digby
Augusta
Montpelier
Vermont
Yarmouth
Portland
New York
Utica
Albany
Boston
2018
5-mile buffer
10-mile buffer
N
0
50
100
Miles

How to Limit Short-Distance & Long-Distance Spread of EAB

MANAGEMENT: Affects local EAB population dynamics and short-distance spread of the infestation.

REGULATIONS: Quarantines reduce long-distance, human-assisted movement of EAB while facilitating safe trade through compliance agreements.

EAB Quarantine


Key
Initial State/Province EAB Detection
Federal Quarantine/Canadian Regulated Area
Maine EAB Regulated Area
State and Federal Lands
Ash Host Range**
** Ash host range is a draft product of the 2012 Risk Map effort. These data are for illustrative purposes and may not represent what is on the ground.
N
W
E
S
0 12.5 25 50
Miles

Implementation

- **Quarantine is critical when:**
  - ***EAB populations are low***
  - ***EAB populations are isolated***
  - ***Human-assisted movement is an important factor***
  - ***State is managing EAB***

Implementation

- **Quarantine is critical when:**
  - ***EAB populations are low***
  - ***EAB populations are isolated***
  - ***Human-assisted movement is an important factor***
  - ***State is managing EAB***

EAB doesn't stay this way…

EAB Management



In general, management in areas with building EAB populations focuses on the ash resource, mitigating impacts by reducing population growth rather than eradication or "control" of the pest itself.

Integrating Tactics to Slow Ash Mortality

- Integrate available tools & strategies appropriate for specific sites
- Slow EAB population growth & spread
- Delay onset & advance of ash mortality

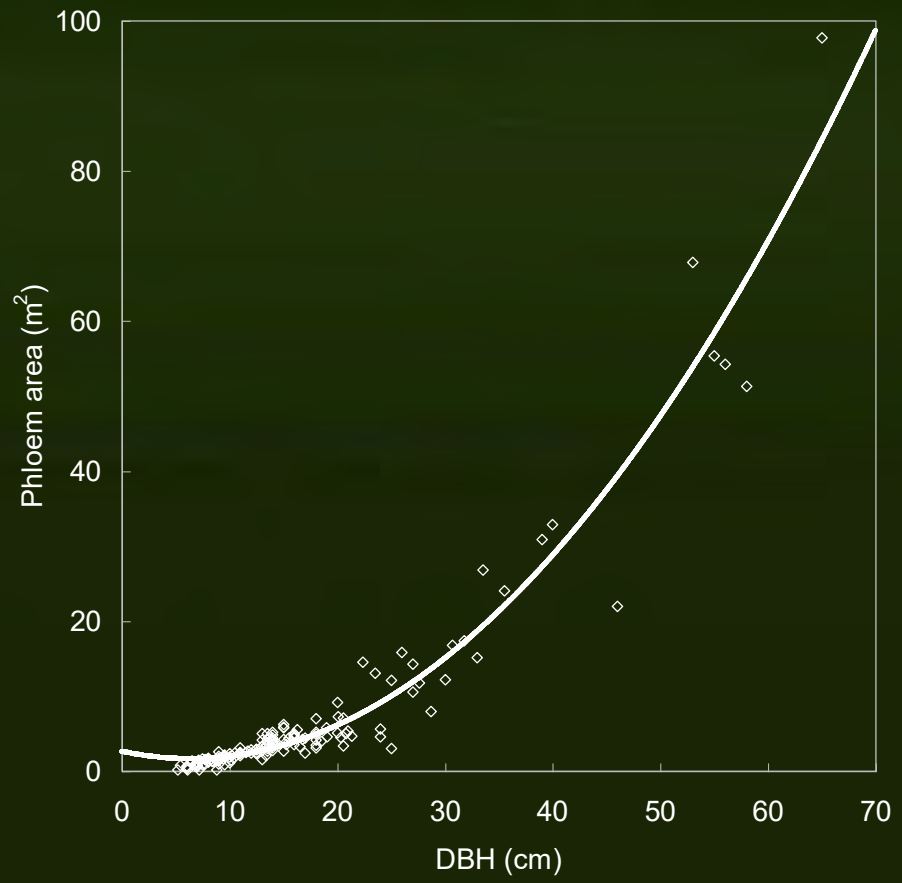
Targeted Ash Removal

Biological Control

Girdled Ash Trees

Insecticide Treatment

Targeted Ash Removal



$$Y = 0.024x^2 - 0.307x + 2.63$$

$$r^2 = 0.94$$

- **Total phloem area can be estimated from DBH**
- **Potential EAB production predicted**

McCullough & Siegert. (2007) Estimating Potential Emerald Ash Borer (Coleoptera: Buprestidae) Populations using Ash Inventory Data. *Journal of Economic Entomology*, 100:1577-1586.

