Munching, Crunching & Sucking: Invasive Forest Insect Pests in the U.S. & Michigan



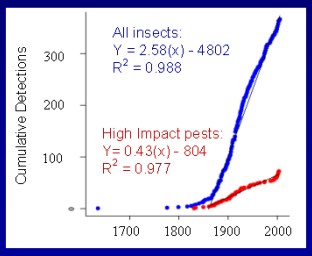




Dr. Deborah G. McCullough, Professor
Depts. of Entomology & Forestry
Michigan State University

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

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

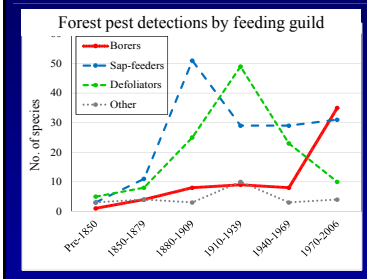


EAB (Borer)

HWA (Sap feeder)

Gypsy moth (Defoliator)

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



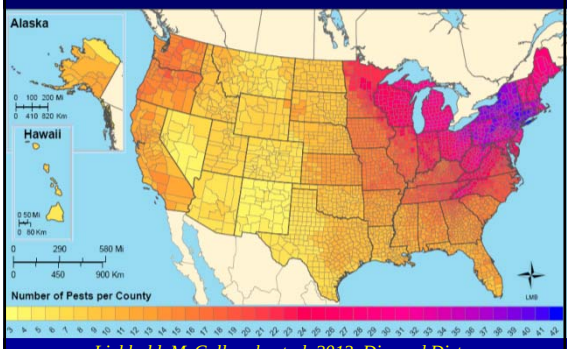


1980-2012: 56% of new forest pest detections were woodborers.

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

"…the known unknowns and the unknown unknowns…"

Distribution of High Impact Invasive Forest Pests



Liebhold, McCullough, et al. 2013. Div. and Dist.

Economic Cost Estimates by Insect Feeding Guild

Annualized marginal damages in millions of $USD

	Government		Households		Markets
TOTALS	Federal	Local	Spent	Property values	Timber
Woodborers (71 species)	92	1770	760	830	130
Defoliators (155 species)	110	170	160	410	18
Sap-feeders (192 species)	14	170	130	260	4

Aukema et al. 2011. PLoS One Vol. 6: 1-7

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.



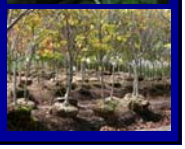


Invasive insects also affect forest ecology & plant-based industries

- 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...

Gypsy moth

EAB

BBD




High Impact Invasive Pests in Michigan are in yellow

Phloem- and Woodborers:
Asian Longhorned Beetle
Asiatic Oak Weevil
Banded 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

Defoliators:
Ambermarked Birch Leafminer
Birch Leafminer
Browntail Moth
Black Vine Weevil
Cherry Bark Tortrix
Elm Leafbeetle
Elm Leafminer
European Pine Sawfly
European Pine Shoot Moth
European Spruce Needleminer
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

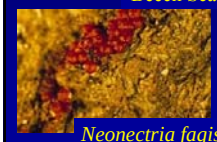
Sap-Feeders:
Balsam Woolly Adelgid
Beech Scale
Calico Scale
Elongate Hemlock Scale
Eucalyptus Psyllid
Eastern Spruce Gall Aphid
Green Spruce Aphid
Hemlock Woolly Adelgid
Introduced Basswood Thrips
Juniper Scale
Oystershell Scale
Pine Bark Adelgid
Pink Hibiscus Mealybug
Pear Thrips
Redgum Lerp Psyllid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

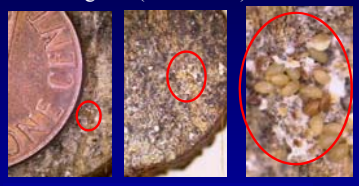
2000: Michigan
2009: Wisconsin

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).



Crawlers

Crawlers & eggs

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.



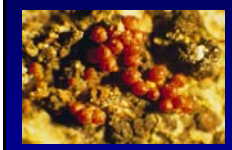


Scales secrete white wax as they feed.

Patches of rough bark are usually colonized first.

Large old trees tend to be infested before young trees with smooth bark.


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.



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.



Tahquamenon Falls Park, MI

New England

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.

Beech with cankers



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

2013 - Cadillac, MI neighborhood

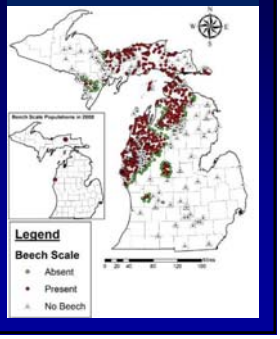
Large (> 40 years) beech trees provide nuts, cavities & perches for many birds & mammals.


