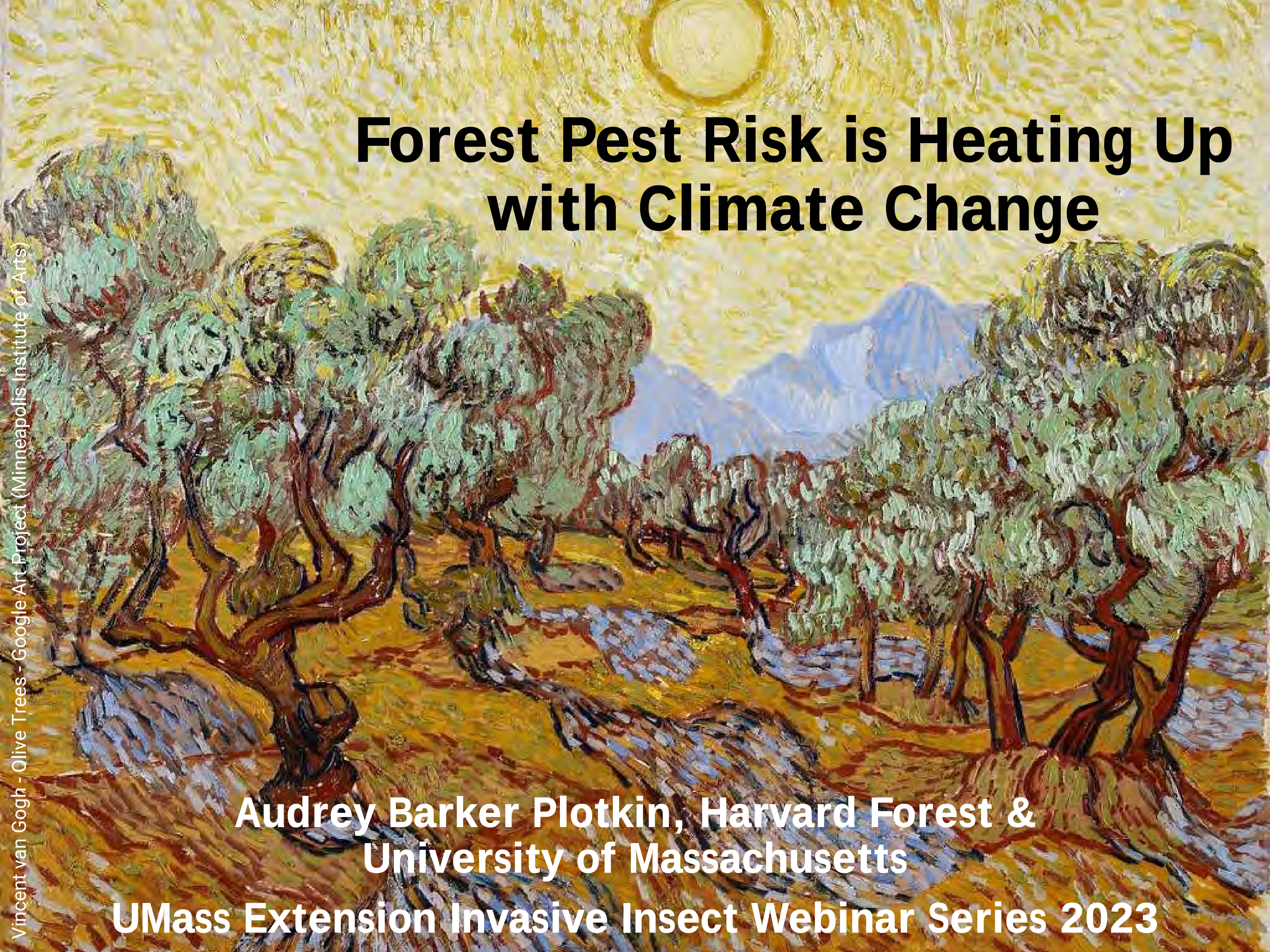


Forest Pest Risk is Heating Up with Climate Change

Audrey Barker Plotkin, Harvard Forest & University of Massachusetts

UMass Extension Invasive Insect Webinar Series 2023

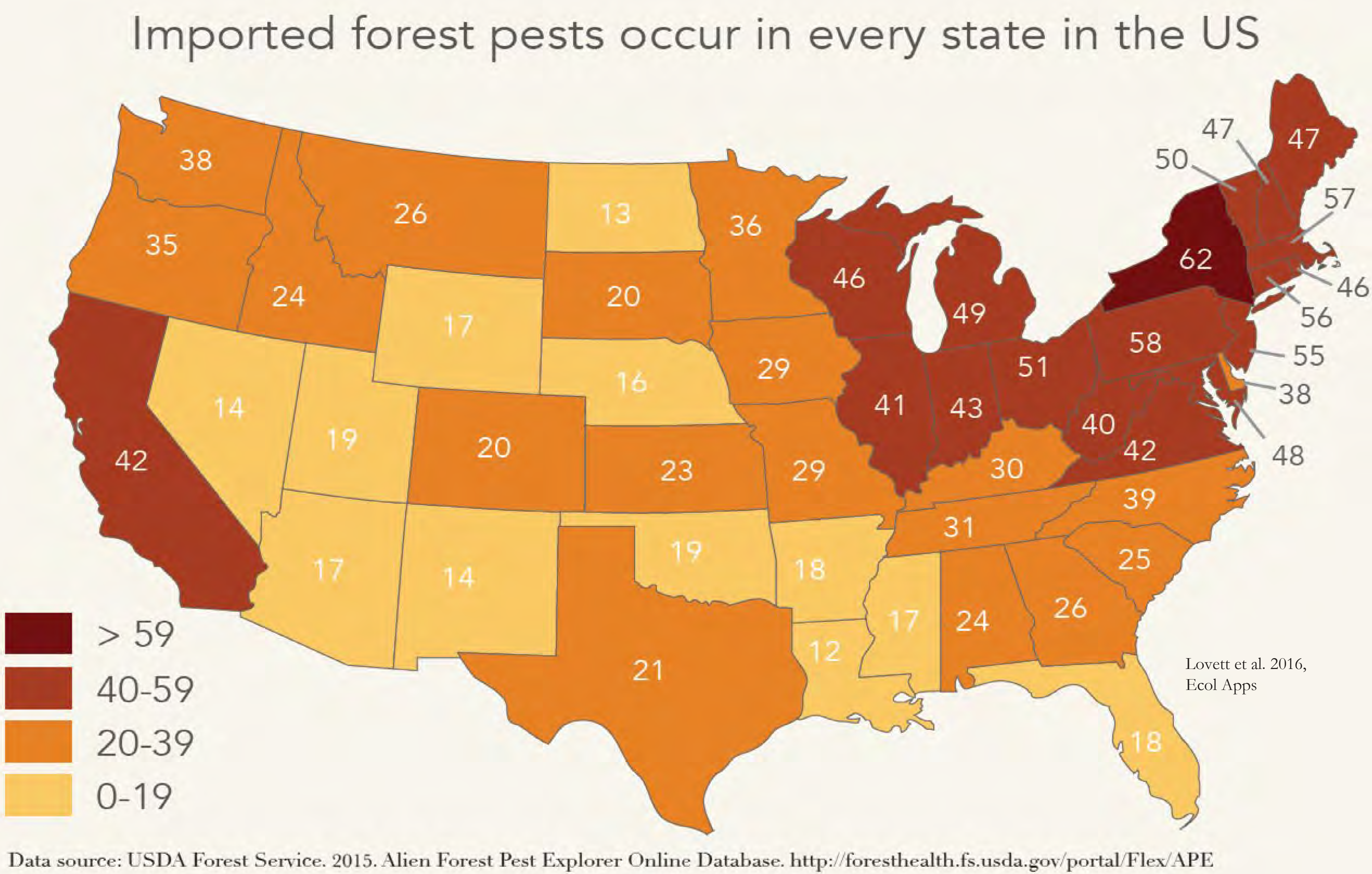
Vincent van Gogh - Olive Trees - Google Art Project (Minneapolis Institute of Arts)

Acknowledgements

- Harvard Forest & UMass Amherst are located on unceded Nipmuc & Pocumtuc lands
- Forest Pest Risk is Heating Up co-authors: Meg Graham MacLean, Cynthia Cheng, Elsa Cousins, Bianca Lopez, Ayodele O'uhuru

Invasive Insects: a major global change driver

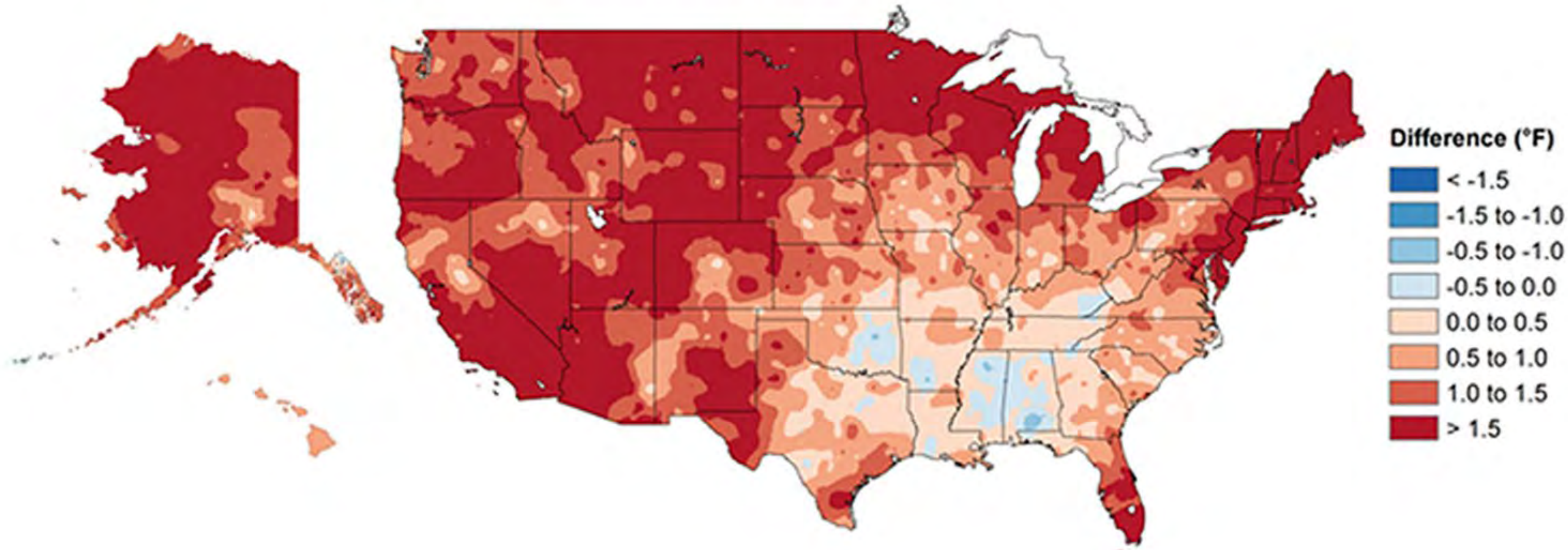
- Can eliminate an entire tree species
- Long-term effects on forest composition & productivity