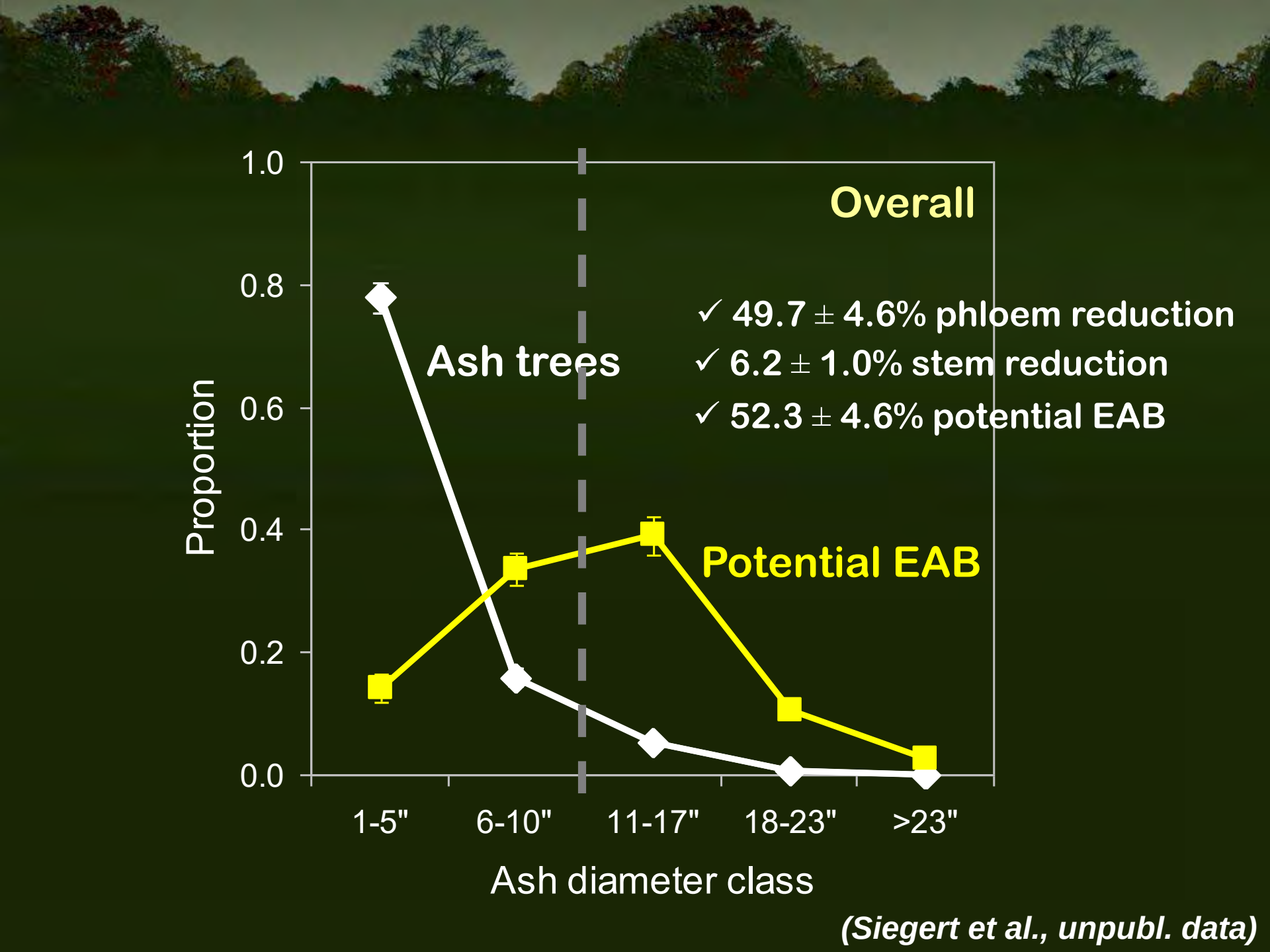
	DBH class (in)				
	1-5	6-10	11-17	18-23	>23
Mean ± SE	69 ± 6	108 ± 10	106 ±10	102 ±9	94 ± 11
95% CI	57-81	87-129	83-129	80-124	59-129

Overall, trees tend to produce about 100 EAB adults per m^2.

McCullough & Siegert. (2007) Estimating Potential Emerald Ash Borer (Coleoptera: Buprestidae) Populations using Ash Inventory Data. *Journal of Economic Entomology*, 100:1577-1586.

- 12 sites: 70,266 ash trees inventoried.
- While all sites were dominated by small trees (77.9 ± 2.4%), they only accounted for 14.3 ± 2.3% of the potential EAB population.
- Large (merchantable) trees comprised 6.2 ± 1.0% of the ash inventory, but accounted for 52.3 ± 4.6% of the potential EAB.
- Sites ranged in size from 40 to 560 ac and were forest, swamp, floodplain and suburban.

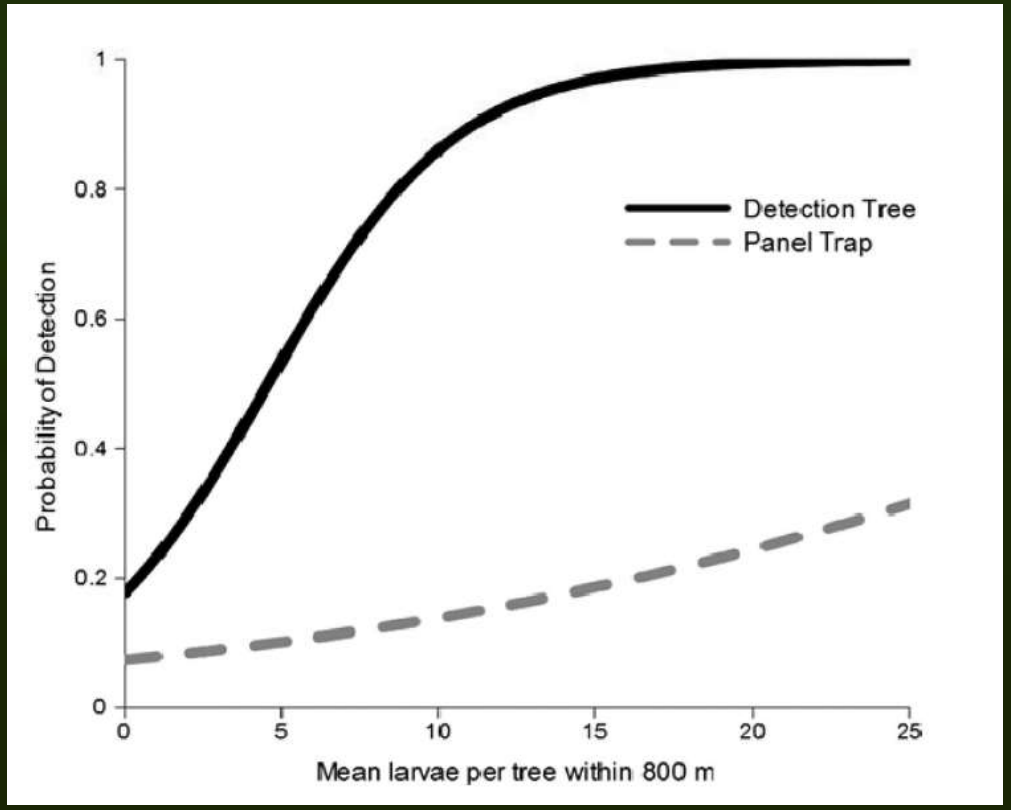
(Siegert et al., unpubl. data)



