# High-Impact Insect Invasion Working Group

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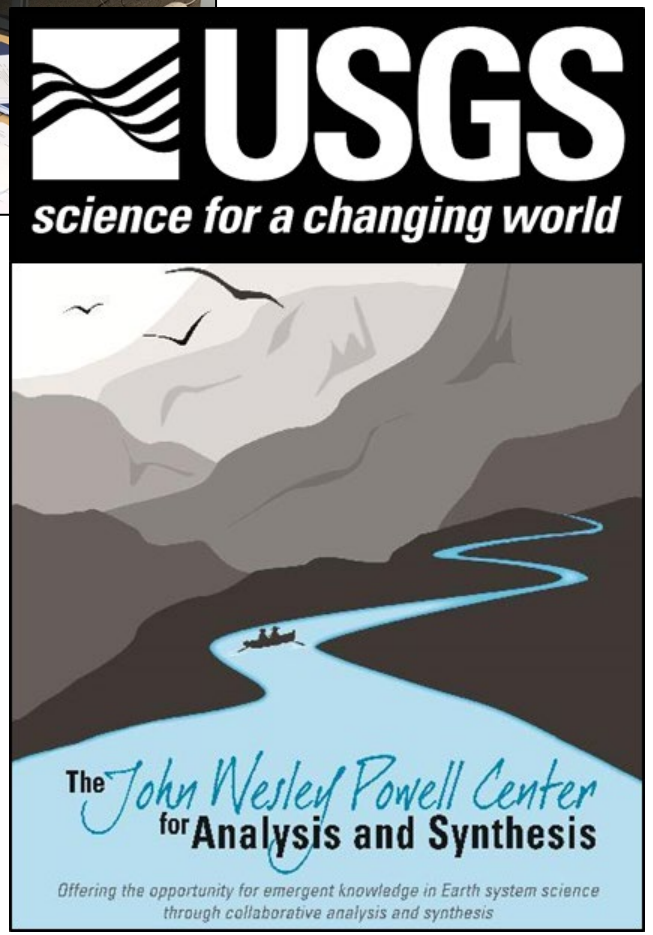
School of Biology & Ecology

Continental Dialogue of Non-native Forest Insects & Diseases

December 7th, 2021

# 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
Ken Raffa – University of Wisconsin
**Ashley Schulz – Colorado State University**
Kathryn Thomas – USGS
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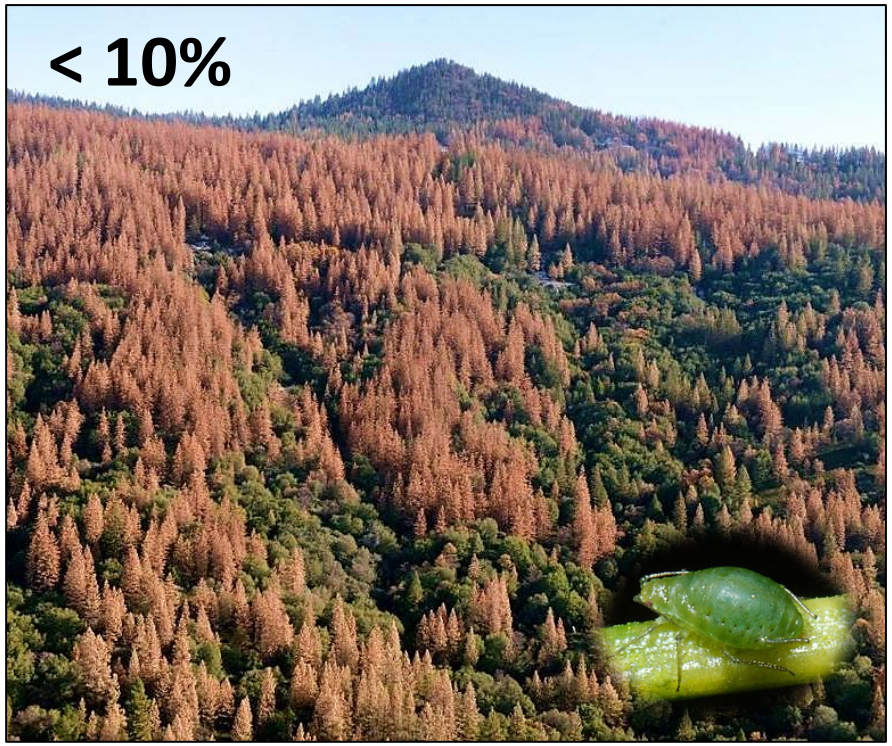
Dan Uden – University of Nebraska

# The problem: Non-native tree-feeding insects *can* devastate tree hosts



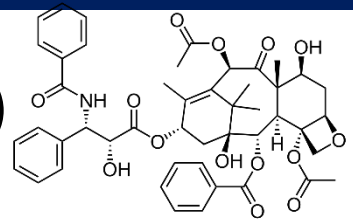


- Why do some introduced insects cause widespread mortality, but most do not?
- What factors drive the level of impact of an introduced forest insect?

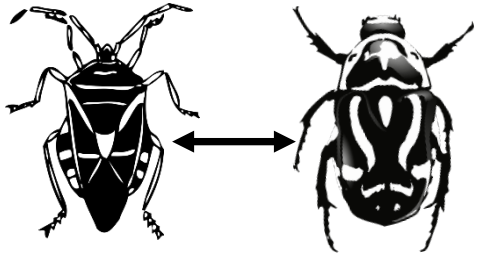
**How do we predict the next high impact insect invaders?**