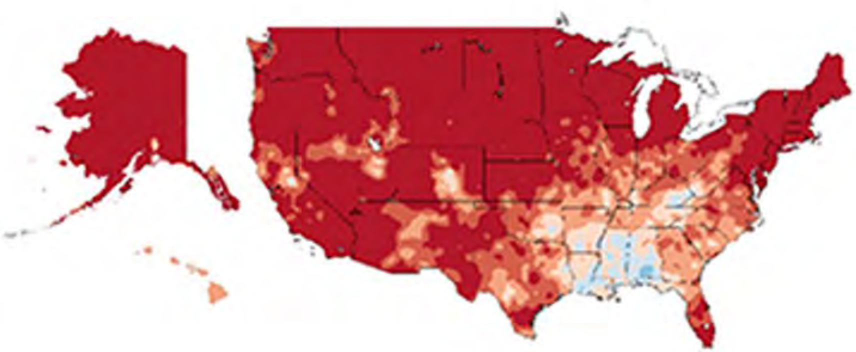
Northeast U.S. is an Invasion Hotspot

Climate change is happening now

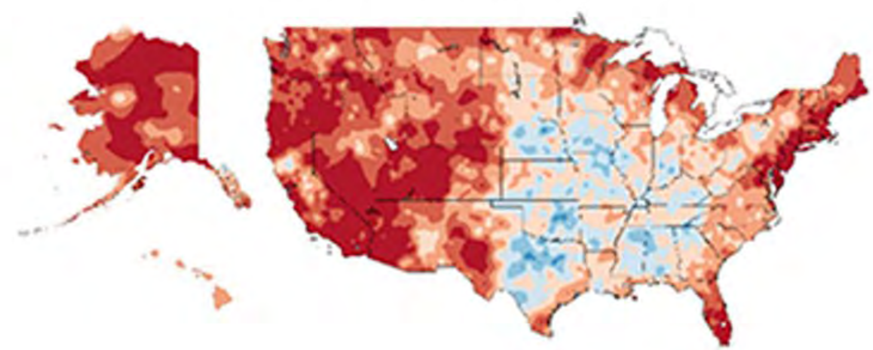
Annual Temperature



Winter Temperature



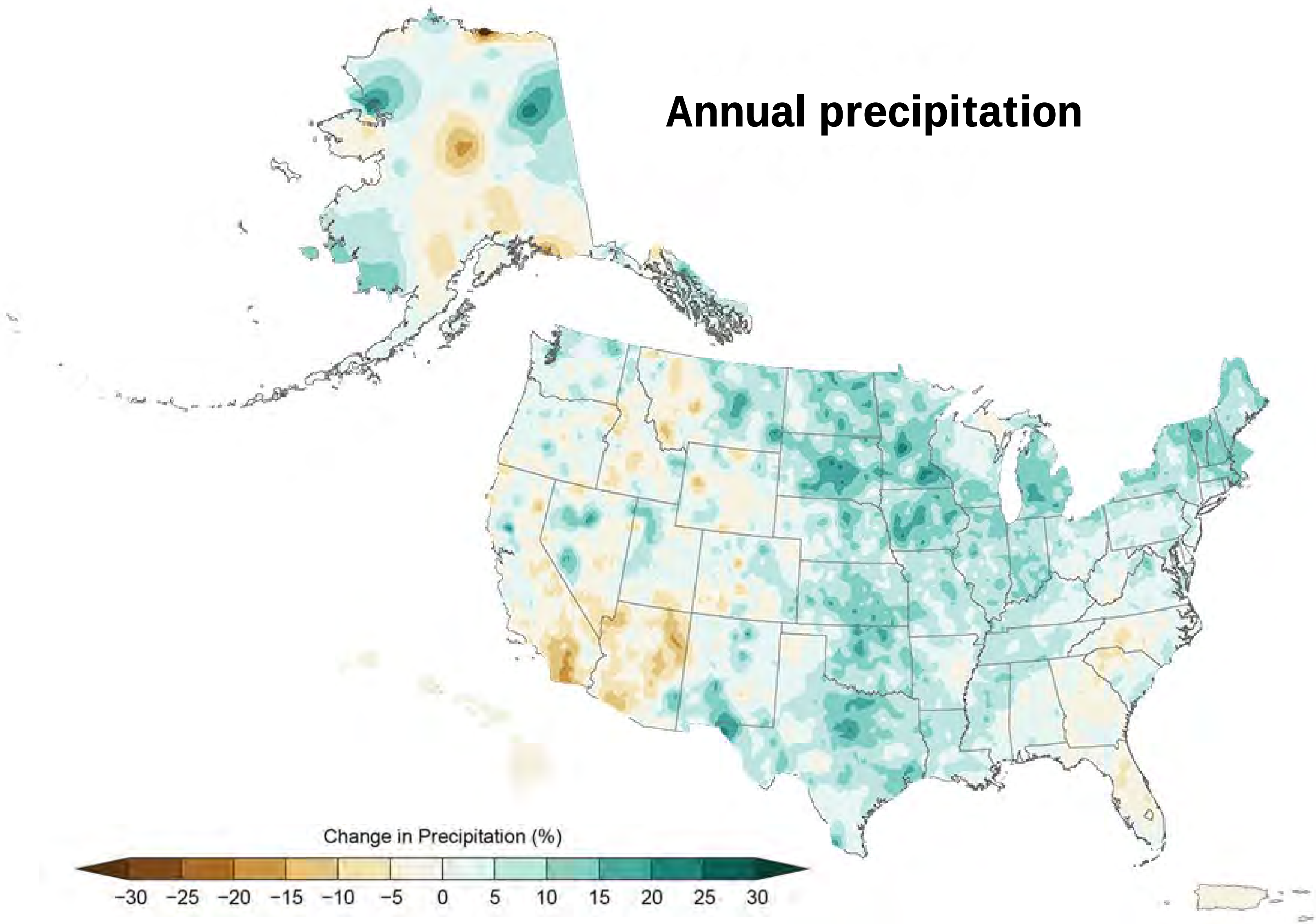
Summer Temperature



Observed changes (1986-2016 vs. 1901-1960)

4th National Climate Assessment, 2018

Climate change is happening now



Observed changes (1986-2016 vs. 1901-1960)

4th National Climate Assessment, 2018

Northeast

RISCC

MANAGEMENT NETWORK

Mission Statement:

The Northeast Regional Invasive Species & Climate Change (RISCC) Management Network aims to **reduce the compounding effects of invasive species and climate change** by **synthesizing** relevant science, **sharing** the needs and knowledge of managers, **building** stronger scientist-manager communities, and **conducting priority research**.

UMass Amherst

USGS science for a changing world

NYISRI New York Invasive Species Research Institute

Cornell University

NE CASC Northeast Climate Adaptation Science Center

Poll Question 1

How does climate change affect forest pests?

Northeast RISCC Management

Regional Invasive Species & Climate Change

Management Challenge

Forest Pest Risk is Heating Up

Summary

Insect pests and pathogens, and climate change, each threaten forest health. But what happens when the two are combined? Climate change brings pests to new areas, makes pests more damaging, reduces trees' defenses to pests, and can alter how forests recover after pest disturbance. Strategies for managing the combined impacts of forest pests and climate change include preventing new pest introductions, resisting pest spread by treating individual trees and diversifying forest stands, promoting more resilient forests that can rebound from pests, and helping forests transition to a state better adapted to our future climate.

How does climate change affect forest pests?

Table 1	Interaction	Example
	**Climate brings a pest to a new area** (1: Climate brings Pest)	Hemlock woolly adelgid's (*Adelges tsugae*, HWA) spread is limited by cold winter temperatures, but warming winters and rapid adaptation to cold are expanding HWA's range and increasing its reproductive rates.
	**A minor pest becomes virulent with climate change** (2: Pest X Climate)	Scale insects, which damage trees by eating their sap, survive and reproduce more in warm environments. Warming allows invasive (e.g. hemlock elongate scale, *Fiorinia externa*) and native (e.g. gloomy scale, *Melanaspis tenebricosa*) scale insects to reach high densities and damage host trees.
	**Climate stress makes trees more vulnerable to pest outbreaks** (3: Climate X Pest)	Gypsy moths (*Lymantria dispar*) defoliate several tree species, but preferentially feed on oaks (*Quercus spp.*). Outbreaks cause more damage and mortality to oaks that are already stressed by drought.
	**Climate change alters the trajectory of recovery after tree mortality** (4: Pest then Climate)	Emerald ash borer (*Agrilus planipennis*, EAB) attacks North American ash (*Fraxinus spp.*) and has become the costliest exotic insect in the U.S. Coupled with climate change, trees killed by EAB are replaced by other species resulting in permanantly altered ecosystems (e.g. converting black ash swamps to non-forests).

Authors: Audrey Barker Plotkin*, Meghan Graham MacLean, Cynthia Cheng, Elsa Cousins, Bianca Lopez, Ayodele O'uhuru

Learn more at: risccnetwork.org

*abarkerplotk@umass.edu

https://doi.org/10.7275/p217-7g43

Forest death spiral - visualizing life trajectories of individual trees

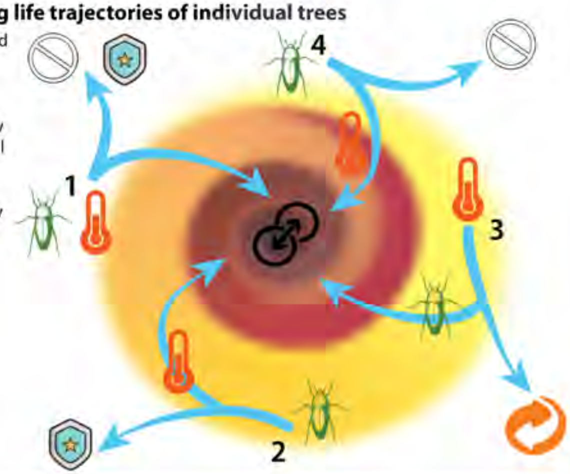


Figure 1. The tree mortality spiral, adapted from Franklin et al. (1987), illustrates how single or multiple stressors can push individual trees towards death (i.e. towards the center of the spiral), and how management actions (see below) can pull trees back to health.

(1) Climate change brings a pest to a new area, **(2)** a minor pest becomes virulent with climate change, **(3)** climate stress makes trees more vulnerable to pest outbreaks, or **(4)** climate change alters recovery after tree mortality.

Examples of each interaction type are in Table 1. Management actions depend on the stage of invasion and type of climate X pest interaction.

Management Actions

PREVENTION
- Support policies that reduce introductions of novel pests, such as switching to pest-free packaging and restricting live-plant imports
- Spread the word about slow-the-spread campaigns such as Don't Move Firewood and engage your networks in monitoring forests for novel pests

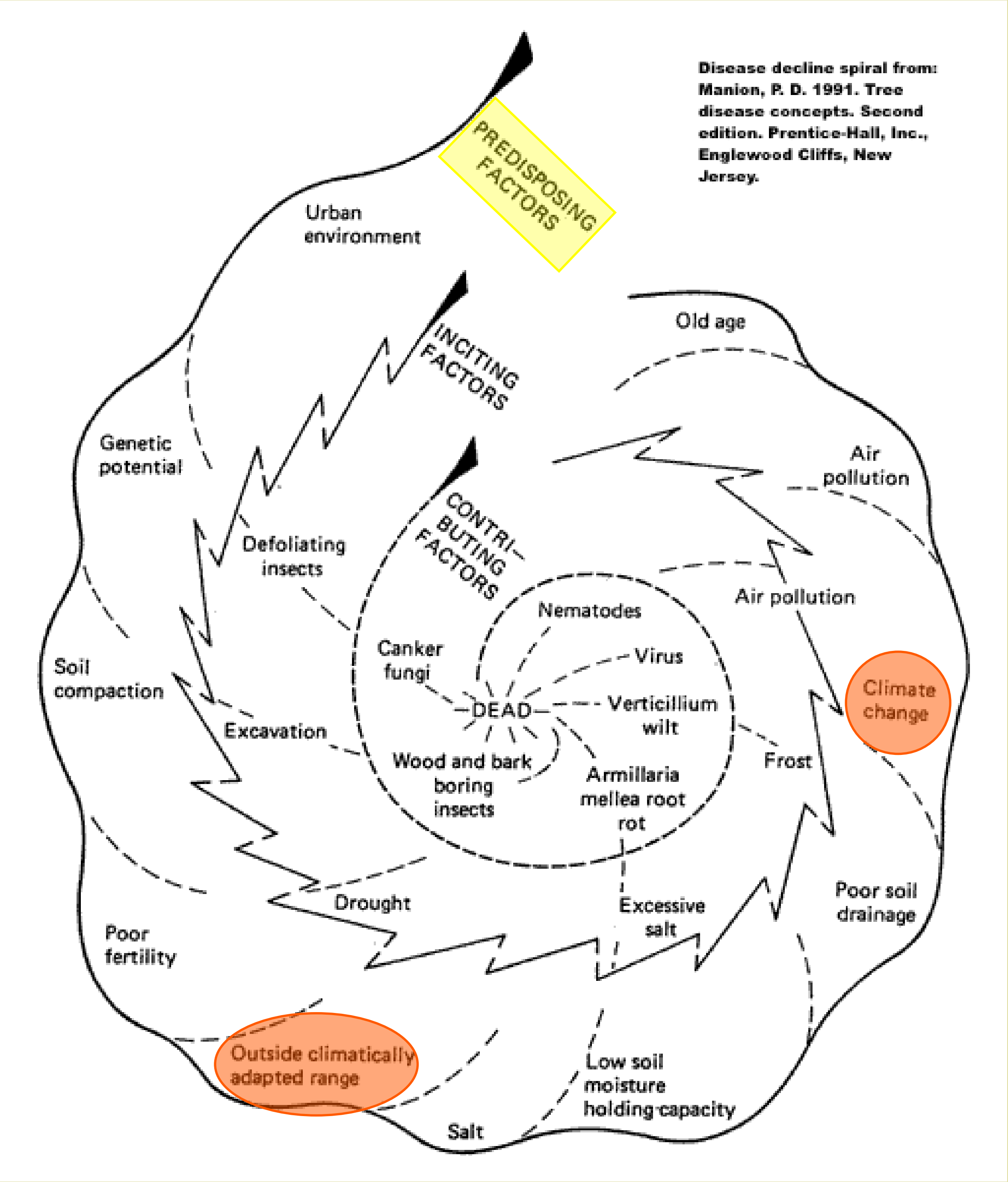
RESISTANCE
- Eradicate small pest populations when possible
- Work with a licensed pesticide applicator to treat individual trees or special groves
- Remove hazard trees near trails and infrastructure
- Work with your forester to promote tree species diversity and/or reduce the abundance of host species for specific pests

