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Depts. of Entomology & Forestry
Michigan State University

“High impact” invaders: 62 species. A new high impact pest is detected every 2 years.

Non-native forest insects: > 470 species in the USA. Roughly 2.5 new species detected per year since 1860.

Dramatic jump in new woodborer detections since 1980 reflects global trade & containerized shipping.

Most of the non-native forest pests in the U.S. are European but most recent pests are from Asia.

Distribution of High Impact Invasive Forest Pests

Economic Cost Estimates by Insect Feeding Guild

Economic costs mostly reflect impacts of invasive forest pests on high value landscape trees in urban & residential areas. Costly to treat trees with insecticides or to remove trees when they die. Homeowners & municipal governments bear most of these costs.

Invasive insects also affect forest ecology & plant-based industries:
- Forest productivity & ecosystem functions altered
- Ecosystem services lost
- Biodiversity, endangered species & wildlife habitat diminished
- Quarantines & regulations are imposed
- Pesticide use & production costs go up

Social & Political Impacts:
- Municipal officials may face unhappy residents.
- City budgets & local resources may be overwhelmed (e.g., EAB).
- Scam artists may take advantage of anxious property owners.

Michigan has its fair share of invasive forests pests – and then some...

High Impact Invasive Pests in Michigan are in yellow

Defoliators:
- Ambermarked Birch Leafminer
- Birch Leafminer
- Birouillat Moth
- Black Vine Weevil
- Cherry Bark Tetrax
- Elm Leafminer
- Elm Leafminer
- European Pine Sawfly
- European Pine Shoot Moth
- European Spruce Needlminer
- European Web-spinning Larch Sawfly
- Gypsy Moth
- Introduced Pine Sawfly
- Imported Willow Leaf Beetle
- Japanese Beetle
- Larch Casebearer
- Larch Sawfly
- Mountain Ash Sawfly
- Mimosa Webworm
- Pine False Webworm
- Poplar sawfly
- Winter Moth

Phloem- and Woodborers:
- Asian Longhorned Beetle
- Asian Oak Weevil
- Burled Elm Bark Beetle
- Columbian Timber Beetle
- Emerald Ash Borer
- European Bark Beetle
- Eucalyptus Longhorned Borer
- Japanese Cedar Longhorn Beetle
- Maple Petiole Borer
- Mediterranean Pine Engraver Beetle
- Pine Shoot Beetle
- Peach Twig Borer
- Poplar and Willow Borer
- Red-haired Pine Bark Beetle
- Smaller European Elm Bark Beetle
- Sirex Wood Wasp

Sap-feeders:
- Balsam Woolly Adelgid
- Beech Scale
- Calico Scale
- Elongate Hemlock Scale
- Eucalyptus Psyllid
- Eastern Spruce Gall Aphid
- Green Spruce Aphid
- Hemlock Woolly Adelgid
- Introduced Basswood Thrips
- Juniper Scale
- Oystershell Scale
- Pine Bark Adelgid
- Pink Hibiscus Mealybug
- Pear Thrips
- Redgum Lerp Psyllid
- Red Pine Scale
- San Jose Scale

Diseases:
- Amylostereum Rot
- Beech Bark Disease
- Butternut Canker
- Chestnut Blight
- Dutch Elm Disease
- Dogwood Anthracnose
- European Larch Canker
- European Mistletoe
- Eurasian Poplar Leaf Rust
- Laurel Wilt Disease
- Oak Wilt
- Pitch Canker
- Port-Orford-Cedar Root Disease
- Phytophthora Root Rot
- Sudden Oak Death
- Thousand Cankers Disease
- White Pine Blister Rust
Beech Bark Disease in Michigan
A bad situation getting worse...

Beech Scale

Neonectria fagisuga fungus

History of BBD in North America

1890: Introduced into Nova Scotia from Europe (but beech scale is native to Asia & was invasive in Europe!)
1930’s: Maritime Provinces, Maine
1960: New England, NY
1975: Pennsylvania
1980-1990’s: VA, NC, WV, TN, OH, Ontario
2000: Michigan
2009: Wisconsin
No federal, state or provincial regulations

Range of American beech

Beech scale (Cryptococcus fagisuga)
Tiny insects pierce the outer bark to feed on nutrients in phloem (inner bark). One generation per year. Parthenogenic (all females).

Eggs & “crawlers” may be present from mid summer to fall. Only crawlers are mobile.

Tiny beech scale crawlers can be carried by wind.
3 adults on a penny
1 crawler on a penny

Crawlers & eggs are likely moved by birds, animals & people.

Each beech scale creates a “wound” in the outer bark. Wounds allow the Neonectria fungi to invade. Fungal pathogen kills patches of inner bark & cambium. Scales can’t survive on tissue killed by the fungus.