Hypothesis: Some or all of these factors influence impact

Tree Host Traits

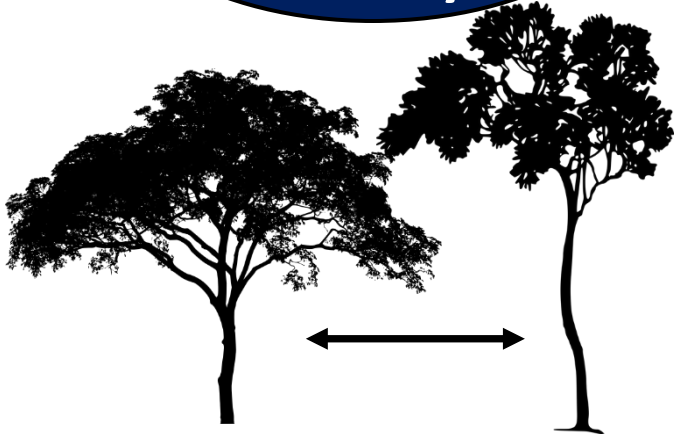


Native + Novel Insect Evolutionary History



Non-native Insect Impact

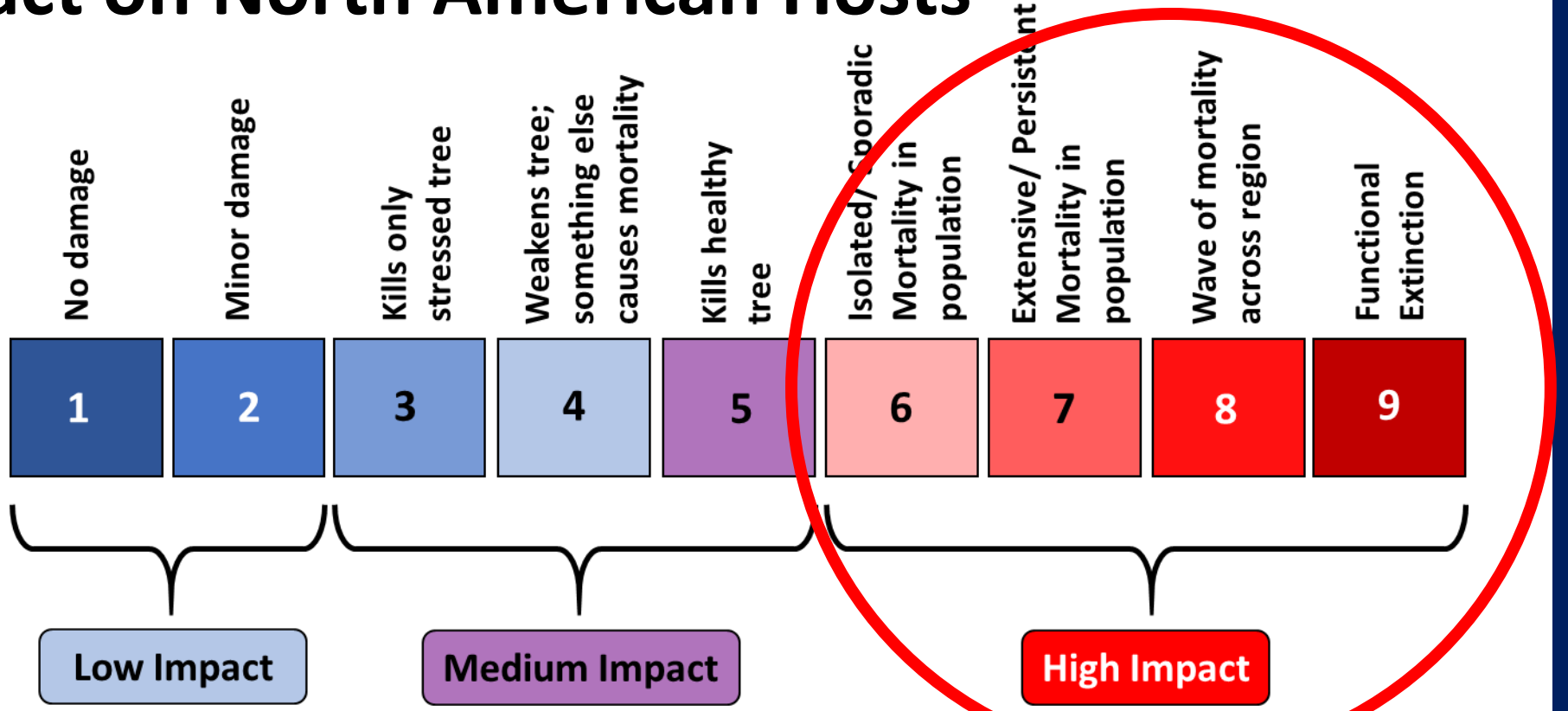
Native + Novel Host Evolutionary History

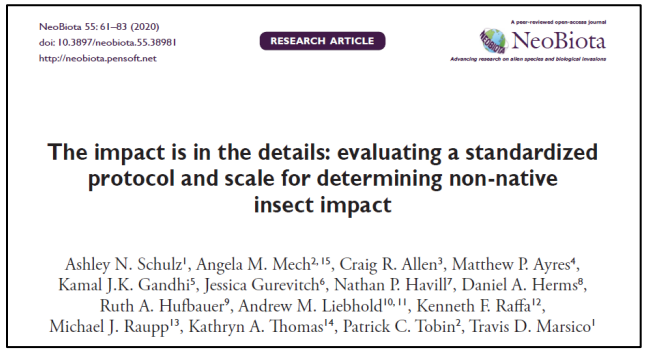


Insect Traits

# Impact on North American Hosts

Step 1: Develop an impact scale





NeoBiota 55: 61–83 (2020)
doi: 10.3897/neobiota.55.38981
http://neobiota.pensoft.net

RESEARCH ARTICLE

NeoBiota

**The impact is in the details: evaluating a standardized protocol and scale for determining non-native insect impact**

Ashley N. Schulz[1], Angela M. Mech[2,15], Craig R. Allen[3], Matthew P. Ayres[4], Kamal J.K. Gandhi[5], Jessica Gurevitch[6], Nathan P. Havill[7], Daniel A. Herms[8], Ruth A. Hufbauer[9], Andrew M. Liebhold[10,11], Kenneth F. Raffa[12], Michael J. Raupp[13], Kathryn A. Thomas[14], Patrick C. Tobin[2], Travis D. Marsico[1]





**Methods** – Look at the non-native insects in North American forests; see if any traits or factors influence their level of impact