RESILIENCE
- Work with your forester to increase stand vigor and diversity, for example by thinning
- Monitor pest populations for early-warning signs of outbreak.
- Utilize the National Phenology Network's forecast tool to identify when insects will reach life stages critical for monitoring and management.
- Consider leaving host trees as a seed source for regeneration and then as wildlife habitat after mortality

TRANSITION
- When mortality is widespread, consider managing the forest for a warmer future. For example, consider diversifying tree species composition at the landscape level with particular attention to climate resilient species. Want to learn more? Check out https://forestadaptation.org/
- Salvage harvesting isn't always necessary: dead and dying trees provide wildlife habitat and diversify the forest structure.

References: Aukema et al. 2011 PLOS One 6(9): e24587; Campbell & Sloan 1977. For. Sci. M19; Franklin et al. 1987 BioScience 37:550-556; Franks & Just 2020 Insects 11:142; Lombardo & Elkinton 2017 Ecol Evol 7:5123-5130; Lovett et al. 2016 Ecol Apps 26:1437-1455; McAvoy et al. 2017 Forests 8:497; Paradis et al. 2007 Mitig Adapt Strat Glob Change 13:541-554; Simler-Williamson et al. 2019 Ann Rev Ecol Evol & Syst 50:381-403; https://ag.umass.edu/home-lawn-garden/fact-sheets/elongate-hemlock-scale; Youngquist et al. 2017 Wetlands 37:787-799; https://www.usanpn.org/data/forecasts; https://www.caryinstitute.org/science/tree-smart-trade; https://usfs.maps.arcgis.com/apps/MapTour/index.html?appid=ade657567ff445d5bb3aaa7d898d9fb9; https://www.risccnetwork.org/dont-move-fire-wood; https://forestadaptation.org/assess/ecosystem-vulnerability/new-england; https://forestadaptation.org/sites/default/files/NE_NEnNY_Species_final.pdf