Beech scale distribution in MI (Advancing Front)

2000: Ludington State Park
Basswood State Park

Beech scale 2002

Beech scale 2014



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

2012-2013
Upper MI: 34 sites; 622 overstory beech examined.
Lower MI: 28 sites; 530 overstory beech examined.



BBD Killing Front in Michigan – 62 MSU Impact Plots

	2002		2013		
No. sites	Sites infested	% dead beech	Sites infested	% dead beech	% dead, infested in 2002
Upper					
34	14	5.4%	33	25.3%	49.4%
Lower					
28	9	10.8%	22	6.2%	8.5%

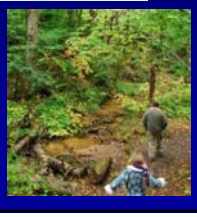
Dead beech basal area in 2013: 23% in Upper MI
5% in Lower MI

Mortality now appears to be increasing in NW Lower MI

Hemlock Woolly Adelgid – Michigan's Newest Invader

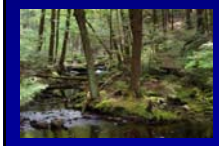
Adelges tsugae



Eastern Hemlock

- Highly 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.

Consequences of HWA in Michigan

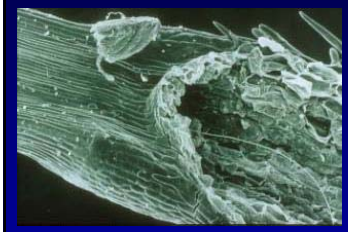
- More than 170 million hemlocks in Michigan forests.
- Hemlock is an important forest & wildlife resource.
- Most trees are mature or overmature & vulnerable.
- Deer browse has limited hemlock regeneration.
- Thousands of hemlocks planted in landscapes.


Adelges tsugae (wax removed)


Infested shoot


Smoky Mtn Nat. Park
Dead hemlocks

HWA nymphs & adults pierce the base of needles then suck nutrients from cells in the shoots.

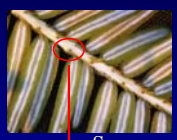



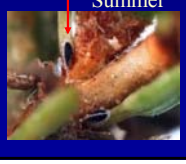

Feeding adelgids are immobile; Secrete white wax called ovisacs (wool) through pores on their bodies as they feed.

- HWA has 2 generations per year.
- Parthenogenic reproduction – all females.
- Insects & eggs protected by ovisacs – white waxy wool.
- Natural dispersal – wind, maybe birds or animals



Eggs


Summer



HWA feed in fall, winter & spring. Immature HWA are dormant during summer. Begin feeding in mid October & continue all winter.


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.

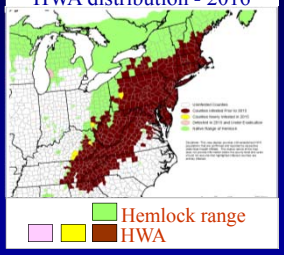
Don't get confused...

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

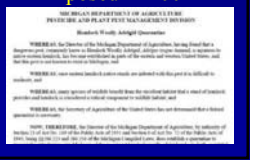
Hemlock woolly adelgid
Invasive, sap-feeding pest that kills its host trees. White "wool" will be at the base of needles or on shoots.

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

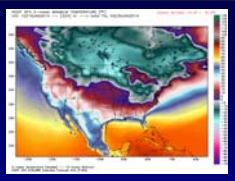
HWA distribution - 2016



MI: HWA Quarantine imposed in 2001



The Upside of Cold Winters – HWA Mortality?



HWA winter mortality in 5 Vermont locations

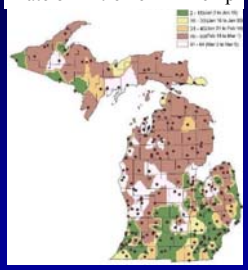
	2009-2010 Winter		2010-2011 Winter	
	Min Temp	**% Dead**	**Min Temp**	**% Dead**
Brattleboro	-1 F	14	-15 F	96
Vernon	-1	13	-11	56
Guilford	-4	74	-15	94
Townshend	0	9	NA	89
Jamaica	-2	13	-11	98
Average	-1 F	25%	-13 F	87%

Is Lake Effect weather "protecting" HWA in MI?