(Siegert et al., unpubl. data)

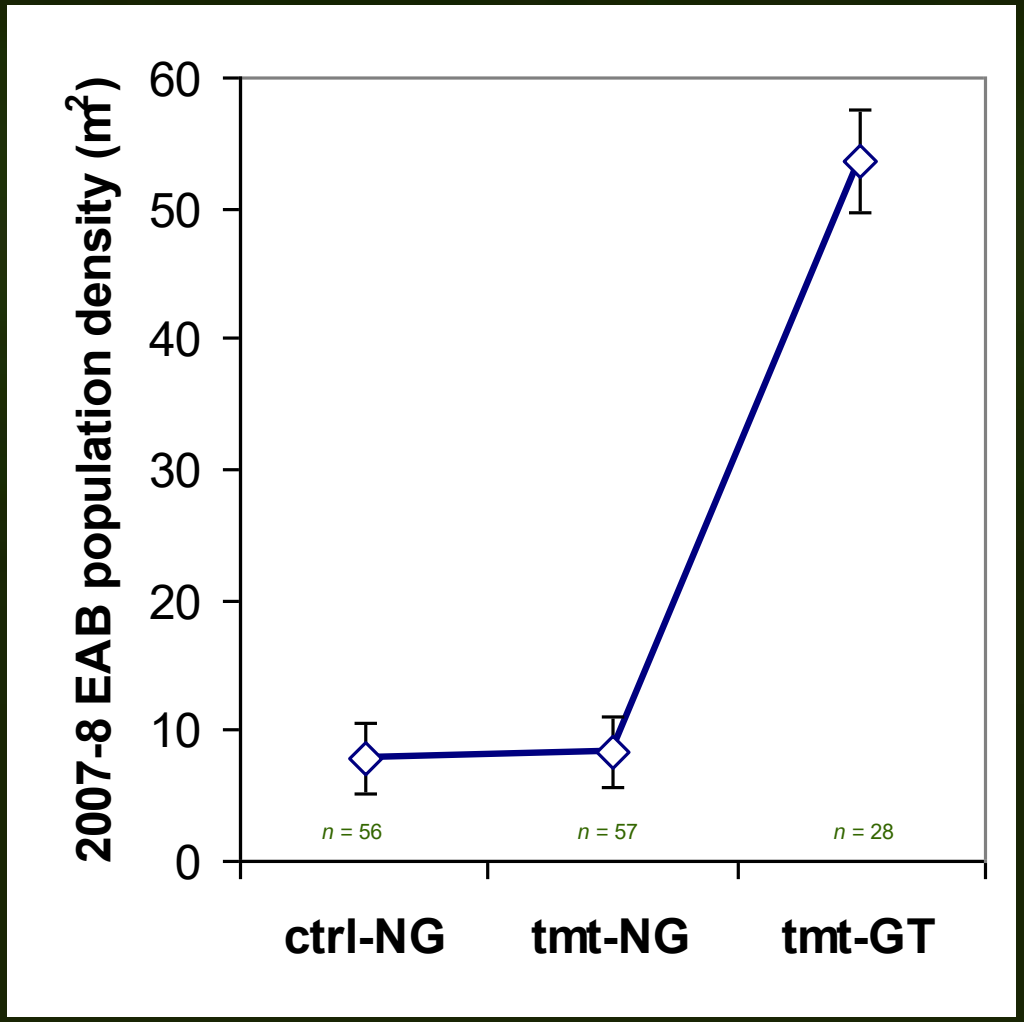
Biological Control


Girdled Ash Trees



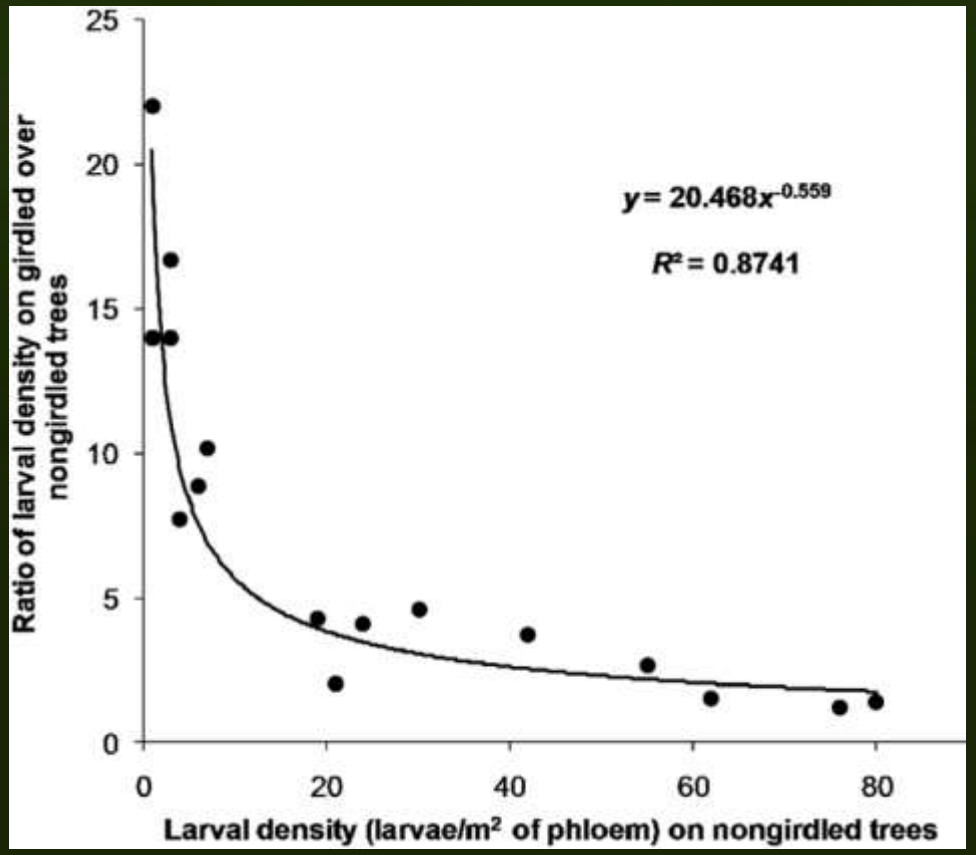
MERCADER ET AL. (2013) A COMPARISON OF GIRDLED ASH DETECTION TREES AND BAITED ARTIFICIAL TRAPS FOR *AGRILUS PLANIPENNIS* DETECTION. *ENVIRON. ENTOMOL.*, 42:1027-1039.