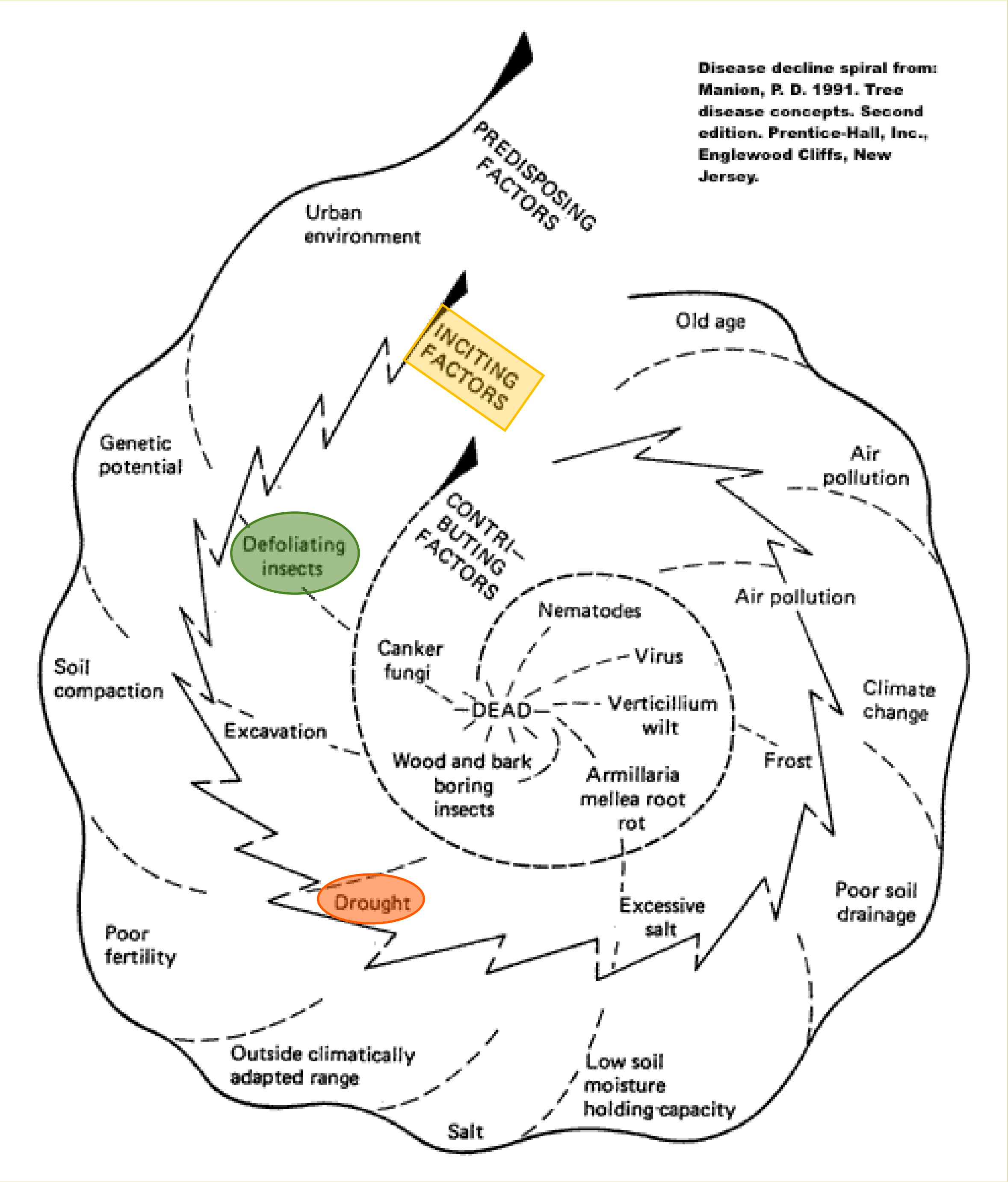
The Forest Death Spiral



Tree death is a *process*

Predisposing Factors

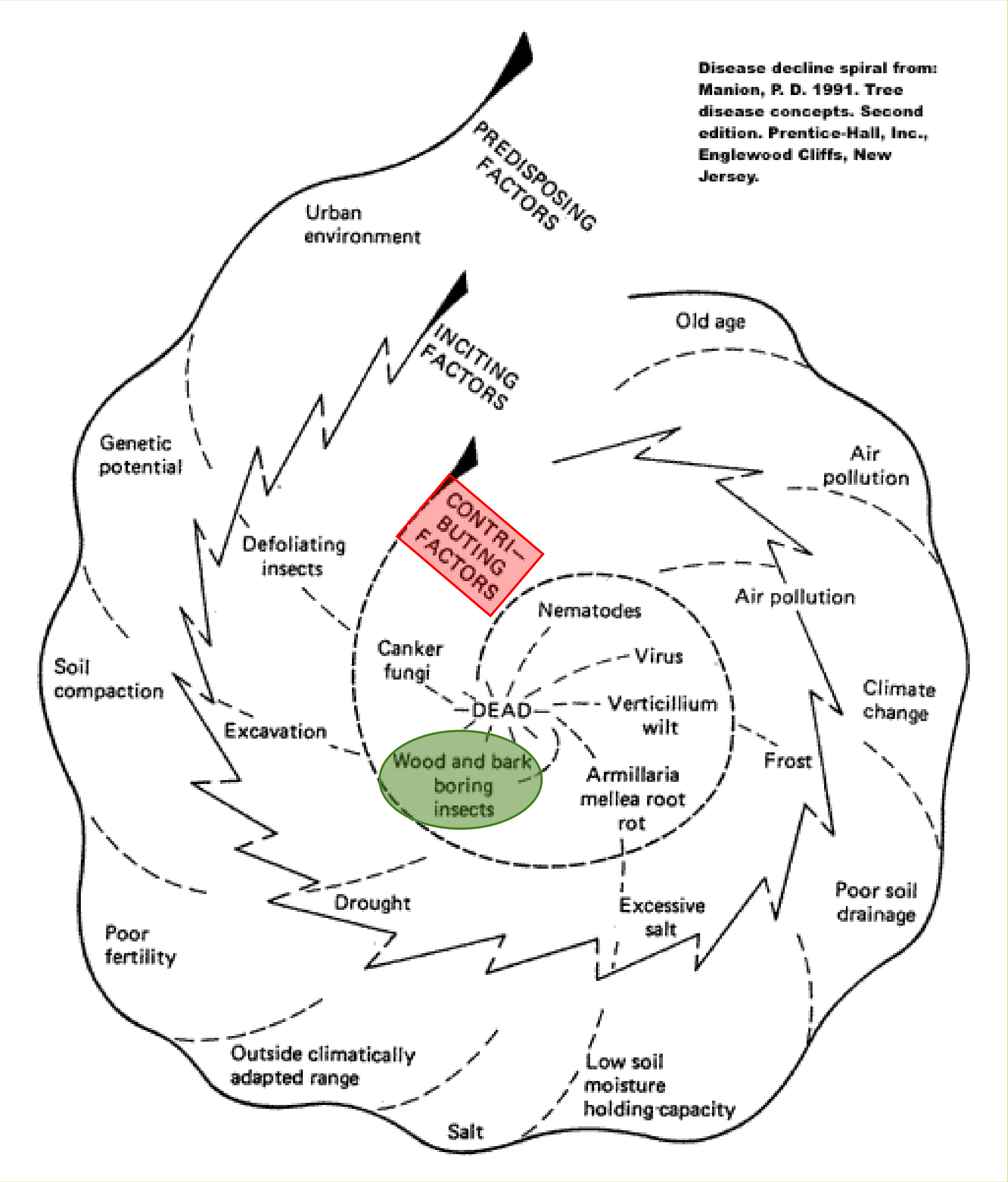
The Forest Death Spiral



Tree death is a *process*

Inciting Factors

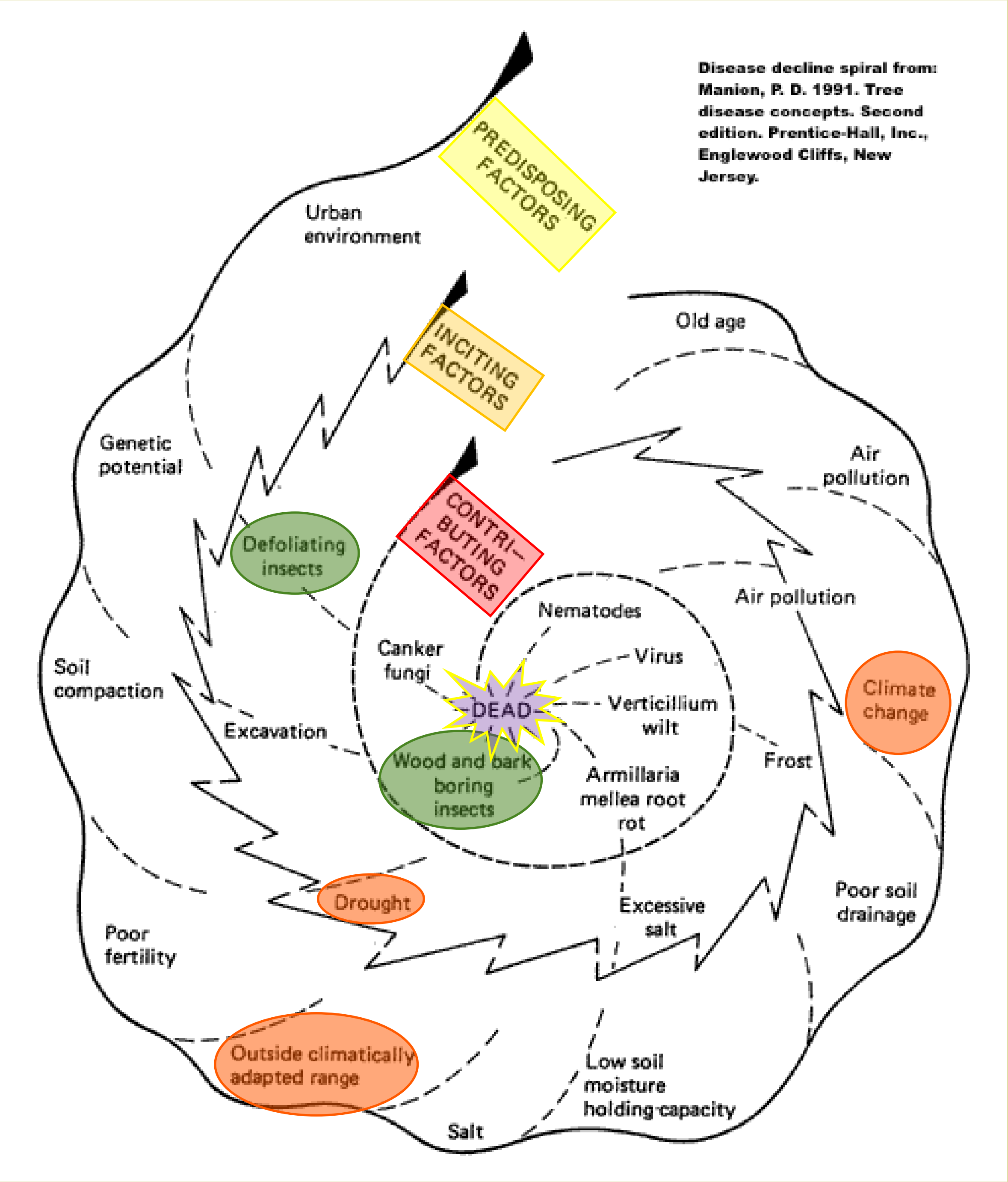
The Forest Death Spiral



Tree death is a *process*

Contributing Factors

The Forest Death Spiral

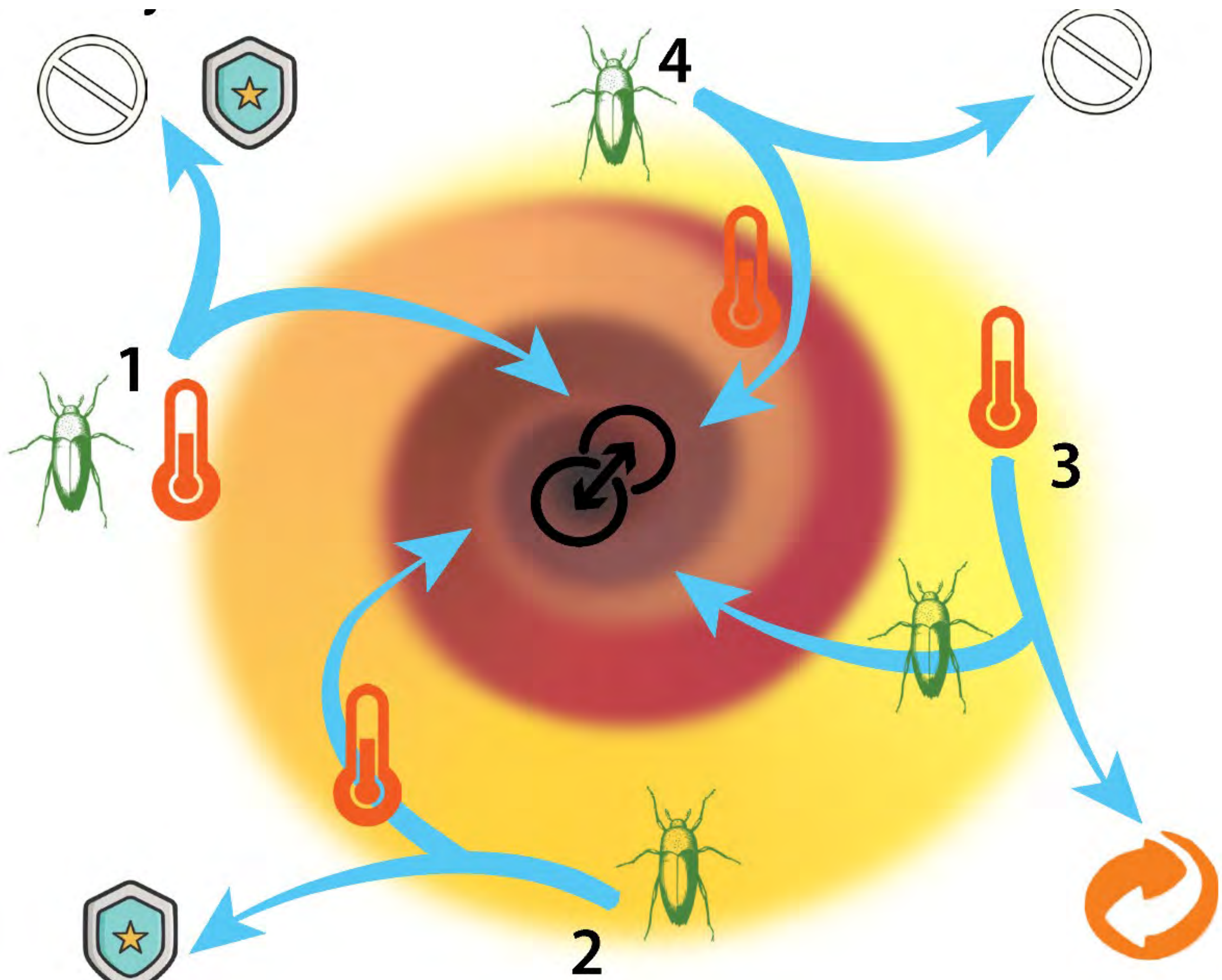


Tree death is a *process*

Predisposing Factors
Inciting Factors
Contributing Factors

Invasive Insects & Climate in the Forest Death Spiral

Interaction
Climate brings a pest to a new area (1: Climate brings Pest)
A minor pest becomes virulent with climate change (2: Pest X Climate) X
Climate stress makes trees more vulnerable to pest outbreaks (3: Climate X Pest) X
Climate change alters the trajectory of recovery after tree mortality (4: Pest then Climate) then



What can we do?

PREVENTION

- Support policies that reduce introductions of novel pests, such as switching to pest-free packaging and restricting live-plant imports
- Spread the word about slow-the-spread campaigns such as Don't Move Firewood and engage your networks in monitoring forests for novel pests

RESISTANCE

- Eradicate small pest populations when possible
- Work with a licensed pesticide applicator to treat individual trees or special groves
- Remove hazard trees near trails and infrastructure
- Work with your forester to promote tree species diversity and/or reduce the abundance of host species for specific pests

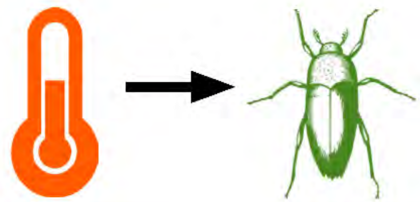
RESILIENCE

- Work with your forester to increase stand vigor and diversity, for example by thinning
- Monitor pest populations for early-warning signs of outbreak.
- Utilize the National Phenology Network's forecast tool to identify when insects will reach life stages critical for monitoring and management.
- Consider leaving host trees as a seed source for regeneration and then as wildlife habitat after mortality

TRANSITION

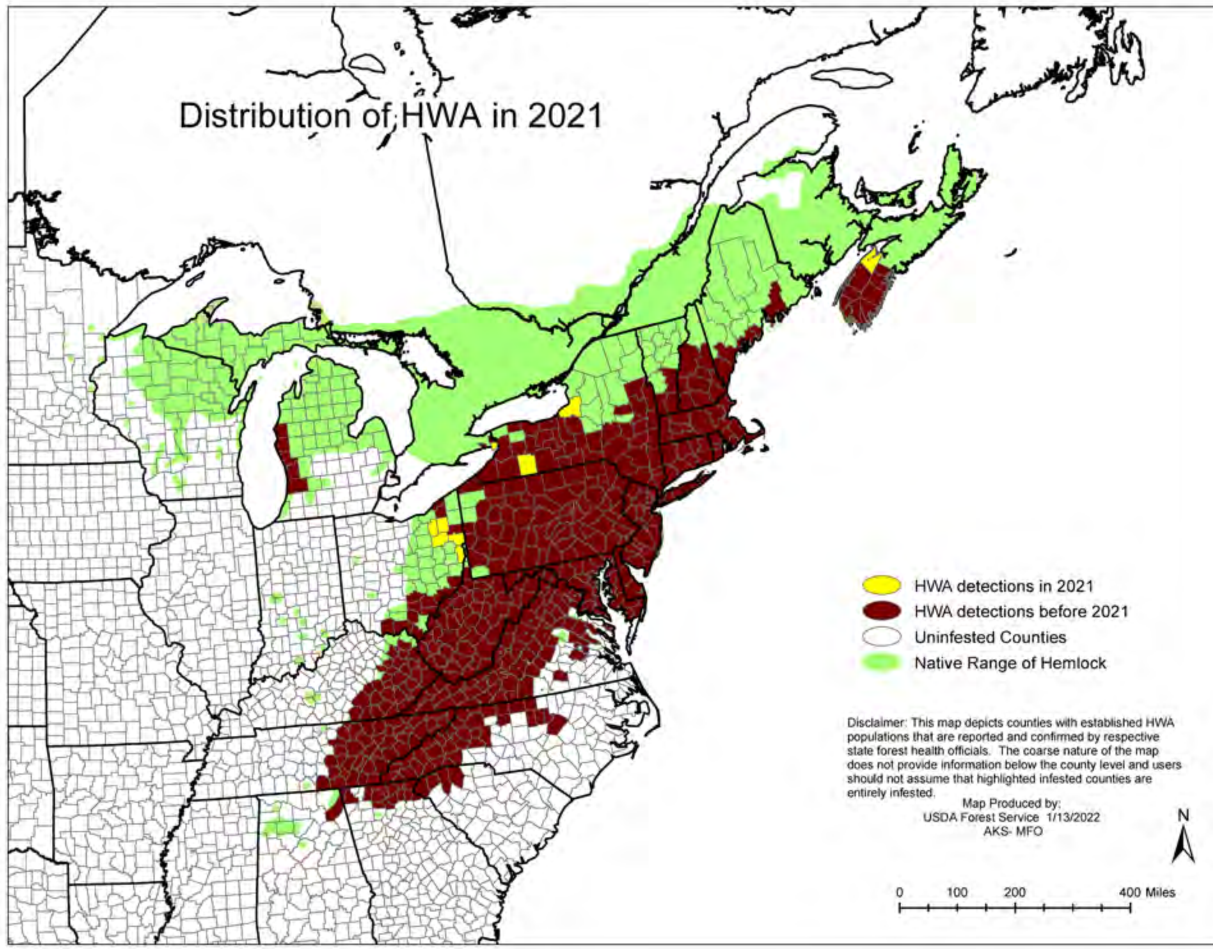
- When mortality is widespread, consider managing the forest for a warmer future. For example, consider diversifying tree species composition at the landscape level with particular attention to climate resilient species. Want to learn more? Check out https://forestadaptation.org/
- Salvage harvesting isn't always necessary: dead and dying trees provide wildlife habitat and diversify the forest structure.