**Part 1: Conifer "specialists"** + **Part 2: Hardwood "specialists"** → Add "generalists" → **Part 3: All non-native forest insects of NA**

# Analyzed the 4 main categories of interest

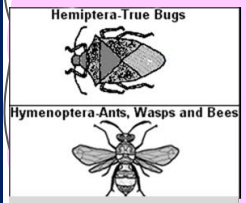
## Insect Traits


Feeding Guild

Dispersal mechanism


Repro. Strategy


Voltinism



Insect Order


Native Range


# host genera in native range

Pest status in native range

## North American Host Traits


Shade tolerance


Foliage texture


Growth rate


Drought tolerance


Fire tolerance


Wood density

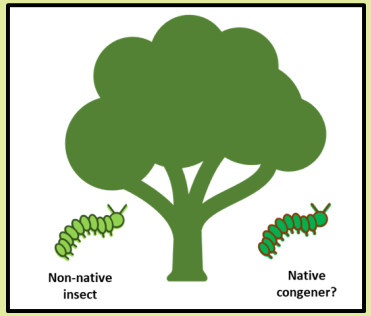
## Native & Novel Host Evolutionary History


*Pinus virginiana*

Divergence time to most recent common ancestor = 10.89 million years ago


*Pinus halepensis*

## 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.**

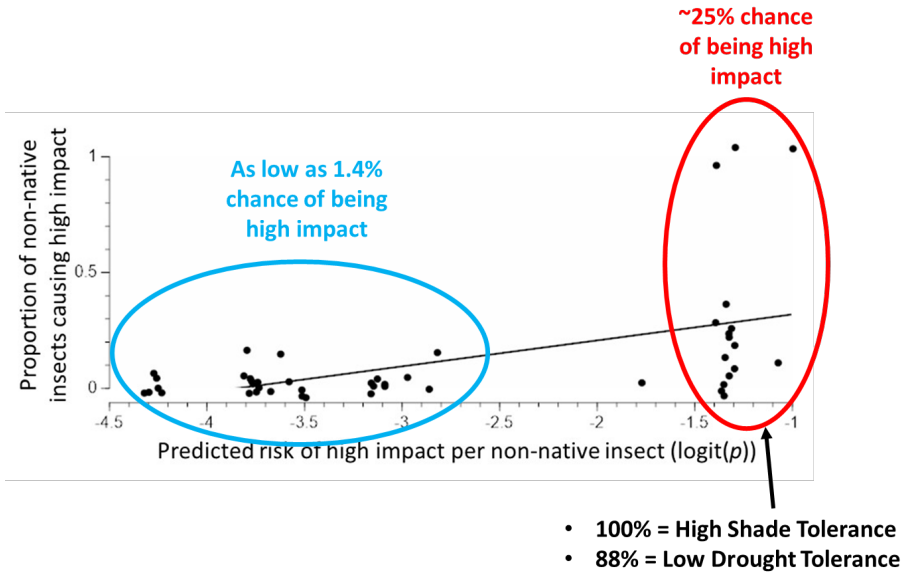
Received: 6 May 2019 | Revised: 16 August 2019 | Accepted: 21 August 2019
DOI: 10.1002/ece3.5709

ORIGINAL RESEARCH

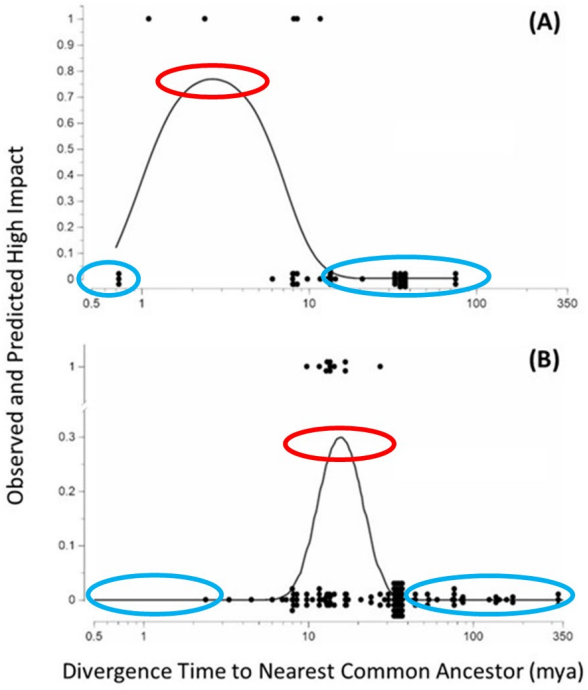
Ecology and Evolution WILEY

## Evolutionary history predicts high-impact invasions by herbivorous insects

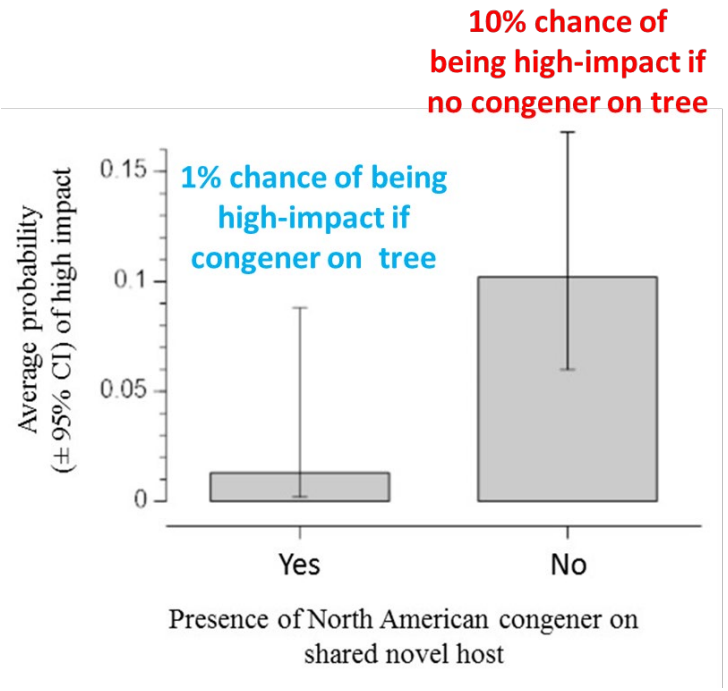
Angela M. Mech[1] | Kathryn A. Thomas[2] | Travis D. Marsico[3] | Daniel A. Herms[4] | Craig R. Allen[5] | Matthew P. Ayres[6] | Kamal J. K. Gandhi[7] | Jessica Gurevitch[8] | Nathan P. Havill[9] | Ruth A. Hufbauer[10] | Andrew M. Liebhold[11] | Kenneth F. Raffa[12] | Ashley N. Schulz[3] | Daniel R. Uden[13] | Patrick C. Tobin[1]