Girdled Ash Trees



Siegert et al. (2010) Effects of Clusters of Girdled Trees on the Spread of Emerald Ash Borer in Low-Density Infestations. *National EAB Research & Technology Development Meeting*.

Girdled Ash Trees



Mercader et al. (2011) Simulating the Effectiveness of Three Potential Management Options to Slow the Spread of Emerald Ash Borer (*Agrilus planipennis*) Populations in Localized Outlier Sites. *Canadian Journal of Forest Research*, 41:254-264.

Insecticide Treatment

Numerous formulations & application methods available but efficacy varies.

No aerial applications for treating forested areas available at this time.

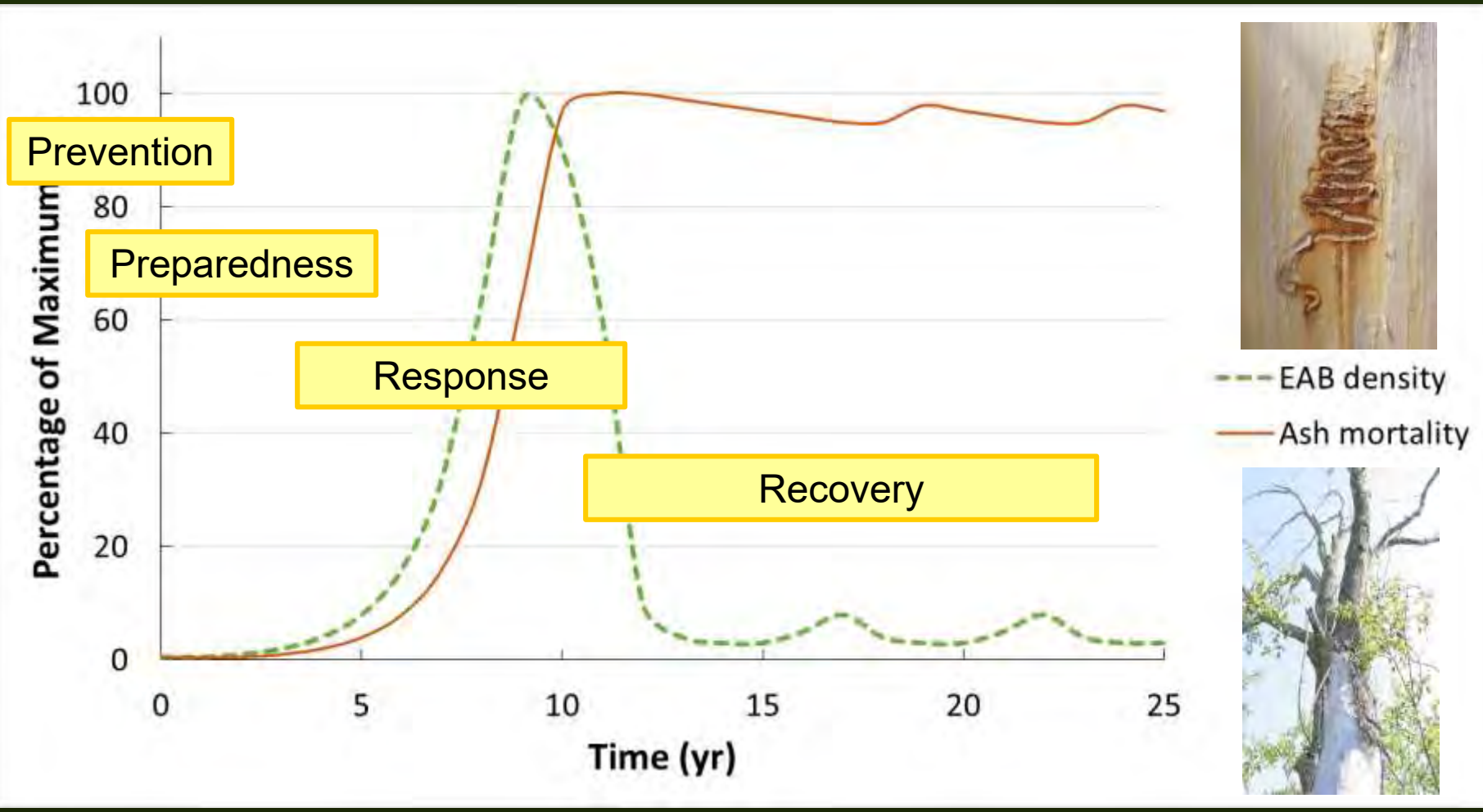
Ability to protect individual high-value landscape trees.

Slowing Ash Mortality

- Integrate the available tools and tactics as appropriate at a given site to slow EAB population growth & delay the onset of ash mortality.