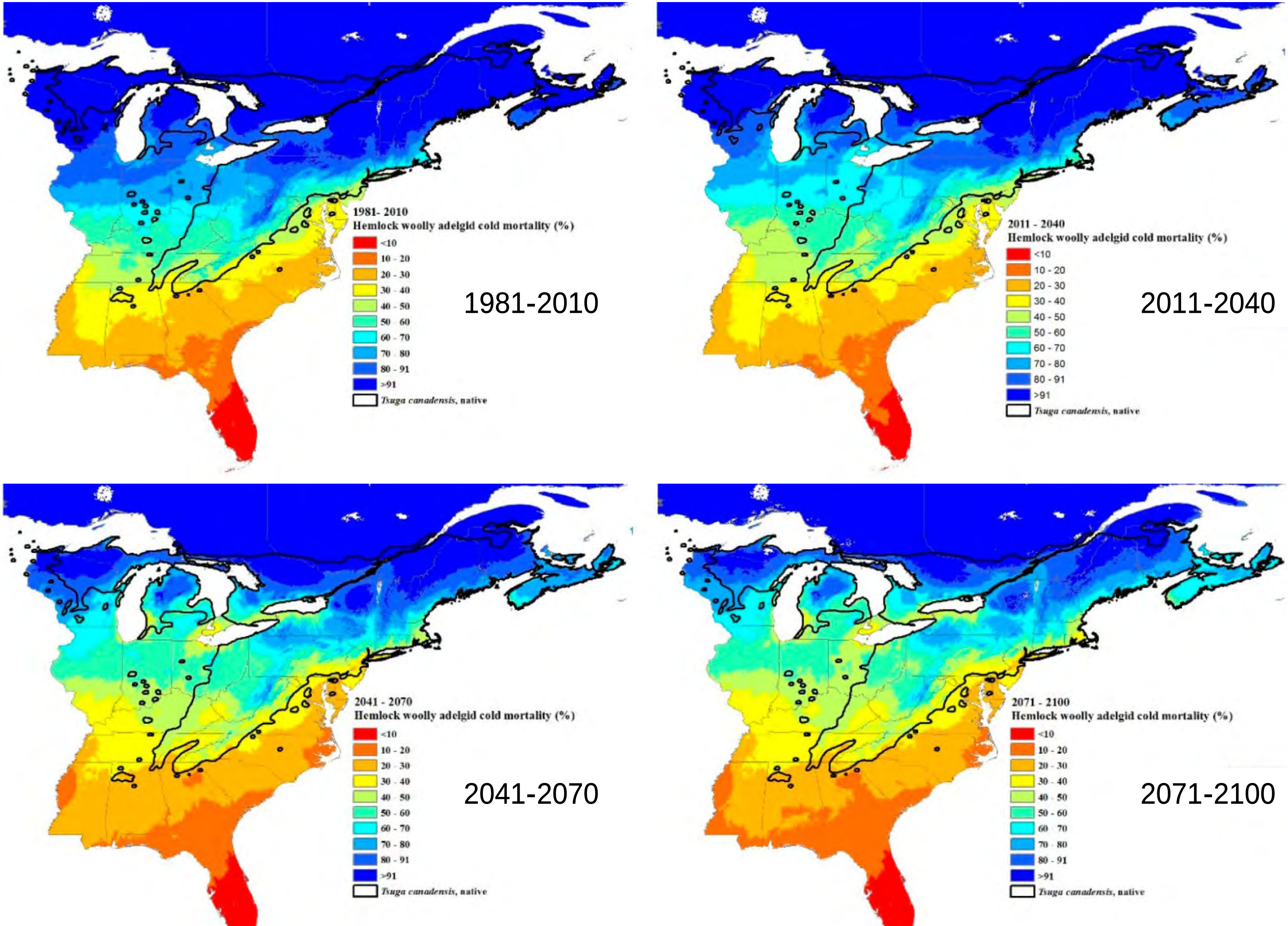
Climate brings a pest to a new area
(1: Climate brings Pest)



Hemlock woolly adelgid's (*Adelges tsugae*, HWA) spread is limited by cold winter temperatures, but warming winters and rapid adaptation to cold are expanding HWA's range and increasing its reproductive rates.

- HWA has quickly adapted to local climate conditions in its invasive range, despite asexual reproduction which can limit adaptive capacity.
- Hemlock decline from HWA is likely to be slower in the northern parts of hemlock's range, but HWA will eventually occupy hemlock's full range.
- Climate change and continued adaptation will hasten HWA's northward spread.





McAvoy et al. 2017, *Forests*

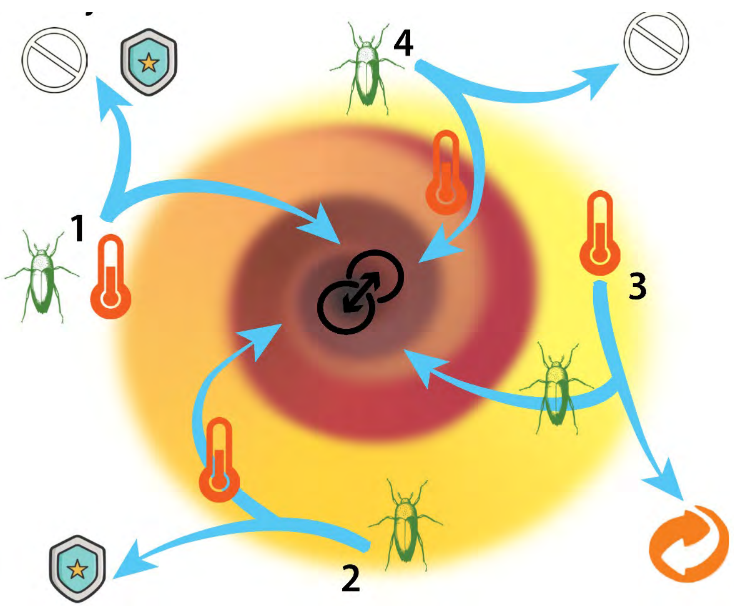
Management Actions

PREVENTION

- Support policies that reduce introductions of novel pests, such as switching to pest-free packaging and restricting live-plant imports
- Spread the word about slow-the-spread campaigns such as Don't Move Firewood and engage your networks in monitoring forests for novel pests

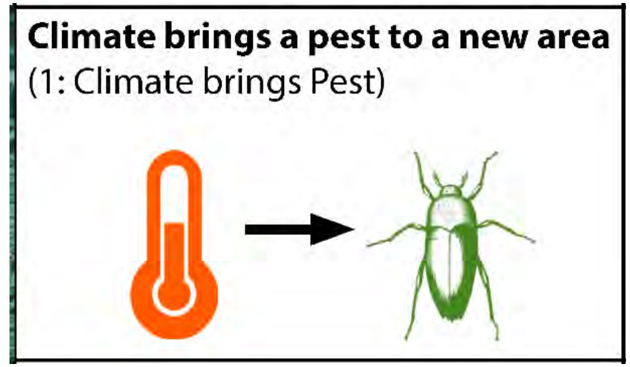
RESISTANCE

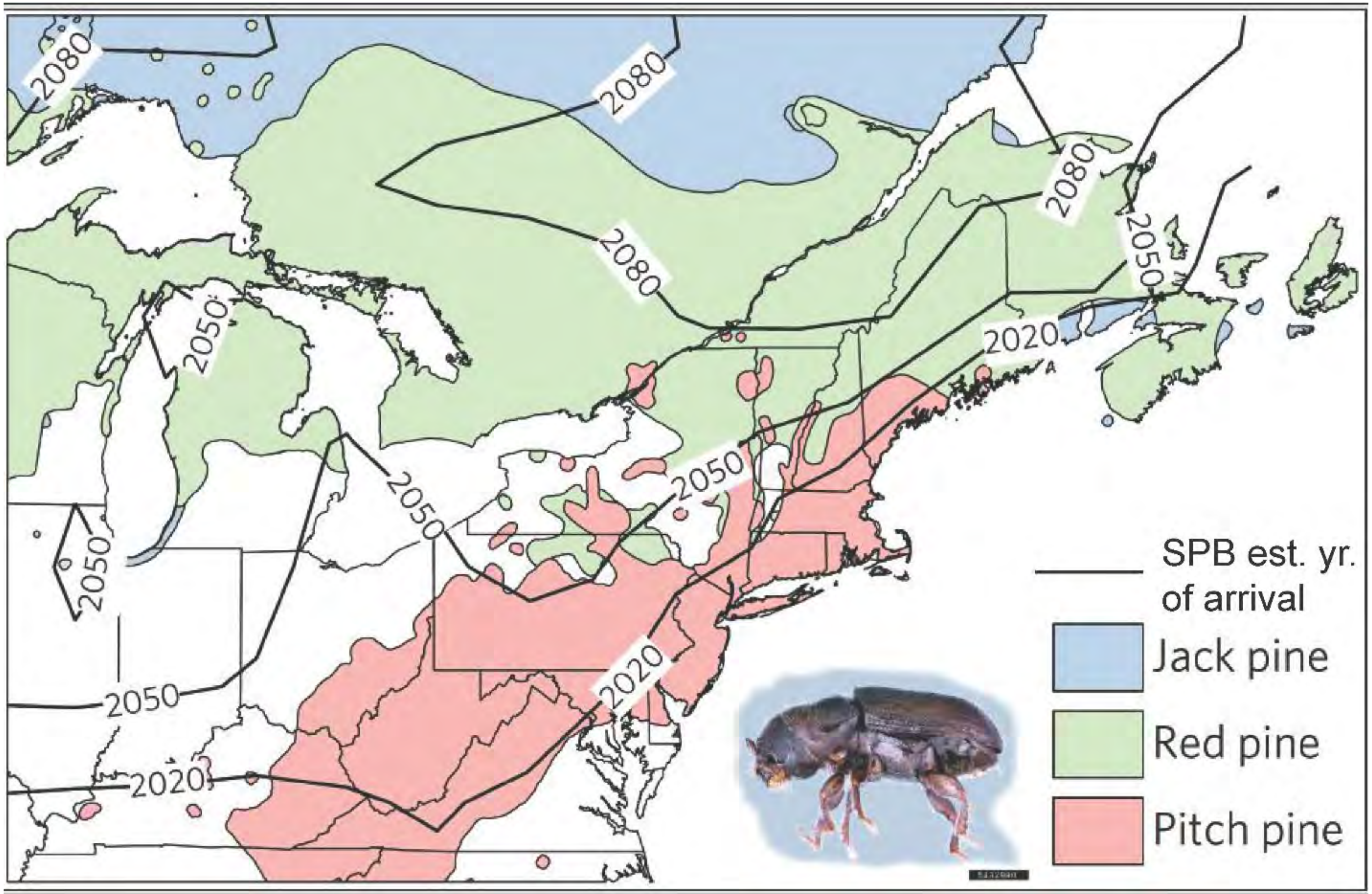
- Eradicate small pest populations when possible
- Work with a licensed pesticide applicator to treat individual trees or special groves
- Remove hazard trees near trails and infrastructure
- Work with your forester to promote tree species diversity and/or reduce the abundance of host species for specific pests



- Don't rely on cold winter temperatures to safeguard northern hemlock populations.
- Don't move potentially infested material. Some states, including Vermont and Maine, have an HWA quarantine that regulates the movement of hemlock plants and wood products.
- Slow the spread of HWA by moving bird feeders away from hemlock trees, especially in the spring and summer when HWA is mobile. Birds offer easy and convenient transportation for the HWA.