Scales secrete white wax as they feed.
Patches of rough bark are usually colonized first.
Large old trees tend to be infested before young trees with smooth bark.

Neonectria sp. fruiting bodies on bark - not commonly seen in MI.
Freshly killed phloem
Cracks over dead tissue
Patches of dead tissue coalesce, girdling branches. Tree canopies become ragged, yellow & decline. Some infected trees may persist as cankered “culls.” Other trees escape infection, at least initially.

Three Stages of BBD

- Advancing front: Beech scale established
- Killing front: *Neonectria* fungus has infected trees; Beech trees are declining, dying & dead.
- Aftermath forest: Few large trees survive. Infected “cull” trees & dense thickets of sprouts may be present.

Historically – NE states

- 50% loss of trees > 10” diam
- 25% survive as “culls”
- 25% escape first wave

*Projected loss in MI: 7.5 million beech >10” diam*

Large (> 40 years) beech trees provide nuts, cavities & perches for many birds & mammals.

MSU established plots in 62 beech sites in 2002. All sites revisited in 2012-2013 to assess BBD impact.

<table>
<thead>
<tr>
<th></th>
<th>Upper MI</th>
<th>Lower MI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sites infested</td>
<td>34</td>
<td>28</td>
</tr>
<tr>
<td>% dead beech</td>
<td>5.4%</td>
<td>10.8%</td>
</tr>
</tbody>
</table>

**BBD Killing Front in Michigan – 62 MSU Impact Plots**

<table>
<thead>
<tr>
<th></th>
<th>2002</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. sites infested</td>
<td>% dead beech</td>
<td>Sites infested</td>
</tr>
<tr>
<td>Upper</td>
<td>34</td>
<td>14</td>
</tr>
<tr>
<td>Lower</td>
<td>28</td>
<td>9</td>
</tr>
</tbody>
</table>

Dead beech basal area in 2013: 23% in Upper MI, 5% in Lower MI

Mortality now appears to be increasing in NW Lower MI
**Hemlock Woolly Adelgid – Michigan’s Newest Invader**

*Adelges tsugae*

- High shade tolerant & long-lived.
- Shallow-rooted & often grows near water.
- Dense canopy provides important cover; considered a key wildlife resource.
- Widespread hemlock mortality in NE states alters soil, nitrogen cycling, water quality & aquatic communities.

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**Eastern Hemlock**

- More than 170 million hemlocks in Michigan forests.
- Hemlock is an important forest & wildlife resource.
- Most trees are mature or overmature & vulnerable.
- Deer browse has limited hemlock regeneration.
- Thousands of hemlocks planted in landscapes.

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**Consequences of HWA in Michigan**

- More than 170 million hemlocks in Michigan forests.
- Hemlock is an important forest & wildlife resource.
- Most trees are mature or overmature & vulnerable.
- Deer browse has limited hemlock regeneration.
- Thousands of hemlocks planted in landscapes.

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**HWA feeding reduces tree vigor. Saliva injected by HWA is also "toxic" - triggers a hypersensitive response by the tree. Needles drop, buds may die & trees decline. Stress from drought or other pests can hasten mortality. Old, large trees often more vulnerable than younger trees.**
Don’t get confused...

**Elongate hemlock scale**
Invasive, sap-feeding pest but not a tree-killer. Hard, white or yellowish scales are on needles.

**Hemlock woolly adelgid**
Invasive, sap-feeding pest that kills its host trees. White “wool” will be at the base of needles or on shoots.

HWA is not federally regulated & survey intensity varies. Several states have HWA quarantines aimed at nursery trees originating in infested areas.

The Upside of Cold Winters – HWA Mortality?

HWA winter mortality in 5 Vermont locations

<table>
<thead>
<tr>
<th></th>
<th>2009-2010 Winter</th>
<th>2010-2011 Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min Temp</td>
<td>% Dead</td>
</tr>
<tr>
<td>Brattleboro</td>
<td>-1 F</td>
<td>14</td>
</tr>
<tr>
<td>Vernon</td>
<td>-1</td>
<td>13</td>
</tr>
<tr>
<td>Guilford</td>
<td>-4</td>
<td>74</td>
</tr>
<tr>
<td>Townshend</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>Jamaica</td>
<td>-2</td>
<td>13</td>
</tr>
<tr>
<td>Average</td>
<td>-1 F</td>
<td>25%</td>
</tr>
</tbody>
</table>

Is Lake Effect weather “protecting” HWA in MI?