- Prevents catastrophic ash mortality & reduces the associated ecological, economic & social impacts.

Management Approach Varies by Stage of EAB Invasion



EAB Risk Assessment

- Proximity to known EAB infestations (>10 mi = low risk; <10 mi = higher risk of invasion in the next 5 yrs).
- Highly dependent on human-aided movement of EAB-infested material.
- Potential economic impacts dependent on inventory.
  - Low = most ash <12” dbh
  - Mod = most ash >12” dbh, but low % of stand
  - High = most ash 12-18” dbh & high % of stand
  - Highest = most ash >18” dbh & high % of stand

Do Nothing (and EAB invades)

- All ash present will likely die, with dead, standing trees typically lasting 5-10 yrs (hazard trees and wildlife trees).
- Most economic value from ash will be lost (more larger-sized ash = higher potential $$$ losses).
- Desirable tree regeneration may be affected (invasive species could dominate).
- EAB population will build rapidly & spread at higher rate.

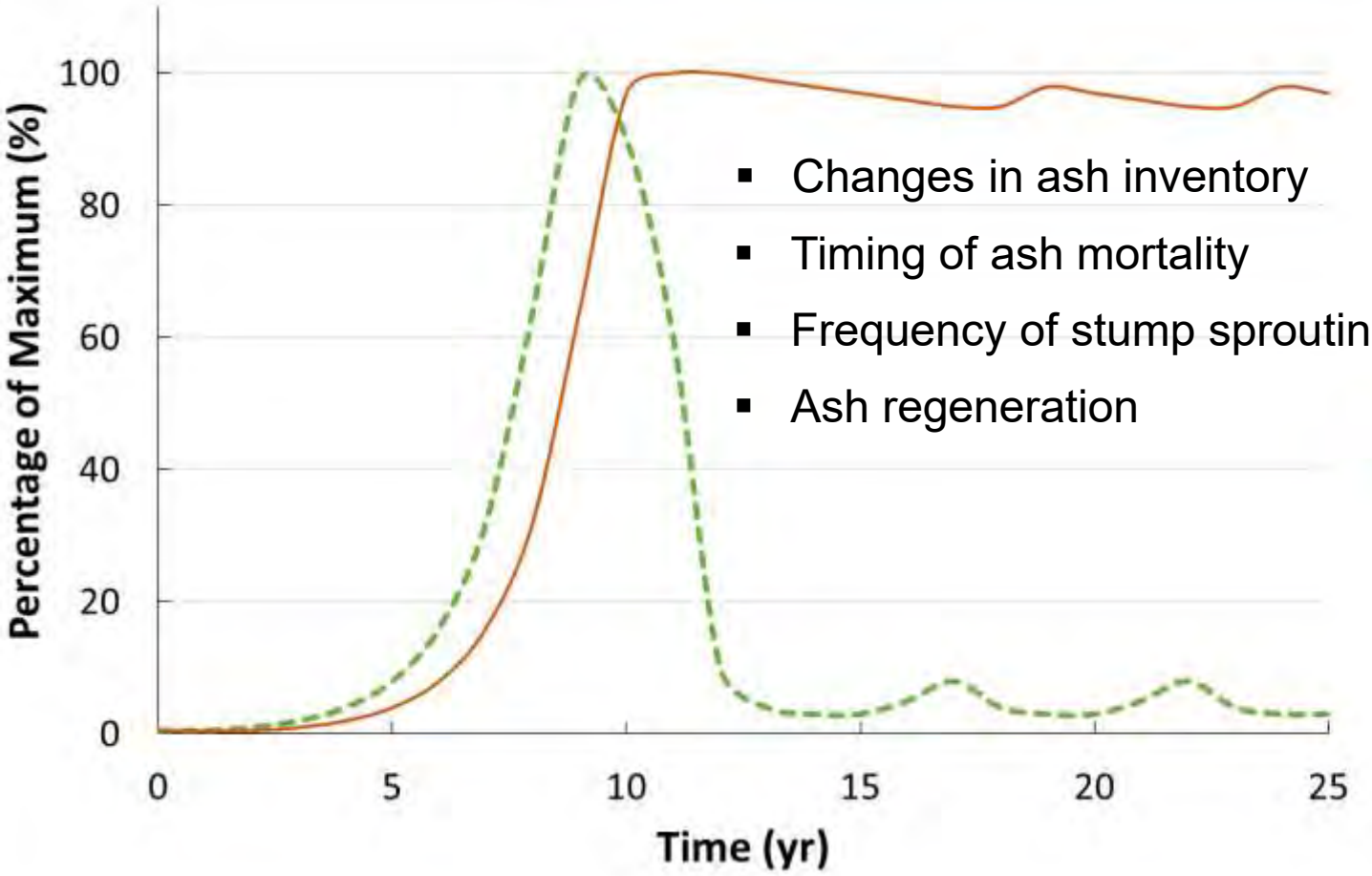
If Potential Economic Damage is Low

- Consider thinning ash (firewood and pulpwood) to shift stand to best residual (non-ash) trees.
- Harvests are likely to create gaps and openings, the size of which may depend on ash distribution.
- Openings may need to be monitored and/or treated for intended regeneration.

If Potential Economic Damage is High

- Consider harvesting high-value ash (sawlogs) and low-quality residual non-ash trees to favor desirable species and quality trees.
- Emphasis on the residual trees would be necessary.
- Development of a regeneration plan would be critical (natural regeneration may be limited).