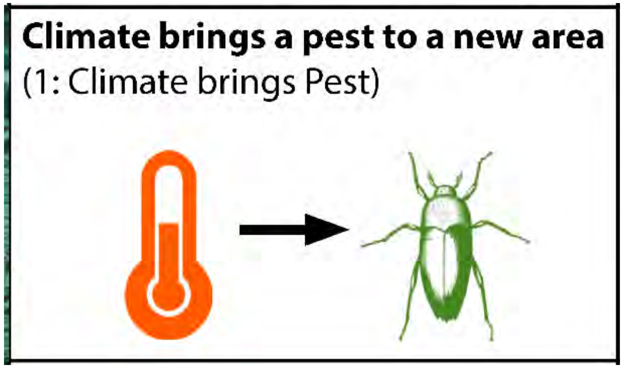
Nuisance neonatives: Southern Pine Beetle





Adapted from Lesk et al. (2017) *Nature*

Nuisance neonatives: Southern Pine Beetle



- Outbreaks can expand rapidly – multiple generations per year

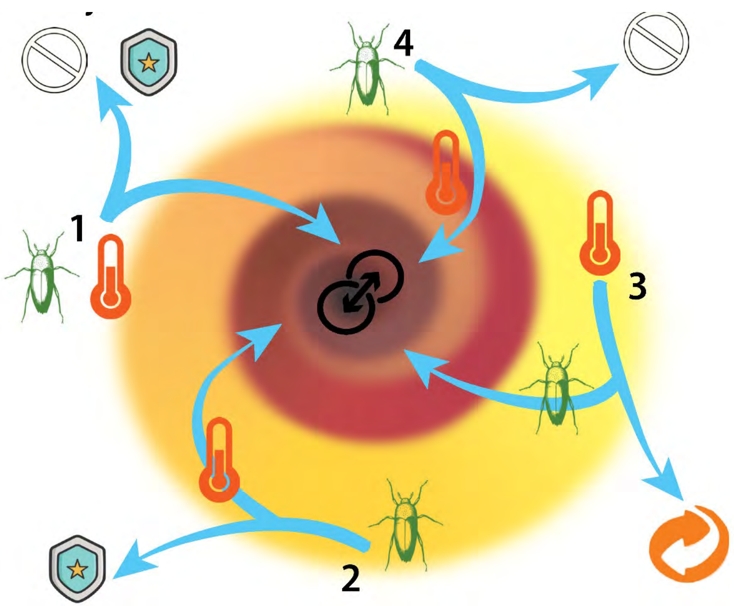
Management Actions

PREVENTION

- Support policies that reduce introductions of novel pests, such as switching to pest-free packaging and restricting live-plant imports
- Spread the word about slow-the-spread campaigns such as Don't Move Firewood and engage your networks in monitoring forests for novel pests

RESISTANCE

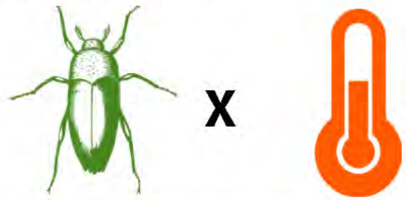
- Eradicate small pest populations when possible
- Work with a licensed pesticide applicator to treat individual trees or special groves
- Remove hazard trees near trails and infrastructure
- Work with your forester to promote tree species diversity and/or reduce the abundance of host species for specific pests



- SPB may exacerbate the conversion of pine barrens to hardwood-dominated communities and could functionally eliminate pitch pine from infested stands.
- Pitch pine barren restoration – thinning and prescribed fire – can reduce susceptibility to SPB by increasing tree vigor and reducing tree density

Poll Question 2

A minor pest becomes virulent with climate change
(2: Pest X Climate)



Scale insects, which damage trees by eating their sap, survive and reproduce more in warm environments. Warming allows invasive (e.g. hemlock elongate scale, *Fiorinia externa*) and native (e.g. gloomy scale, *Melanaspis tenebricosa*) scale insects to reach high densities and damage host trees.

- EHS less problematic than HWA
- Gloomy scale affects urban red maples in hot, dry conditions

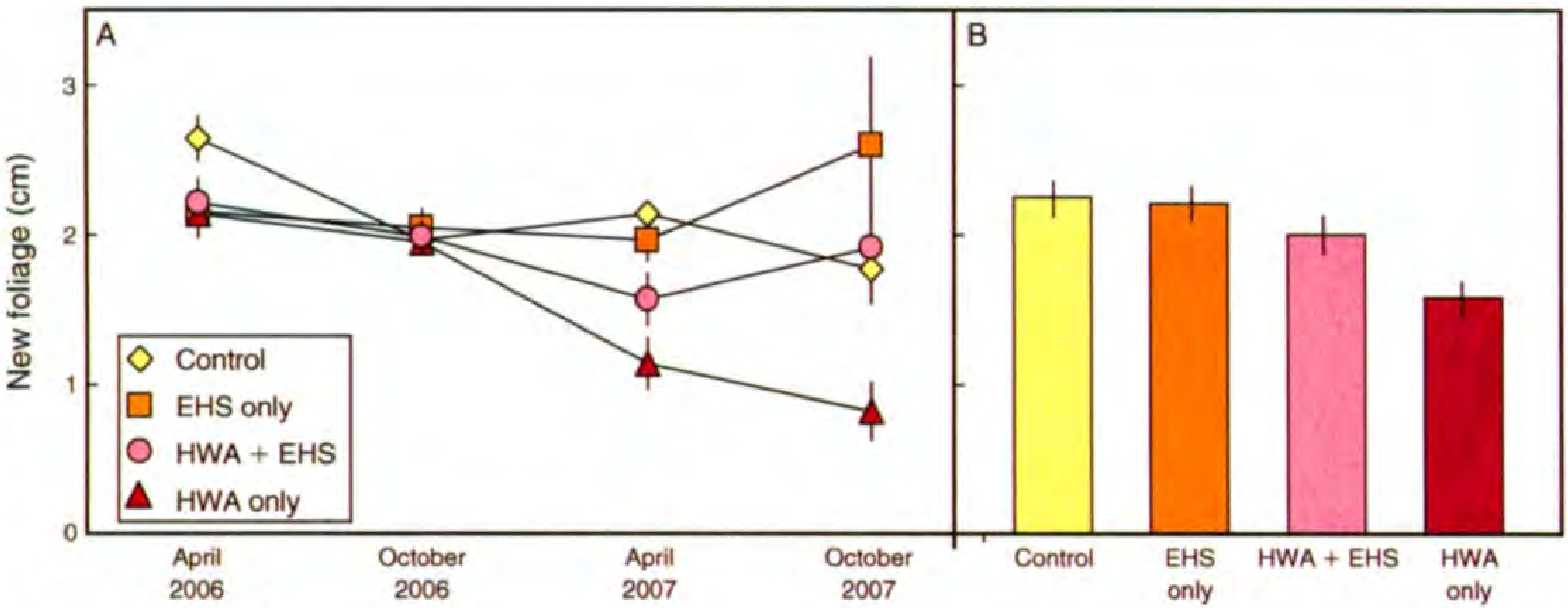
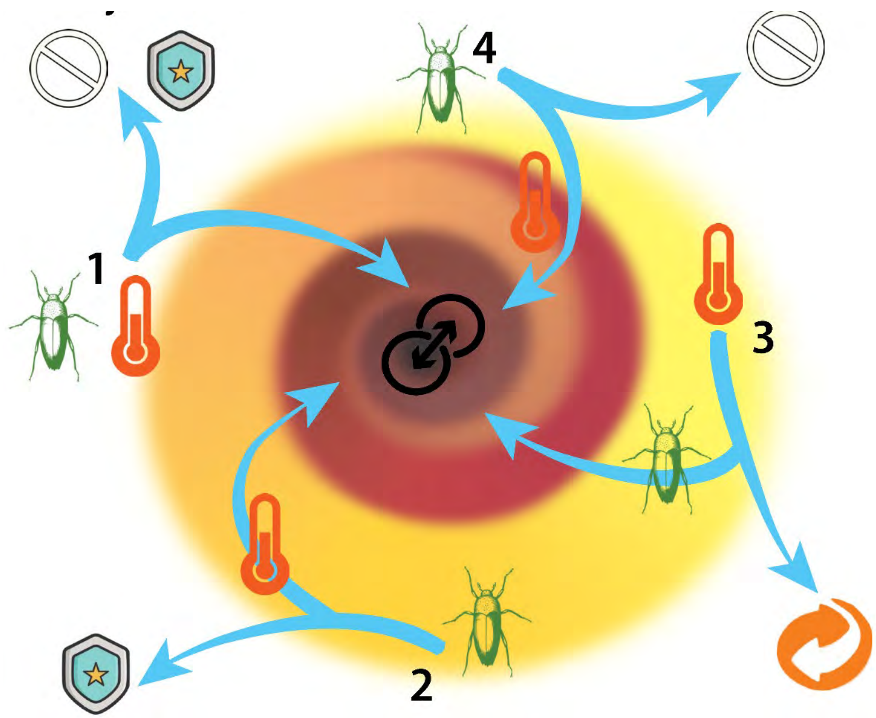


FIG. 2. New foliage growth (mean ± SE) (A) at each of four sampling dates during the experiment and (B) across all sampling dates, by treatment. Diamonds, control treatment; squares, EHS-only treatment; circles, HWA + EHS treatment; triangles, HWA-only treatment.

Preisser and Elkinton 2008, *Ecology*

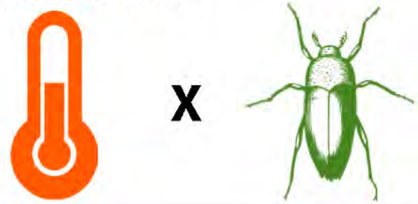
RESISTANCE

- Eradicate small pest populations when possible
- Work with a licensed pesticide applicator to treat individual trees or special groves
- Remove hazard trees near trails and infrastructure
- Work with your forester to promote tree species diversity and/or reduce the abundance of host species for specific pests



- Gloomy scale not yet in New England – but may become a problem, especially in urban areas, with warming temperatures
- For landscape trees, provide adequate water but do not use excessive nitrogen fertilizer

Climate stress makes trees more vulnerable to pest outbreaks
(3: Climate X Pest)



Spongy moths (*Lymantria dispar*) defoliate several tree species, but preferentially feed on oaks (*Quercus spp.*). Outbreaks cause more damage and mortality to oaks that are already stressed by drought.