Winter 2013-2014

Maps & data courtesy of Jeff Andresen, MSU
Systemic insecticides can protect hemlocks from HWA

Dinotefuran provides rapid control & persists 1-2 years. Imidacloprid moves slowly but persists ≥ 5 years. Large, declining trees - tank mix of both products. Timing: Fall or spring Method: Basal trunk spray or soil drench

Emerald ash borer is the most destructive forest insect to ever invade North America

≈1990: EAB becomes established in southeast Michigan.
2002: EAB “discovered” - identified as Agrilus planipennis
2016: EAB in 28 US states & 2 Canadian provinces

www.emeraldashborer.info

Hundreds of millions of ash (Fraxinus spp.) trees in landscapes & forests have been killed by EAB.

EAB has encountered 4 major ash species to date

- White Ash (Fraxinus americana)
- Green Ash (Fraxinus pennsylvanica)
- Black Ash (Fraxinus nigra)
- Blue Ash (Fraxinus quadrangulata)

Female EAB select hosts for leaf-feeding & oviposition.

Larvae must feed & develop on the host selected by the female beetles.

Adult EAB host preference varies among ash species

Preferred & vulnerable

<table>
<thead>
<tr>
<th>Black ash</th>
<th>Green ash</th>
<th>White ash</th>
<th>Blue ash</th>
</tr>
</thead>
</table>

Less preferred

Anulewicz et al. 2007; Rebek et al. 2007; Chen & Poland 2010, Tanis & McCullough 2012; Tanis & McCullough 2015
EAB host preference & suitability of five ash species: Plantation study

Five ash species planted in 21 randomized blocks:
Black, Blue, Green, White & Manchurian (Asian species)
Trees were protected from EAB for 5+ years, then exposed to high local EAB densities.
All trees were debarked in fall to quantify larval density.

- All black ash & green ash were killed.
- Most EAB larvae on black & green ash died from intraspecific competition.
- White ash was an intermediate host.
- Blue ash & Manchurian ash had < 2 larval galleries per tree; largely ignored by EAB.

Tanis & McCullough 2015 Environ. Entomol.

**Black Ash** (*Fraxinus nigra*)
Common in northern bogs & swamps in 19 states; slow growth & infrequent seeding.
Cultural resource for Native American & 1st Nation tribes

Black ash: Highly preferred & most vulnerable host. No evidence to date that black ash will survive the EAB invasion.

Long-Term Evaluation of EAB & Green Ash - Jasper
Green ash were inventoried (by DBH class) in 2007 in 2 sites, each 16.2 ha, then re-surveyed in 2015. From 2007 to 2013, ≥ 8 ash were felled & debarked annually to monitor larval density.

Average density of EAB larvae increased exponentially from 2007 to 2015. Less than 10% of the green ash trees (~4 inches dbh) remained alive in 2015.
**Blue Ash**  
*Fraxinus quadrangulata*

Tolerates a wide range of soils; Native in at least 12 states; Monoecious; Distinct ridges on shoots; Attractive landscape tree.

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**White ash versus Blue ash**

Most dominant blue ash (all diameter classes) remain alive & appear healthy in both sites. By 2012, the only live white ash were small trees, all ≤ 4 inches dbh.

<table>
<thead>
<tr>
<th>Superior site</th>
<th>No. trees</th>
<th>% live</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue ash</td>
<td>210</td>
<td>63%</td>
</tr>
<tr>
<td>White ash</td>
<td>125</td>
<td>0</td>
</tr>
<tr>
<td>Plymouth site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blue ash</td>
<td>381</td>
<td>71%</td>
</tr>
<tr>
<td>White ash</td>
<td>186</td>
<td>16%</td>
</tr>
</tbody>
</table>

**Is EAB always a death sentence for white ash?**

White Ash (*F. americana*)

Native forest species in ≥ 34 states. Valuable timber species; often grows in mixed stands. Common in landscapes.

**Assessing White Ash Survival in the EAB Core**

- Scouted public forest lands across 12 counties in SE & central Michigan with >10-12 years of EAB presence.
- Identified 28 sites with abundant white ash (dead or live).
- Established a 1 ha site with a center point & 4 fixed radius plots (18 m) & surveyed overstory species.
- Two baited double-decker EAB traps per site.
Overall, 74% of the 2546 white ash stems tallied are alive, including 79% of recruits & 62% of trees >4 inches dbh. Survival among sites ranges from 3 to 97% of stems. Many trees are recovering from past EAB injury.

Evidence of recovery common
Robinett et al. unpubl. data

We captured 503 EAB beetles in 2014 & 543 beetles in 2015. Area of live white ash phloem was not strongly related to EAB captures in either year. Indicates EAB captures are not limited by the carrying capacity of the site.

Not yet clear whether site or stand factors determine white ash survival rates. But ...the persistence of healthy blue ash & at least some white ash after years of EAB presence gives us some hope!