Aftermath Forest Dynamics



- Changes in ash inventory
- Timing of ash mortality
- Frequency of stump sprouting
- Ash regeneration

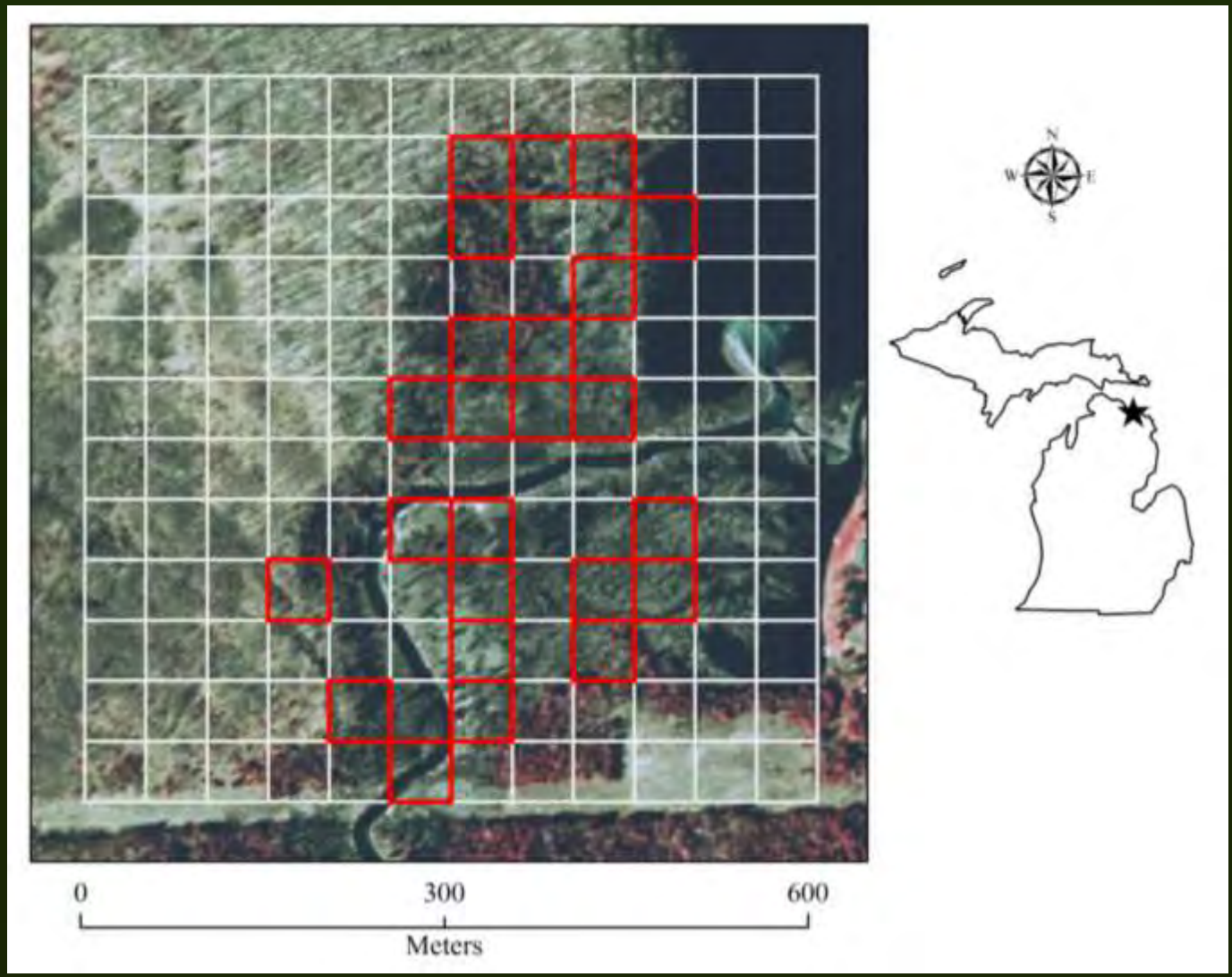
Cusp	Crest	Post Crest

Aftermath Forest Study Site

36-ha site

18-ha floodplain

EAB in 2004



Densities of EAB were at or near infestation levels capable of killing trees, averaging 36.3 ± 9.8 larvae per m^2.

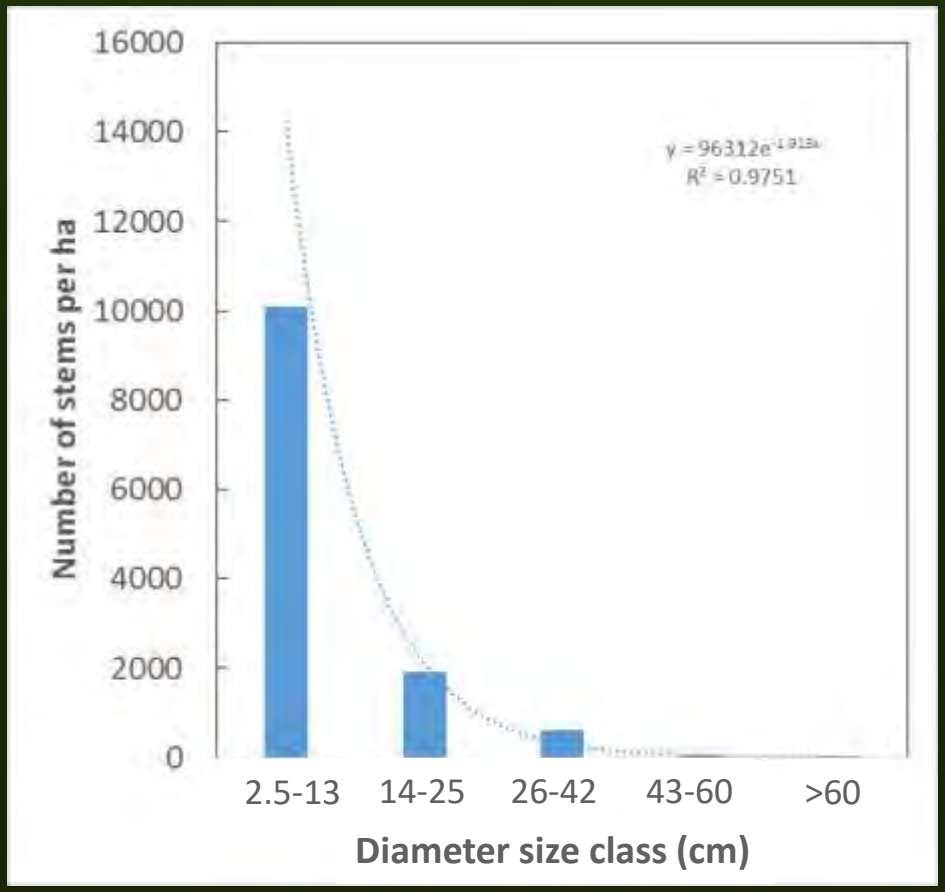
Live ash inventoried by diameter class in winter 2006-07 prior to EAB-induced ash mortality.

