High-Impact Insect Invasion
Working Group

Angela Mech, Ph.D.
University of Maine
School of Biology & Ecology

Continental Dialogue of Non-native Forest Insects & Diseases

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The 2016 Working Group
USGS John Wesley Powell Center for Analysis and Synthesis

Dan Herms – The Davey Tree Expert Company
Travis Marsico – Arkansas State University
Kathryn Thomas – USGS
Patrick Tobin – University of Washington
Craig R. Allen – USGS/University of Nebraska
Matt Ayres – Dartmouth College
Kamal Gandhi – University of Georgia
Jessica Gurevitch – Stony Brook University
Nathan Havill – USDA Forest Service
Ruth Hufbauer – Colorado State University
Sandy Liebhold – USDA Forest Service
Angela Mech – University of Washington
Ken Raffa – University of Wisconsin
Ashley Schulz – Arkansas State University
Dan Uden – University of Nebraska
The 2018 Working Group
USFS National Urban and Community Forestry
Advisory Council Challenge Cost-Share Grant Program

Matt Ayres – Dartmouth College
Dan Herms – The Davey Tree Expert Company
Ruth Hufbauer – Colorado State University
Angela Mech – University of Maine
Carissa Aoki – Bates College
Kamal Gandhi – University of Georgia
Nathan Havill – USDA Forest Service
Sandy Liebhold – USDA Forest Service
Scott Maco – The Davey Tree Expert Company
Travis Marsico – Arkansas State University
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Ashley Schulz – Colorado State University
Kathryn Thomas – USGS
Patrick Tobin – University of Washington
Dan Uden – University of Nebraska
The problem: Non-native tree-feeding insects *can* devastate tree hosts

- Why do some introduced insects cause widespread mortality, but most do not?
- What factors drive the level of impact of an introduced forest insect?

How do we predict the next high impact insect invaders?
Hypothesis: Some or all of these factors influence impact.
Impact on North American Hosts

Step 1: Develop an impact scale

1. No damage
2. Minor damage
3. Kills only stressed tree
4. Weakens tree; something else causes mortality
5. Kills healthy tree
6. Isolated/Sporadic mortality in population
7. Extensive/Persistent mortality in population
8. Wave of mortality across region
9. Functional Extinction

Low Impact | Medium Impact | High Impact
Methods – Look at the non-native insects in North American forests; see if any traits or factors influence their level of impact
Analyzed the 4 main categories of interest

Insect Traits
- Feeding Guild
- Dispersal mechanism
- Repro. Strategy
- Voltinism

Native & Novel Host Evolutionary History
- Pinus virginiana
- Divergence time to most recent common ancestor = 10.89 million years ago

North American Host Traits
- Shade tolerance
- Foliage texture
- Growth rate
- Drought tolerance
- Fire tolerance
- Wood density

Native & Novel Insect Evolutionary History
- 248 non-native insects
- 4,000+ North American insects
- 173 North American conifer and hardwood tree species
Part 1: Conifer "specialists"

N = 58 spp.

Host Traits = Yes

Host Relatedness = Yes

Insect Relatedness = Yes

As low as 1.4% chance of being high impact

10% chance of being high-impact if no congener on tree

1% chance of being high-impact if congener on tree
Part 1: Conifer “specialists”

• Combining the 3 sub-models = better predictive power than individual models
• Composite model predicts range from 1 in 6.5 to 1 in 2,858 chance of insect being high-impact
It’s more than just if a conifer is shade tolerant & drought intolerant...
It about if it is also being attacked by an insect that coevolved with a conifer host that shared a common ancestor with that conifer ~12-17 mya
And if the conifer didn’t coevolve with an insect in the same genus as the attacking insect

Example:
Abies balsamea (balsam fir)
Attacked by BWA (Adelges piceae)
Shade tolerant & drought intolerant
Native host relative = Abies alba (13.5 mya)
No coevolved native Adelges sp.
Part 2: Hardwood “specialists”

N = 191 spp.  
n = 100 spp.