Winter 2013-2014

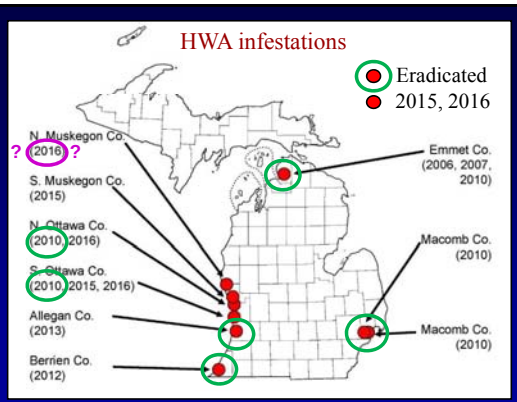
Extreme Minimum Temp

Date of Extreme Min Temp



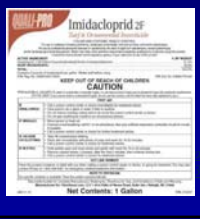
Maps & data courtesy of Jeff Andresen, MSU

HWA infestations



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

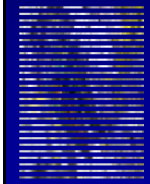
≈1990: EAB becomes established in southeast Michigan.
2002: EAB "discovered" - identified as *Agrilus planipennis*
2016: EAB in 28 US states & 2 Canadian provinces

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

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 → Less preferred

Black ash	Green ash	White ash	Blue ash

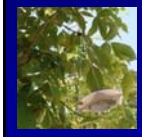
Anulewicz et al. 2007; Rebek et al. 2007; Chen & Poland 2010, Tanis & McCullough 2012; Tanis & McCullough 2015

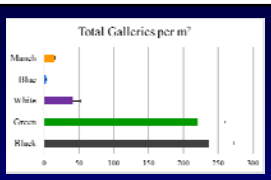
EAB host preference & suitability of five ash species: Plantation study

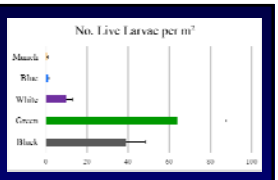
Five ash species planted in 21 randomized blocks:
Black, Blue, Green, White & Manchurian (Asian species)

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.

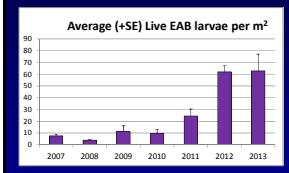


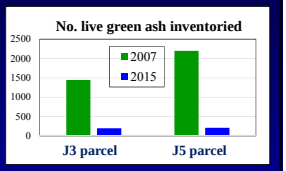

Long-Term Evaluation of EAB & Green Ash - Jasper

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.

50 x 50 m grids

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.

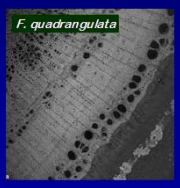






Blue Ash
Fraxinus quadrangulata

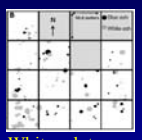
Tolerates a wide range of soils; Native in at least 12 states; Monoecious; Distinct ridges on shoots; Attractive landscape tree.



White ash versus Blue ash

In 2010-2011, we inventoried 100% of the live & dead ash trees in 2 woodlots in SE MI invaded in the early 2000's. Recorded condition, size & distribution of all ash trees.

Blue ash trees



White ash trees

Tanis & McCullough. 2012. Can. J. For. Res. 42: 1542–1550.

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.

Superior site	No. trees	% live
Blue ash	210	63%
White ash	125	0
Plymouth site		
Blue ash	381	71%
White ash	186	16%

Tanis & McCullough. 2012.

Adult EAB host preference varies among ash species

Preferred & vulnerable → Less preferred

Black ash | Green ash | White ash | Blue ash

Anulewicz et al. 2007; Rebek et al. 2007; Chen & Poland 2010, Tanis & McCullough 2012; Tanis & McCullough 2015

Is EAB always a death sentence for white ash?

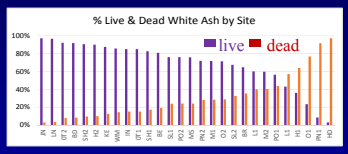
White Ash (*F. americana*) Native forest species in ≥ 34 states. Valuable timber species; often grows in mixed stands. Common in landscapes.

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.

Results - 2015 (28 sites)

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.

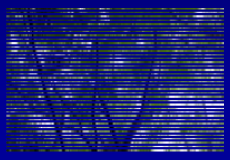


Evidence of recovery common

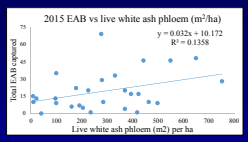
Robinett et al. unpubl. data

More than 60% of the white ash basal area remains alive in 24 of the 28 sites. Live trees appear healthy. Most (85%) live white ash had healthy canopies (< 30% dieback).

No. sites	Live stems	Live basal area
12	80-97%	82-99%
12	50-79%	62-77%
4	3-49%	< 40%



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!

How many invasive forest pests are too many?

Nonnative forest insects and pathogens in the US: Impacts and policy options. 2016. Ecological Applications, Vol. 26.

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Profound & irreversible effects of invasive forest insects & pathogens are the most serious threat to eastern forests.