In summer 2016, live ash was re-inventoried by diameter class 10+ years after EAB invasion.

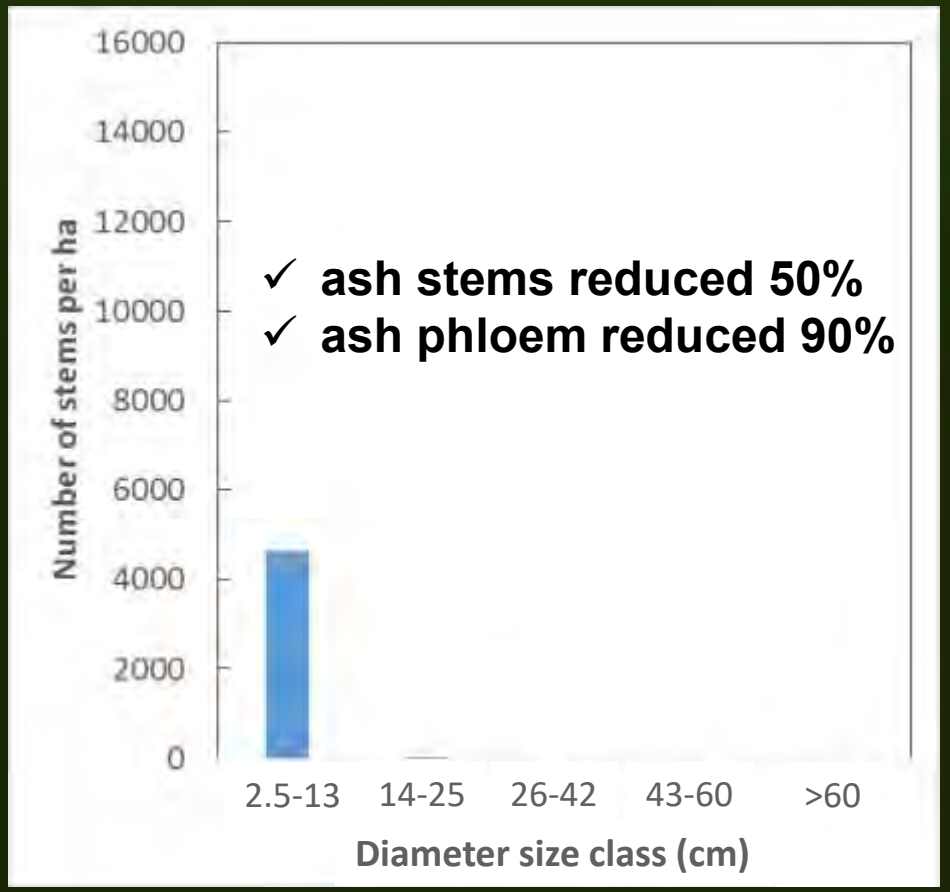
Summary of EAB Impacts

- Inventory: drastically reduced; smallest diameter class present but about half of pre-EAB inventory