Entomophaga maimiaga


PEST CONTROL
Fungus Fights Moth Menace
Researchers experiment with relocating a natural biological enemy of gypsy-moth caterpillars
By Laurent Belsie

Towns/Region
Fungus saves much of area from gypsy moths

Fungus Saves Trees From Gypsy Moths
By TRUDY TYNAN
AP Writer
AMHERST, Mass. — A nearly forgotten fungus is proving to be deadly on voracious

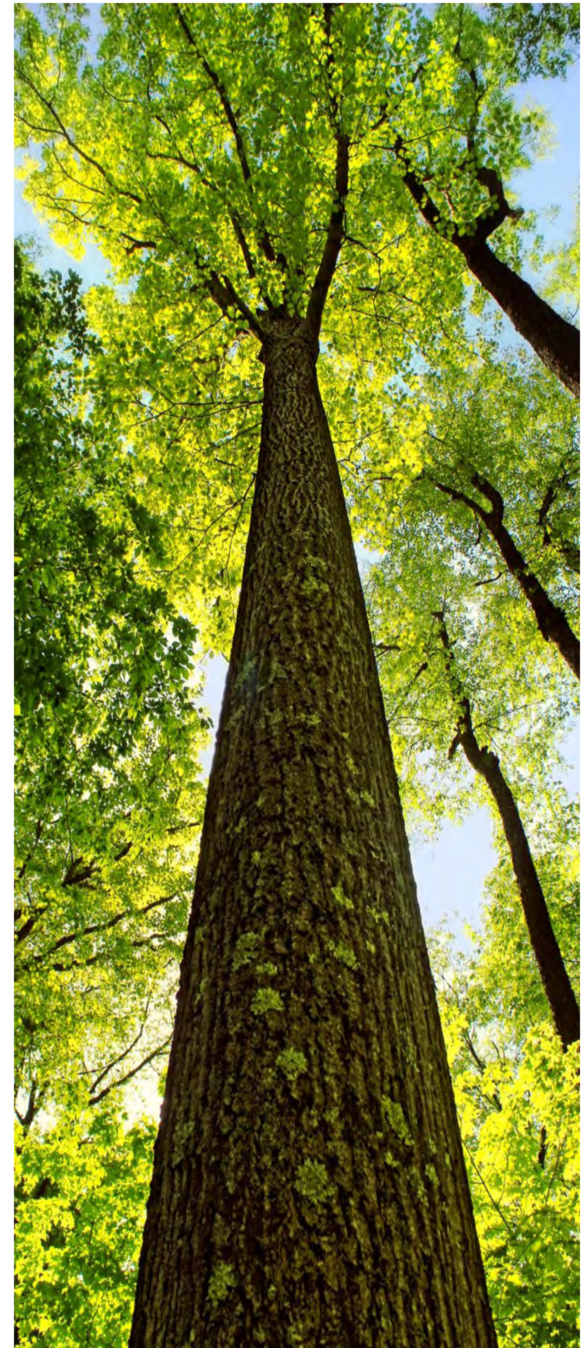
Overview Articles

The Drought Response of Eastern US Oaks in the Context of Their Declining Abundance

KIMBERLY NOVICK, INSU JO, LOÏC D'ORANGEVILLE, MICHAEL BENSON, TSUN FUNG AU, MALLORY BARNES, SANDER DENHAM, SONGLIN FEI, KELLY HEILMAN, TAEHEE HWANG, TARA KEYSER, JUSTIN MAXWELL, CHELCY MINIAT, JASON MCLACHLAN, NEIL PEDERSON, LIXIN WANG, JEFFREY D. WOOD, AND RICHARD P. PHILLIPS

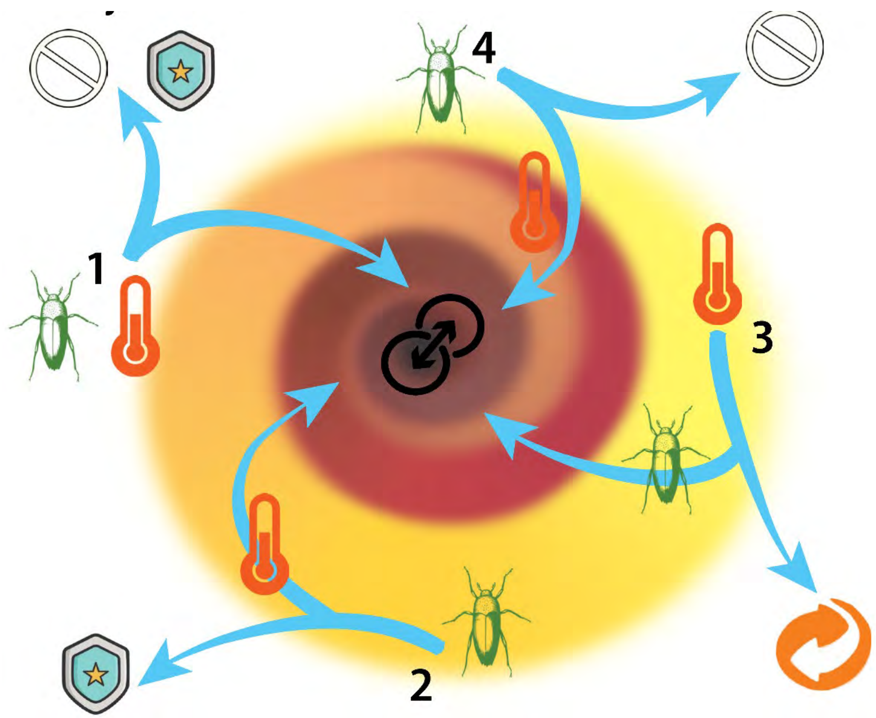
BioScience 2022

Oaks grow well in dry conditions, but may have higher risk of mortality from hydraulic failure



RESILIENCE

- Work with your forester to increase stand vigor and diversity, for example by thinning
- Monitor pest populations for early-warning signs of outbreak.
- Utilize the National Phenology Network's forecast tool to identify when insects will reach life stages critical for monitoring and management.
- Consider leaving host trees as a seed source for regeneration and then as wildlife habitat after mortality



Assess oak forest resiliency https://foreststewardsguild.org/oak-resiliency

Increase oak vigor by thinning forests

Climate change alters the trajectory of recovery after tree mortality
(4: Pest then Climate)

then

Emerald ash borer (*Agrilus planipennis,* EAB) attacks North American ash (*Fraxinus spp.*) and has become the costliest exotic insect in the U.S. Coupled with climate change, trees killed by EAB are replaced by other species resulting in permanantly altered ecosystems (e.g. converting black ash swamps to non-forests).

Youngquist et al. 2017, *Wetlands*

Undisturbed *Fraxinus nigra* community supporting diversity of facultative and obligate wetland plant species.

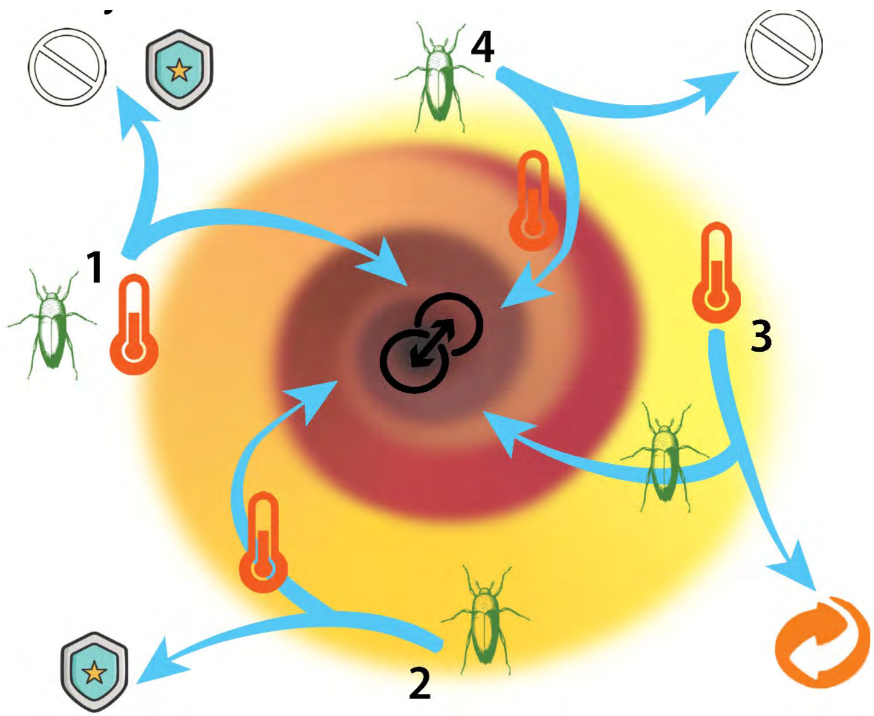
Post-disturbance *Fraxinus nigra* community dominated by obligate wetland plant species, including lake sedge (*Carex lacustris*) and cattail (*Typha* spp.).

RESILIENCE

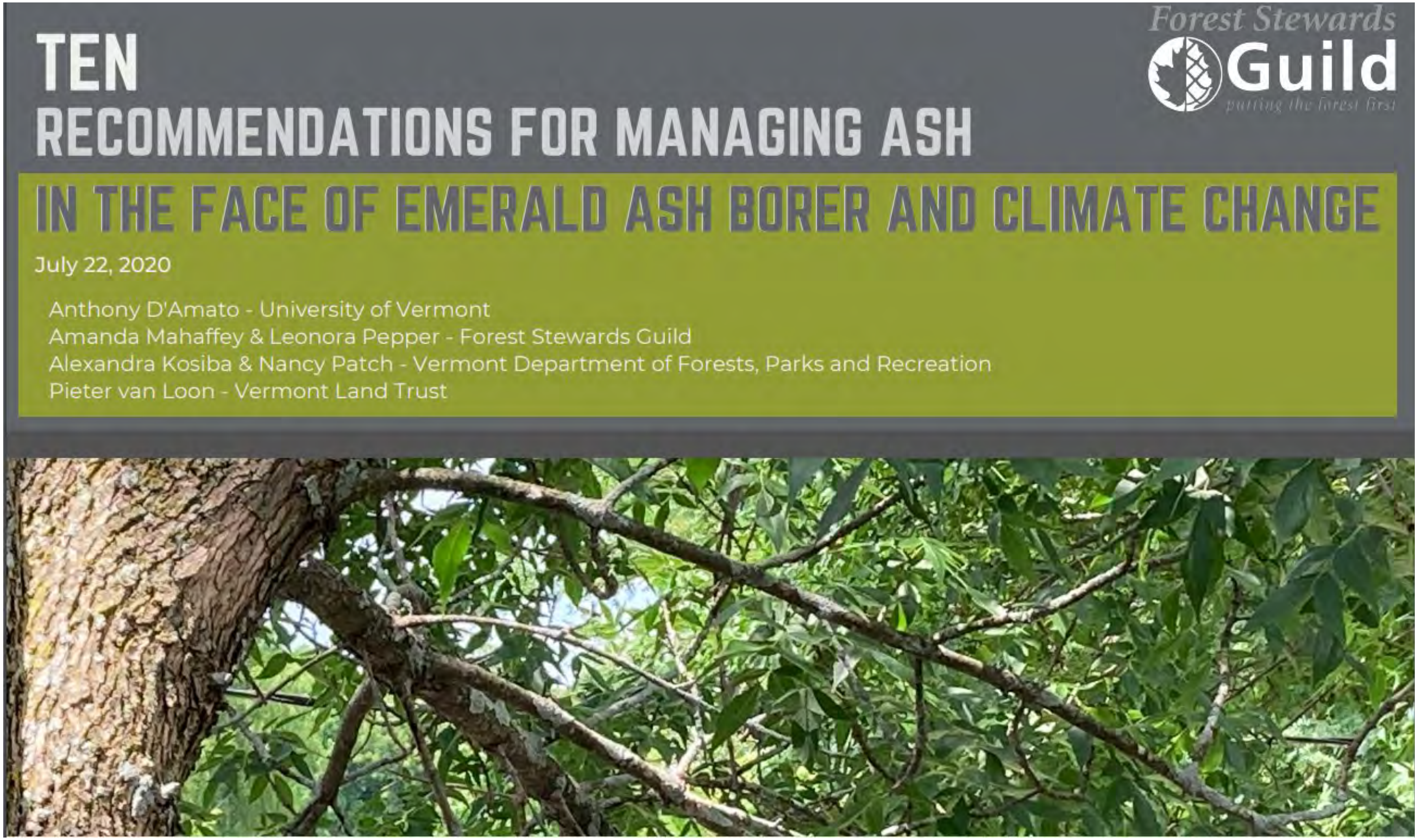
- Work with your forester to increase stand vigor and diversity, for example by thinning
- Monitor pest populations for early-warning signs of outbreak.
- Utilize the National Phenology Network's forecast tool to identify when insects will reach life stages critical for monitoring and management.
- Consider leaving host trees as a seed source for regeneration and then as wildlife habitat after mortality

TRANSITION

- When mortality is widespread, consider managing the forest for a warmer future. For example, consider diversifying tree species composition at the landscape level with particular attention to climate resilient species. Want to learn more? Check out https://forestadaptation.org/
- Salvage harvesting isn't always necessary: dead and dying trees provide wildlife habitat and diversify the forest structure.