**Host Traits = Yes**

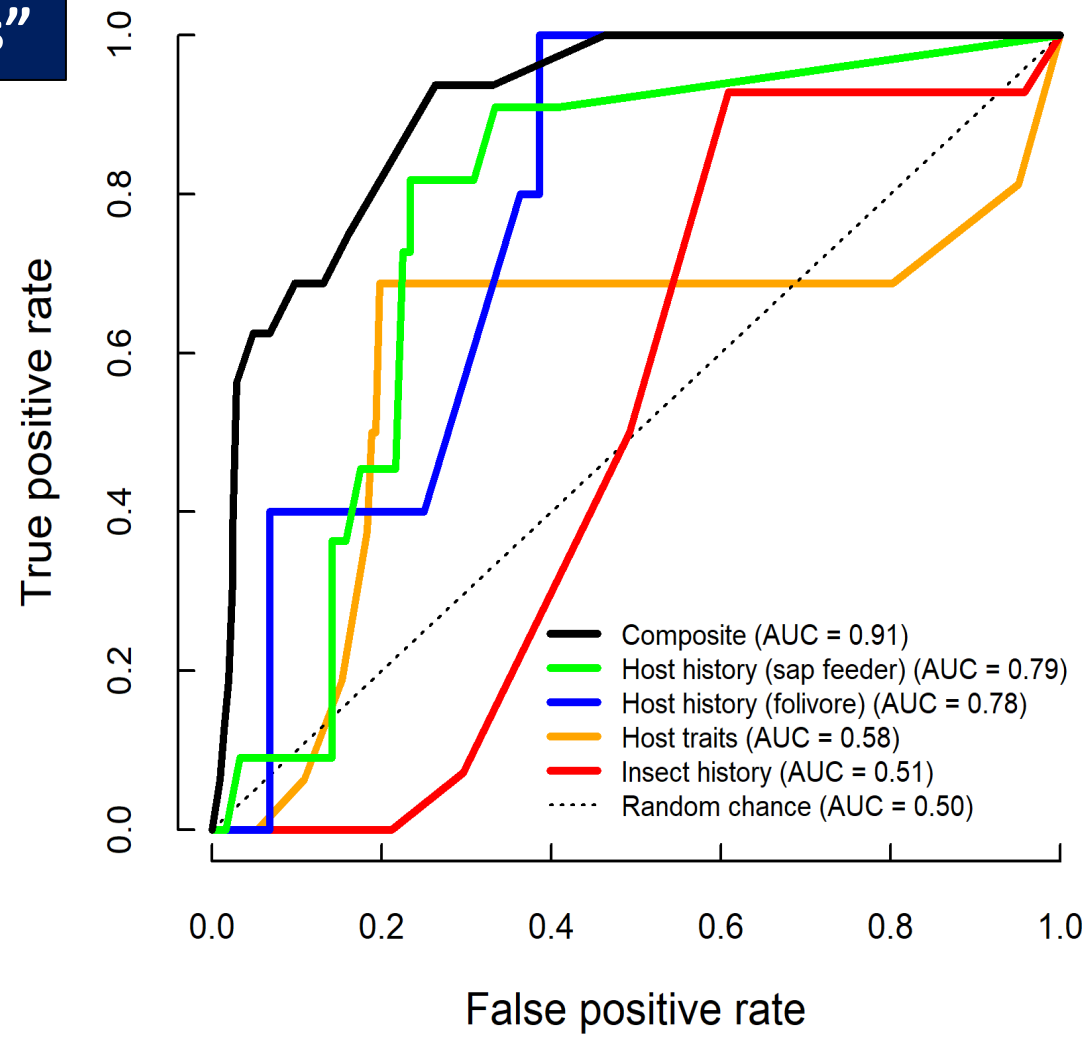



**Host Relatedness = Yes**




**Insect Relatedness = Yes**

# Part 1: Conifer "specialists"




$$R_{t,i} = \frac{\sum_{m=1}^{3} \text{logit}(\widehat{P_{m,t,i}}) - \text{logit}(P_{m..})}{N_m} + \text{logit}(P_{...})$$

- 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

# Evolutionary Recipe for Destruction

- It's more than just if a conifer is shade tolerant & drought intolerant…
- It about if it is <u>also</u> being attacked by an insect that coevolved with a conifer host that shared a common ancestor with that conifer ~12-17 mya
- <u>And</u> 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"