Changes in Ash Density



Pre-EAB Ash Inventory

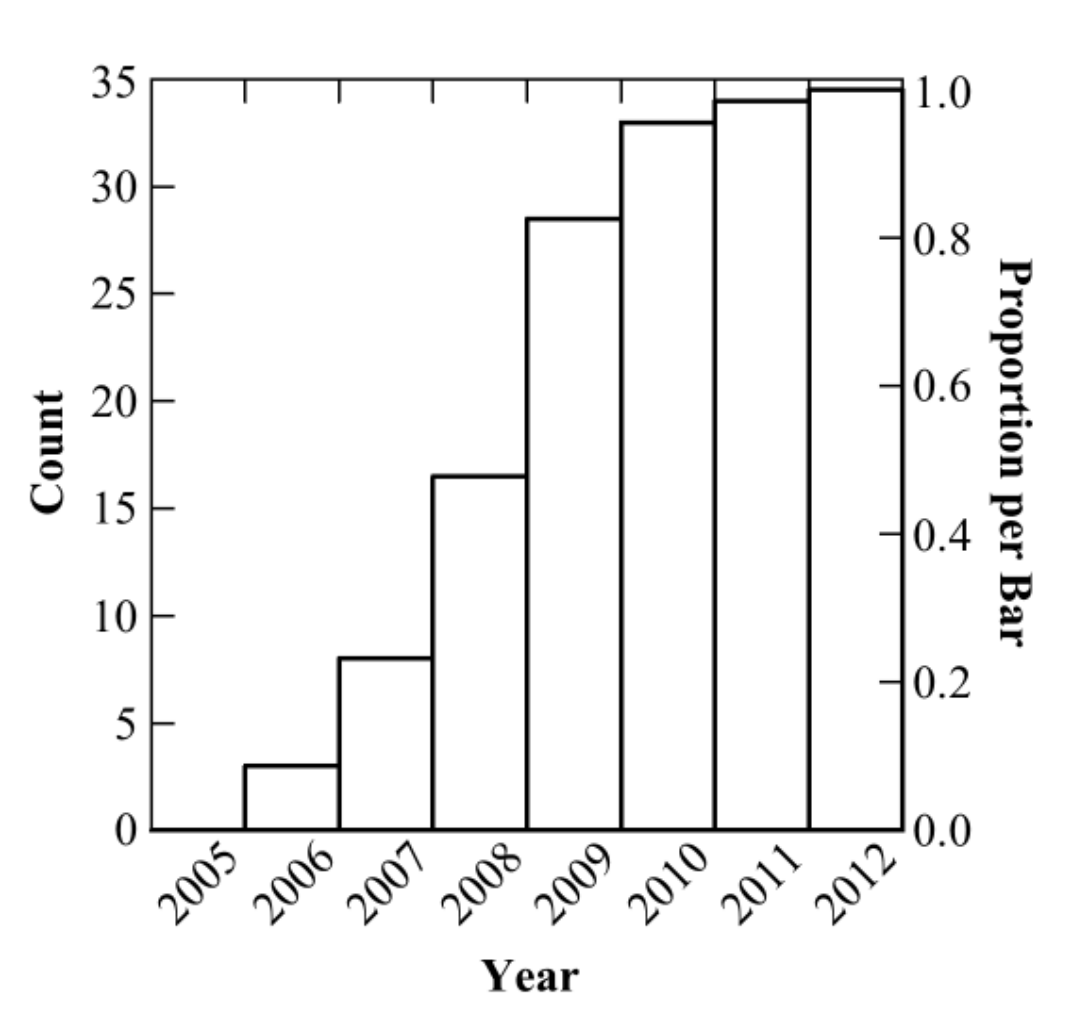


Post-EAB Ash Inventory


Summary of EAB Impacts

- Inventory: drastically reduced; smallest diameter class present but about half of pre-EAB inventory
- Timing: ash mortality advanced rapidly; mortality >90% about 8-10 years after EAB invasion

Ash Chronology & Mortality



Summary of EAB Impacts

- Inventory: drastically reduced; smallest diameter class present but about half of pre-EAB inventory
- Timing: ash mortality advanced rapidly; mortality >90% about 8-10 years after EAB invasion
- Stump sprouting: approximately 30% of EAB-killed green ash had live stump sprouts 10+ years after EAB invasion; sprouting not related to tree dbh; EAB-killed black ash did not have surviving stump sprouts

No Surviving Black Ash Stump Sprouts

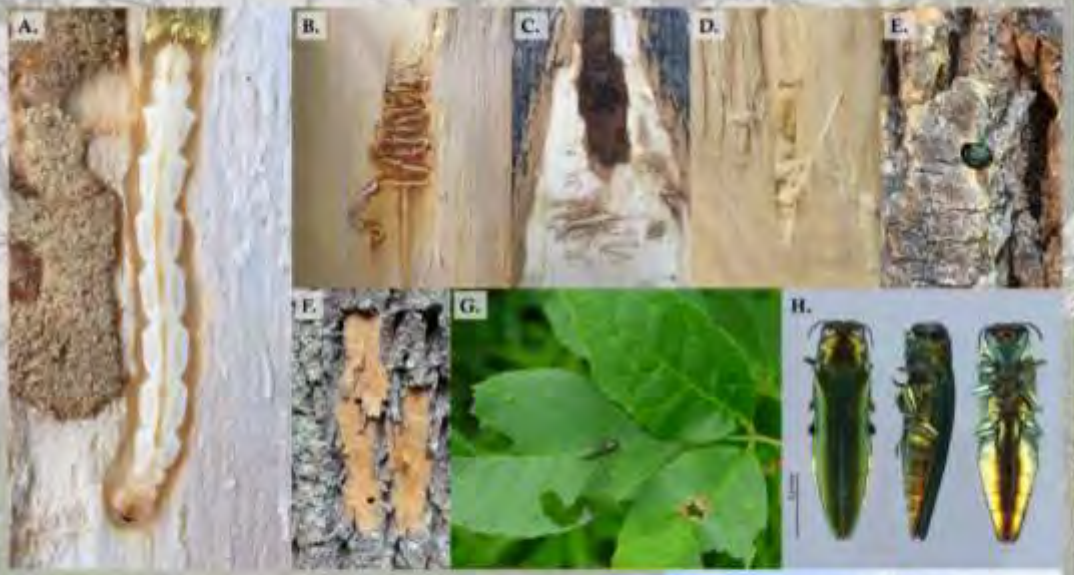
Summary of EAB Impacts

- Inventory: drastically reduced; smallest diameter class present but about half of pre-EAB inventory
- Timing: ash mortality advanced rapidly; mortality >90% about 8-10 years after EAB invasion
- Stump sprouting: approximately 30% of EAB-killed green ash had live stump sprouts 10+ years after EAB invasion; sprouting not related to tree dbh; EAB-killed black ash did not have surviving stump sprouts
- Ash regeneration: green ash, black ash, and white ash among top 5 seedling and sapling species present

Current Pressure on Ash Dynamics

- EAB pressure over time and effect on ash dynamics.
- Deer browse heavily impacts growth of ash seedlings, saplings, and stump sprouts.
- Loss of overstory ash may affect water table and establishment of invasive plants, which in turn affects residual trees and stress/survival of regeneration.
- Loss of ash seed source.
- Strategies for ash management in post crest forests will need to be developed and evaluated.

Emerald Ash Borer (*Agrilus planipennis*)



A. Late-instar emerald ash borer (EAB) larvae
B. Characteristic serpentine EAB larval gallery
C. Multiple stages of larval development are commonly present
D. EAB larvae in sapwood prior to developing into an adult beetle
E. Emerging EAB adult beetle
F. D-shaped exit holes from emerged EAB adults
G. Adult EAB on ash leaf with feeding along leaf margins
H. Adult EAB (dorsal, lateral, & ventral views)
I. EAB-infested ash trees with thinning crowns

www.emeraldashborer.info

www.maine.gov/eab

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