- To keep options open for future ash regeneration in the forest, create larger openings (>0.25 acre)
- Retain large, healthy ash trees, especially female trees
- Standing dead trees valuable for birds, insects



https://foreststewardsguild.org/wp-content/uploads/2020/07/Ten-Recommendations-for-Managing-Ash.pdf

Webinar: 'Building community to address the threat of emerald ash borer to northern forests' https://www.youtube.com/watch?v=RpHrZKnmxKo

Poll Question 3

What can we do?

PREVENTION

- Support policies that reduce introductions of novel pests, such as switching to pest-free packaging and restricting live-plant imports
- Spread the word about slow-the-spread campaigns such as Don't Move Firewood and engage your networks in monitoring forests for novel pests

RESISTANCE

- Eradicate small pest populations when possible
- Work with a licensed pesticide applicator to treat individual trees or special groves
- Remove hazard trees near trails and infrastructure
- Work with your forester to promote tree species diversity and/or reduce the abundance of host species for specific pests

RESILIENCE

- Work with your forester to increase stand vigor and diversity, for example by thinning
- Monitor pest populations for early-warning signs of outbreak.
- Utilize the National Phenology Network's forecast tool to identify when insects will reach life stages critical for monitoring and management.
- Consider leaving host trees as a seed source for regeneration and then as wildlife habitat after mortality

TRANSITION

- When mortality is widespread, consider managing the forest for a warmer future. For example, consider diversifying tree species composition at the landscape level with particular attention to climate resilient species. Want to learn more? Check out https://forestadaptation.org/
- Salvage harvesting isn't always necessary: dead and dying trees provide wildlife habitat and diversify the forest structure.

What can we do?

PREVENTION

- Support policies that reduce introductions of novel pests, such as switching to pest-free packaging and restricting live-plant imports
- Spread the word about slow-the-spread campaigns such as Don't Move Firewood and engage your networks in monitoring forests for novel pests

RESISTANCE

- Eradicate small pest populations when possible
- Work with a licensed pesticide applicator to treat individual trees or special groves
- Remove hazard trees near trails and infrastructure
- Work with your forester to promote tree species diversity and/or reduce the abundance of host species for specific pests

RESILIENCE

- Work with your forester to increase stand vigor and diversity, for example by thinning
- Monitor pest populations for early-warning signs of outbreak.
- Utilize the National Phenology Network's forecast tool to identify when insects will reach life stages critical for monitoring and management.
- Consider leaving host trees as a seed source for regeneration and then as wildlife habitat after mortality

TRANSITION

- When mortality is widespread, consider managing the forest for a warmer future. For example, consider diversifying tree species composition at the landscape level with particular attention to climate resilient species. Want to learn more? Check out https://forestadaptation.org/
- Salvage harvesting isn't always necessary: dead and dying trees provide wildlife habitat and diversify the forest structure.

https://www.caryinstitute.org/science/tree-smart-trade

What can we do?

PREVENTION

- Support policies that reduce introductions of novel pests, such as switching to pest-free packaging and restricting live-plant imports
- Spread the word about slow-the-spread campaigns such as Don't Move Firewood and engage your networks in monitoring forests for novel pests

RESISTANCE

- Eradicate small pest populations when possible
- Work with a licensed pesticide applicator to treat individual trees or special groves
- Remove hazard trees near trails and infrastructure
- Work with your forester to promote tree species diversity and/or reduce the abundance of host species for specific pests

RESILIENCE

- Work with your forester to increase stand vigor and diversity, for example by thinning
- Monitor pest populations for early-warning signs of outbreak.
- Utilize the National Phenology Network's forecast tool to identify when insects will reach life stages critical for monitoring and management.
- Consider leaving host trees as a seed source for regeneration and then as wildlife habitat after mortality

TRANSITION

- When mortality is widespread, consider managing the forest for a warmer future. For example, consider diversifying tree species composition at the landscape level with particular attention to climate resilient species. Want to learn more? Check out https://forestadaptation.org/
- Salvage harvesting isn't always necessary: dead and dying trees provide wildlife habitat and diversify the forest structure.

Center for Agriculture, Food, and the Environment

UMass Extension Landscape, Nursery and Urban Forestry Program

Fact Sheets

Cultural Practices
Diseases
Earthworms
Environmental Stress
Insects and Mites

Emerald Ash Borer

Pest: *Agrilus planipennis* (Fairmaire)

Order: Coleoptera

Family: Buprestidae

Host/Range

The emerald ash borer (EAB) is a non-native, invasive insect that was first discovered in North America in 2002 in Michigan. It is native to eastern Russia, northern China, Japan, and Korea. EAB utilize ash (*Fraxinus* spp.) as their primary hosts. However, emerald ash borer was found attacking and developing in white fringe tree (*Chionanthus virginicus*) in Ohio and has most recently been confirmed as able to feed and develop successfully on cultivated olive (*Olea europaea*).

- Learn more about specific stressors
- Find treatment information

What can we do?

PREVENTION

- Support policies that reduce introductions of novel pests, such as switching to pest-free packaging and restricting live-plant imports
- Spread the word about slow-the-spread campaigns such as Don't Move Firewood and engage your networks in monitoring forests for novel pests

RESISTANCE

- Eradicate small pest populations when possible
- Work with a licensed pesticide applicator to treat individual trees or special groves
- Remove hazard trees near trails and infrastructure
- Work with your forester to promote tree species diversity and/or reduce the abundance of host species for specific pests

RESILIENCE

- Work with your forester to increase stand vigor and diversity, for example by thinning
- Monitor pest populations for early-warning signs of outbreak.
- Utilize the National Phenology Network's forecast tool to identify when insects will reach life stages critical for monitoring and management.
- Consider leaving host trees as a seed source for regeneration and then as wildlife habitat after mortality

TRANSITION

- When mortality is widespread, consider managing the forest for a warmer future. For example, consider diversifying tree species composition at the landscape level with particular attention to climate resilient species. Want to learn more? Check out https://forestadaptation.org/
- Salvage harvesting isn't always necessary: dead and dying trees provide wildlife habitat and diversify the forest structure.

USA npn National Phenology Network

Spongy moths were introduced in Massachusetts 150 years ago, by an amateur entomologist seeking an alternative to silk worms.

Image credit: CharlesC (Wikipedia)

Data

- Explore Data
- Observational Data
- Models and Maps
- Visualization Tool
- Data Quality

SPONGY MOTH FORECAST

European spongy moth (formerly gypsy moth) caterpillars feed on deciduous trees, causing major defoliation and tree mortality. They are considered one of the worst forest pests in the United States.

Pheno Forecast maps predict key life cycle stages in invasive and pest species, to improve management efficacy. For insect pest species, Pheno Forecasts are based on published growing degree day (GDD) thresholds for key points in species life cycles. These key points typically represent life cycle stages when management actions are most effective. These maps are updated daily and available 6 days in the future.

Spongy Moth Current Day Forecast.

What can we do?

PREVENTION

- Support policies that reduce introductions of novel pests, such as switching to pest-free packaging and restricting live-plant imports
- Spread the word about slow-the-spread campaigns such as Don't Move Firewood and engage your networks in monitoring forests for novel pests

RESISTANCE

- Eradicate small pest populations when possible
- Work with a licensed pesticide applicator to treat individual trees or special groves
- Remove hazard trees near trails and infrastructure
- Work with your forester to promote tree species diversity and/or reduce the abundance of host species for specific pests

RESILIENCE

- Work with your forester to increase stand vigor and diversity, for example by thinning
- Monitor pest populations for early-warning signs of outbreak.
- Utilize the National Phenology Network's forecast tool to identify when insects will reach life stages critical for monitoring and management.
- Consider leaving host trees as a seed source for regeneration and then as wildlife habitat after mortality

TRANSITION

- When mortality is widespread, consider managing the forest for a warmer future. For example, consider diversifying tree species composition at the landscape level with particular attention to climate resilient species. Want to learn more? Check out https://forestadaptation.org/
- Salvage harvesting isn't always necessary: dead and dying trees provide wildlife habitat and diversify the forest structure.

[TABLE 1] Predicted Change in Suitable Habitat

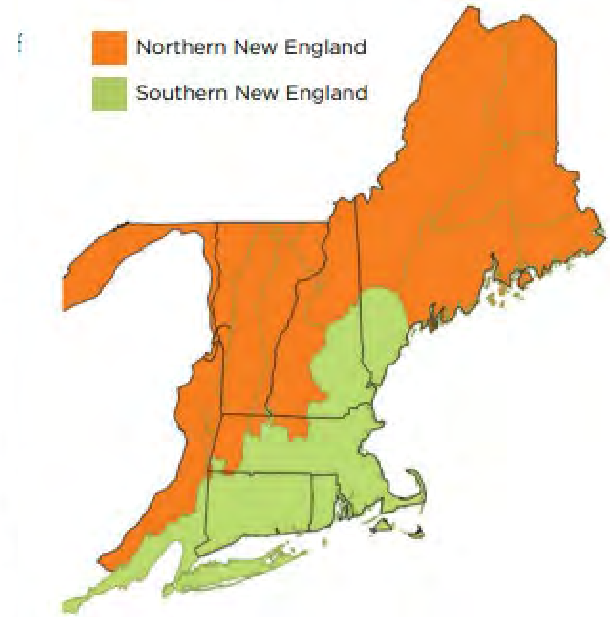
The following table provides tree species and predictions of how competitive they will be in the future. The values following each species name indicate whether species-suitable habitats will increase (+), decrease (−), or stay the same (●) under projected climate change.

Northern New England
(Ecological subsections M211A, B, C, and D, and M211E and J)

Tree Species	Low Emissions (PCM B1)	High Emissions (GFDL A1FI)
Balsam Fir	−	−
Black Spruce	−	−
Northern White Cedar	−	−
Paper Birch	−	−
Red Spruce	−	−
Tamarack	−	−
White Spruce	−	−
American Beech	●	−
Quaking Aspen	●	−
Sugar Maple	●	−
Yellow Birch	●	−
Bear/Scrub Oak	●	●
Bigtooth Aspen	●	●
Eastern White Pine	●	●
Red Maple	●	●
American Basswood	●	+
Bitternut Hickory	●	+
Black Cherry	●	+
Pitch Pine	+	●
Black Birch	+	+
Black Oak	+	+
Chestnut Oak	+	+
Northern Red Oak	+	+
Shagbark Hickory	+	+
White Oak	+	+

Southern New England
(Ecological subsection M221A)

Tree Species	Low Emissions (PCM B1)	High Emissions (GFDL A1FI)
Balsam Fir	−	−
Black Spruce	−	−
Eastern White Pine	−	−
Northern White Cedar	−	−
Paper Birch	−	−
Quaking Aspen	−	−
Red Spruce	−	−
White Spruce	−	−
Tamarack	−	●
American Beech	●	−
Northern Red Oak	●	−
Red Maple	●	−
Yellow Birch	●	−
Bear/Scrub Oak	●	●
Black Cherry	●	●
Sugar Maple	●	●
Bigtooth Aspen	+	●
Pitch Pine	+	●
American Basswood	●	+
Bitternut Hickory	+	+
Black Oak	+	+
Chestnut Oak	+	+
Shagbark Hickory	+	+
White Oak	+	+



Catanzaro, D'Amato, & Silver Huff. 2016. Increasing Forest Resiliency for an Uncertain Future. https://masswoods.org/sites/masswoods.net/files/Forest-Resiliency.pdf

Northeast RISCC MANAGEMENT NETWORK

Join us!

RISCC Website:

https://www.risccnetwork.org/

Sign up for biweekly Research Summaries:

email "ne-riscc-l-request@cornell.edu" with subject "join"

UMass Amherst

USGS science for a changing world

NYISRI New York Invasive Species Research Institute

Cornell University

NE CASC Northeast Climate Adaptation Science Center

Register here: https://cornell.zoom.us/meeting/register/tJcqd-CpqT8tGtSUfVttc_xrs3ZXDnR9SUIj

Thank you!

Vincent van Gogh - Olive Trees - Google Art Project (Minneapolis Institute of Arts)

Audrey Barker Plotkin
aabarker@fas.harvard.edu