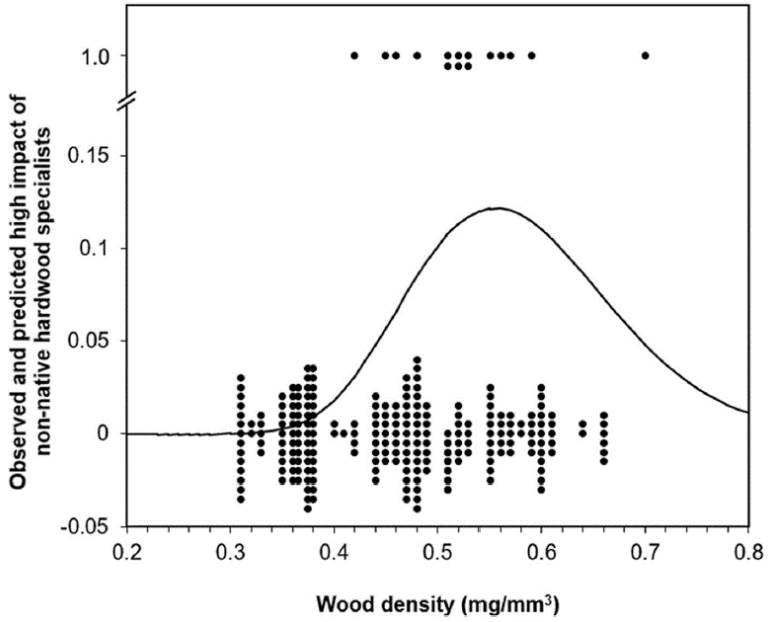
**N = 191 spp.**
**n = 100 spp.**

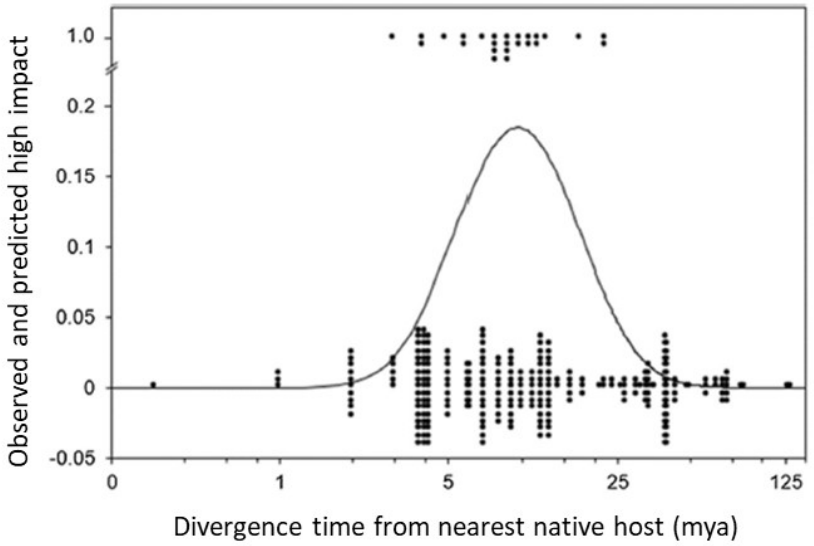
Biol Invasions
https://doi.org/10.1007/s10530-021-02621-5

ORIGINAL PAPER

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

Ashley N. Schulz · Angela M. Mech · Matthew P. Ayres · Kamal J. K. Gandhi · Nathan P. Havill · Daniel A. Herms · Angela M. Hoover · Ruth A. Hufbauer · Andrew M. Liebhold · Travis D. Marsico · Kenneth F. Raffa · Patrick C. Tobin · Daniel R. Uden · Kathryn A. Thomas