Host Traits = Yes  
Host Relatedness = Yes  
Insect Traits = Yes

Predicting non-native insect impact: focusing on the trees to see the forest

Composite model = best for conifer specialists & hardwood specialists

**Conifer specialists**

- **Host traits + Host evolutionary history + Insect evolutionary history** = AUC of 0.91

**Hardwood specialists**

- **Insect traits + Host traits + Host evolutionary history** = AUC of 0.95
Part 3: All non-native forest insects of NA

- N = 251 spp.  
  n = 90 spp.

- N = 500 spp.  
  n = 248 spp.

But debate about the definition of “specialist”

Phylogenetic Diversity (PD)

- PD = sum of the branch lengths; measure of native host breadth
- Range of 0 (only 1 documented native host) to 7,723 (diverse range of hosts)

PD < 2,250 = narrow host breadth = “specialists”

PD > 2,250 = broad host breadth = “generalists”

Xylosandrus germanus, PD = 7,723
152 tree spp. in 48 families

Matsucoccus matsumurae, PD = 17
2 tree spp. in 1 family
How do we predict the next high impact invaders?

**The i-Tree Pest Predictor (iTPP) tool**

Input data

- Insect Taxonomy (Order, Family, Genus, species)
- Feeding Guild
- Native Range
- Native Köppen Climate
- Native range host trees

Run model

Output

iTPP will be a part of the i-Tree software suite
**Ultimate goal:** help a variety of stakeholders generate non-native insect risk assessments on North American trees for species that haven’t invaded yet.

**Example output:** 1 in 7.6 chance of being high impact on some elm species if this particular species established in North America.

**Host Suitability:**
- **High:** the insect feeds on the same plant GENUS in its native range.
- **Medium:** the insect feeds on the same plant FAMILY, but not the same GENUS.
- **Low:** the insect doesn't feed on this FAMILY or GENUS in its native range.
Based on the data you enter, iTPP chooses the right composite model (there are 5)

The model predicts the risk on more than 400 North American conifer & hardwood potential host trees
The composite model is best for all models = multiple factors influence impact

<table>
<thead>
<tr>
<th>Model</th>
<th>Conifer</th>
<th>Hardwood</th>
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<tbody>
<tr>
<td>Insect Traits</td>
<td></td>
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<tr>
<td>North American Host Traits</td>
<td>Sapfeeder</td>
<td>Specialists Scolytine</td>
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<td></td>
<td>Shade + Drought AUC = 0.77</td>
<td>Feeding Guild AUC = 0.89</td>
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<td>Quadratic AUC = 0.85</td>
<td>Linear AUC = 0.88</td>
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<td>AUC = 0.88</td>
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<td>non-Sapfeeder</td>
<td>Specialists non-Scolytine</td>
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<td>Shade + Drought AUC = 0.77</td>
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<td>Quadratic AUC = 0.73</td>
<td>Tribe AUC = 0.80</td>
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<td>AUC = 0.85</td>
<td>AUC = 0.94</td>
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<td>Host Evol. History</td>
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<td>Insect Evol. History</td>
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<td>Composite</td>
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In Summary

- Evolutionary history is a driver of insect impact!
- Important traits and factors differ based on which group of insects you’re looking at
- Overall, only 4.2% of non-native insects in North American forests are high impact
  - 12.1% of conifer specialists
  - 4.2% of hardwood specialists
  - 2.4% of generalists
- We can use the significant drivers to predict the risk of high impact for insect species not yet established in North America
- iTPP will be available in 2022

For more information:
Three peer-reviewed publications
- Mech et al. (2019) *Ecology and Evolution*
- Schulz et al. (2020) *NeoBiota*
- Schulz et al. (2021) *Biological Invasions*

Two datasets (USGS ScienceBase)
- Mech et al. (2020a) TRAFAC: Conifer Specialists
- Mech et al. (2020b) TRAFAC: Hardwood Specialists
Questions?
Email: angela.mech@maine.edu

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