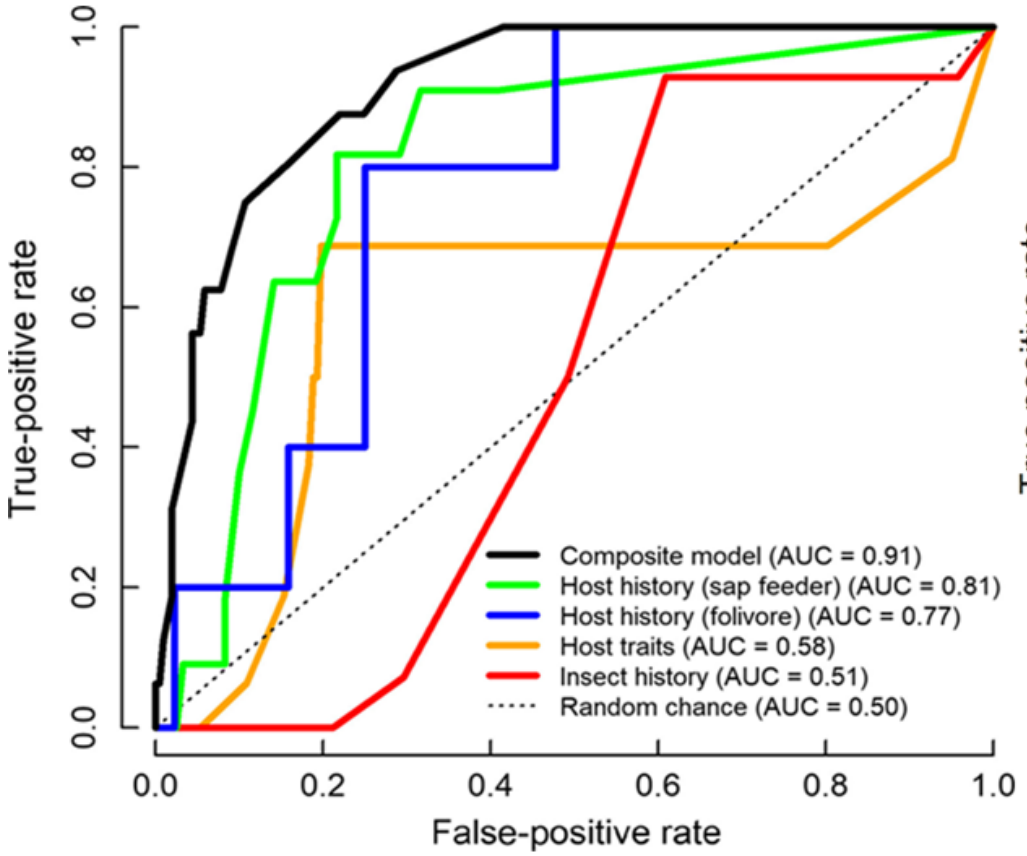


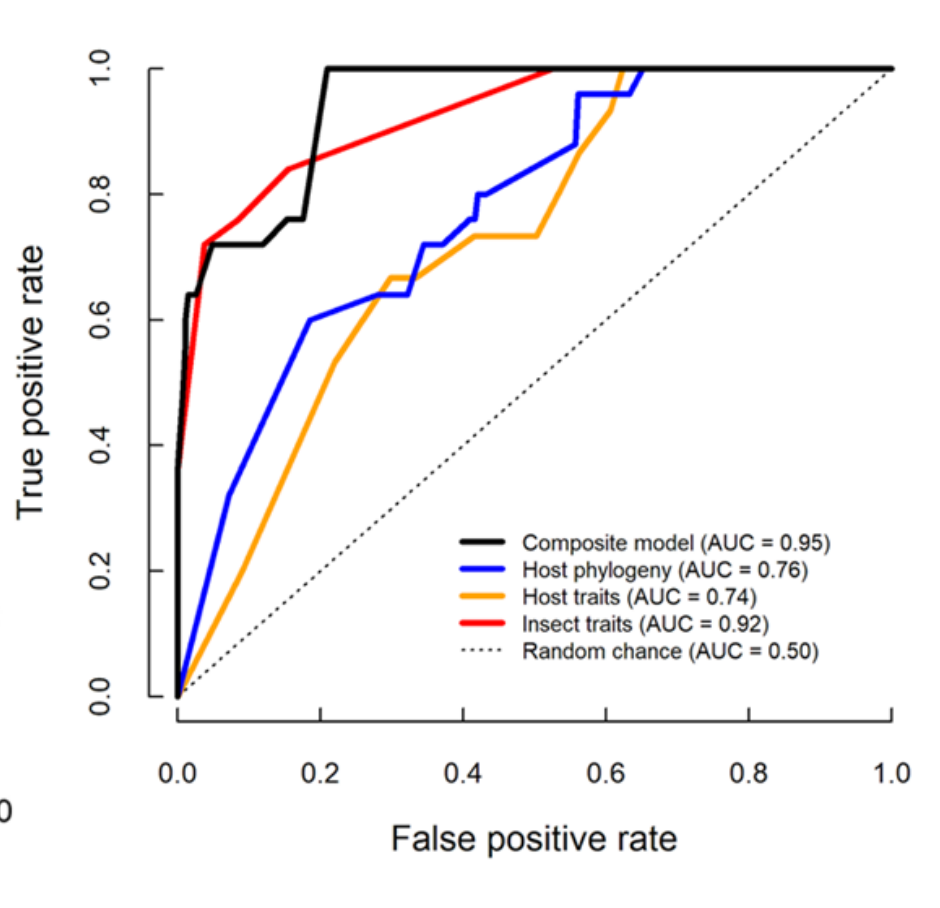
**Host Traits = Yes**

**Host Relatedness = Yes**

**Insect Traits = Yes**

# Composite model = best for conifer specialists & hardwood specialists




| Conifer specialists | Hardwood specialists |
|---|---|
| Host traits + Host evolutionary history + Insect evolutionary history = AUC of 0.91 | Insect traits + Host traits + Host evolutionary history = AUC of 0.95 |

Add "generalists"

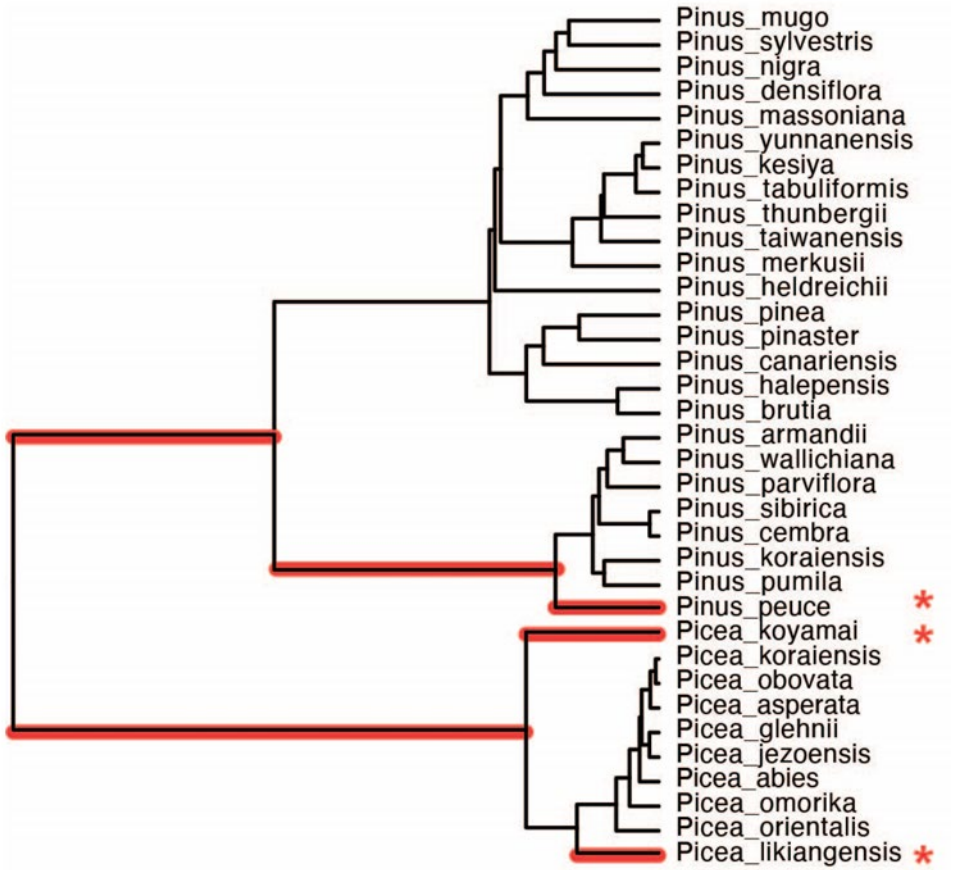
**N = 251 spp.**
**n = 90 spp.**

**Part 3: All non-native forest insects of NA**

**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"**

*Matsucoccus matsumurae, PD = 17*
*2 tree spp. in 1 family*

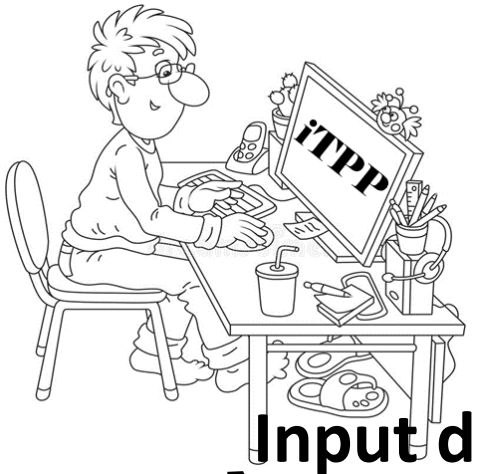
5508345

**PD > 2,250 = broad host breadth = "generalists"**

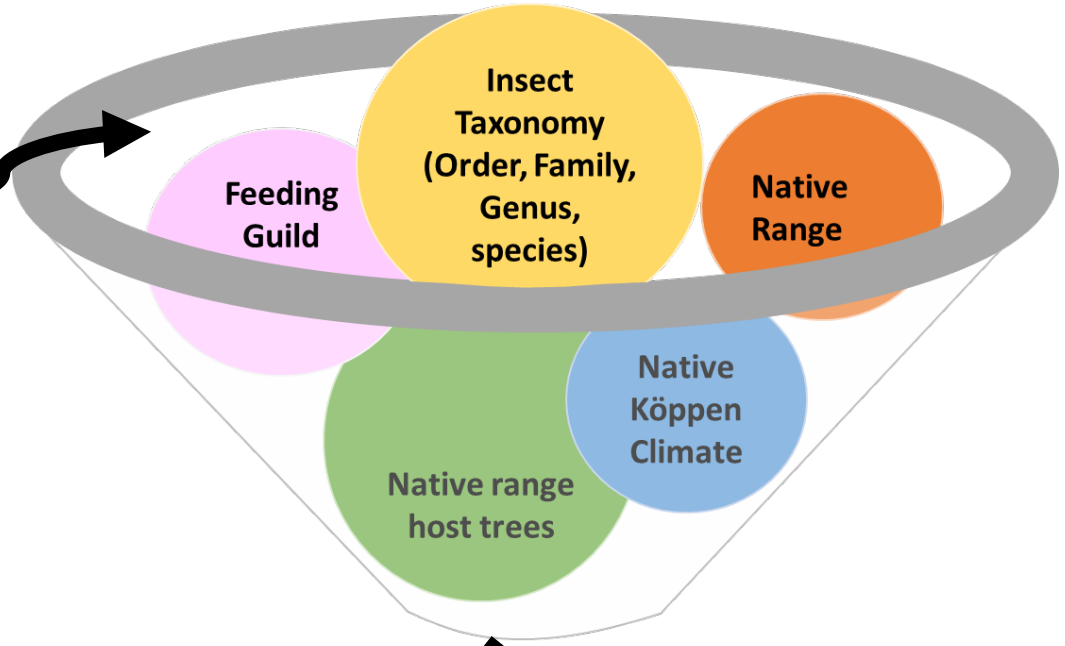
*Xylosandrus germanus, PD = 7,723*
*152 tree spp. in 48 families*

# How do we predict the next high impact invaders?

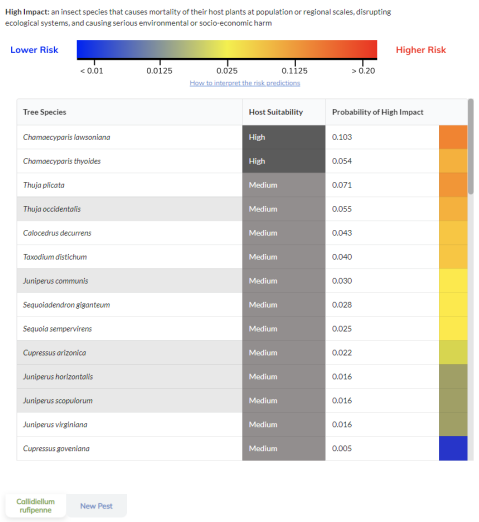
# The i-Tree Pest Predictor (iTPP) tool




## Input data




## Output



**High Impact:** an insect species that causes mortality of their host plants at population or regional scales, disrupting ecological systems, and causing serious environmental or socio-economic harm

Lower Risk — Higher Risk

< 0.01 | 0.0125 | 0.025 | 0.1125 | > 0.20

How to interpret the risk predictions

| Tree Species | Host Suitability | Probability of High Impact |
|---|---|---|
| *Chamaecyparis lawsoniana* | High | 0.103 |
| *Chamaecyparis thyoides* | High | 0.054 |
| *Thuja plicata* | Medium | 0.071 |
| *Thuja occidentalis* | Medium | 0.055 |
| *Calocedrus decurrens* | Medium | 0.043 |
| *Taxodium distichum* | Medium | 0.040 |
| *Juniperus communis* | Medium | 0.030 |
| *Sequoiadendron giganteum* | Medium | 0.028 |
| *Sequoia sempervirens* | Medium | 0.025 |
| *Cupressus arizonica* | Medium | 0.022 |
| *Juniperus horizontalis* | Medium | 0.016 |
| *Juniperus scopulorum* | Medium | 0.016 |
| *Juniperus virginiana* | Medium | 0.016 |
| *Cupressus goveniana* | Medium | 0.005 |

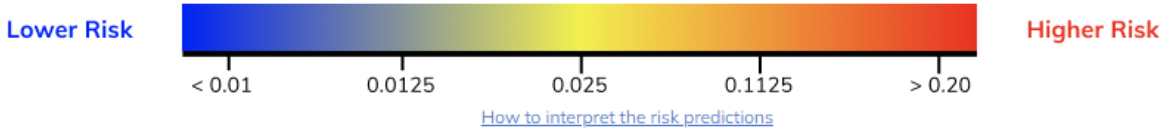
Callidiellum rufipenne | New Pest

## Run model

**iTPP will be a part of the i-Tree software suite**

i-Tree

**High Impact:** an insect species that causes mortality of their host plants at population or regional scales, disrupting ecological systems, and causing serious environmental or socio-economic harm




How to interpret the risk predictions

| Tree Species | Host Suitability | Probability of High Impact |
|---|---|---|
| *Ulmus crassifolia* | High | 0.131 |
| *Ulmus serotina* | High | 0.131 |
| *Ulmus thomasii* | High | 0.131 |
| *Ulmus rubra* | High | 0.120 |
| *Ulmus alata* | High | 0.104 |
| *Ulmus americana* | High | 0.103 |
| *Planera aquatica* | Medium | 0.115 |
| *Celtis tenuifolia* | Low | <0.001 |
| *Pipturus albidus* | Low | <0.001 |
| *Trema micrantha* | Low | <0.001 |
| *Celtis iguanaea* | Low | <0.001 |
| *Celtis laevigata* | Low | <0.001 |
| *Celtis occidentalis* | Low | <0.001 |
| *Ficus aurea* | Low | <0.001 |

**Ultimate goal:** help a variety of stakeholders generate non-native insect risk assessments on North American trees for species that haven't invaded yet

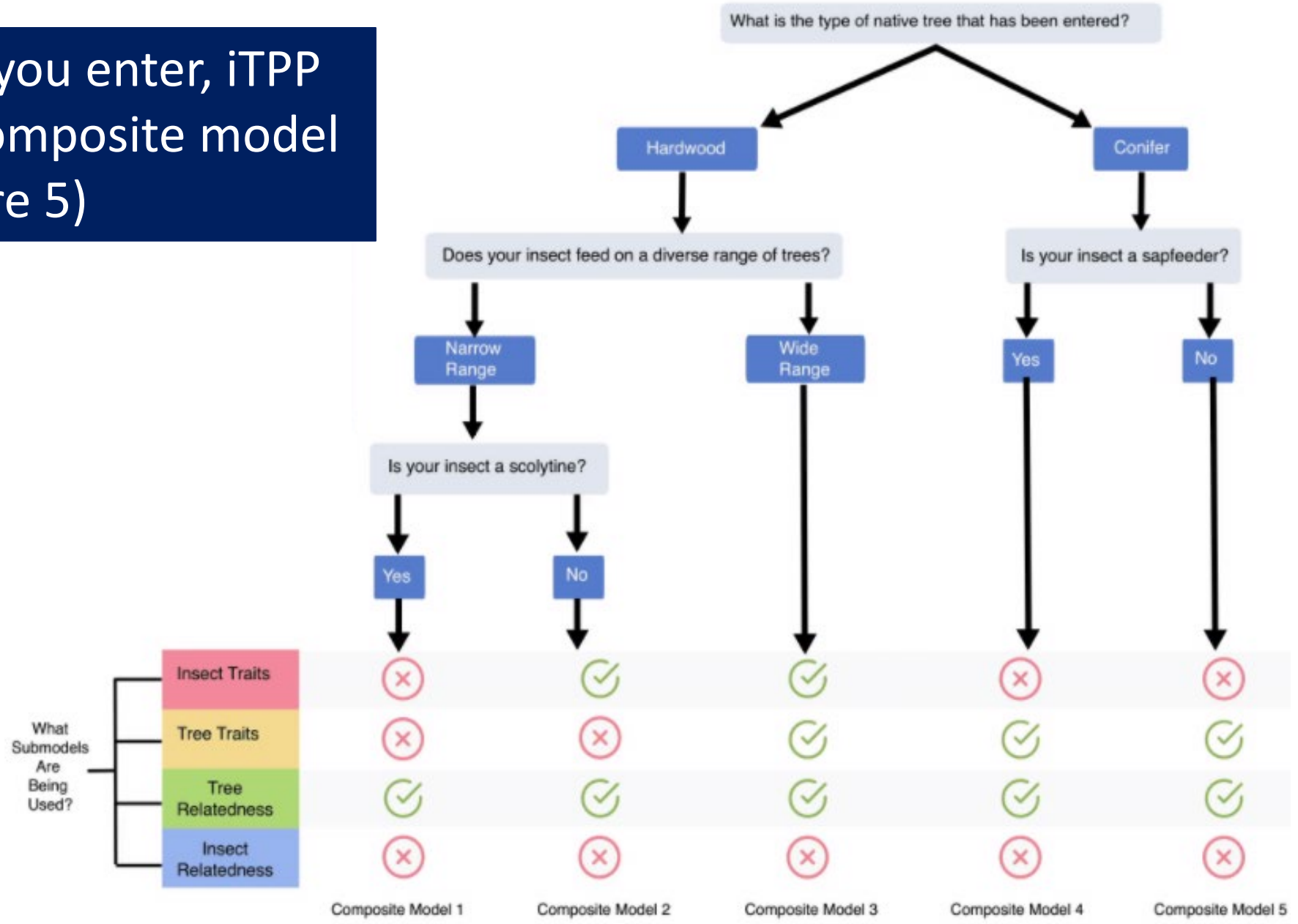
**Example output**: 1 in 7.6 chance of being high impact on some elm species if this particular species established in North America

**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

| | Conifer | | Hardwood | | |
|---|---|---|---|---|---|
| Model | Sapfeeder | non-Sapfeeder | Specialists Scolytine | Specialists non-Scolytine | Generalists |
| Insect Traits | | | | Feeding Guild AUC = 0.89 | Feeding Guild AUC = 0.92 |
| North American Host Traits | Shade + Drought AUC = 0.77 | Shade + Drought AUC = 0.77 | | | Shade Tolerance AUC = 0.60 |
| Host Evol. History | Quadratic AUC = 0.85 | Quadratic AUC = 0.73 | Linear AUC = 0.88 | Quadratic AUC = 0.78 | Quadratic AUC = 0.73 |
| Insect Evol. History | | | Tribe AUC = 0.80 | | |
| Composite | AUC = 0.88 | AUC = 0.85 | AUC = 0.92 | AUC = 0.94 | AUC = 0.95 |

# 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

## Funding


- USGS John Wesley Powell Center for Analysis and Synthesis
- USDA Forest Service National Urban and Community Forestry Advisory Council
- Nebraska Cooperative Fish and Wildlife Research Unit, University of Washington, USDA Forest Service Eastern Forest Environmental Threat Assessment, National Science Foundation LTER program, USDA Forest Service International Programs, USDA National Institute of Food and Agriculture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