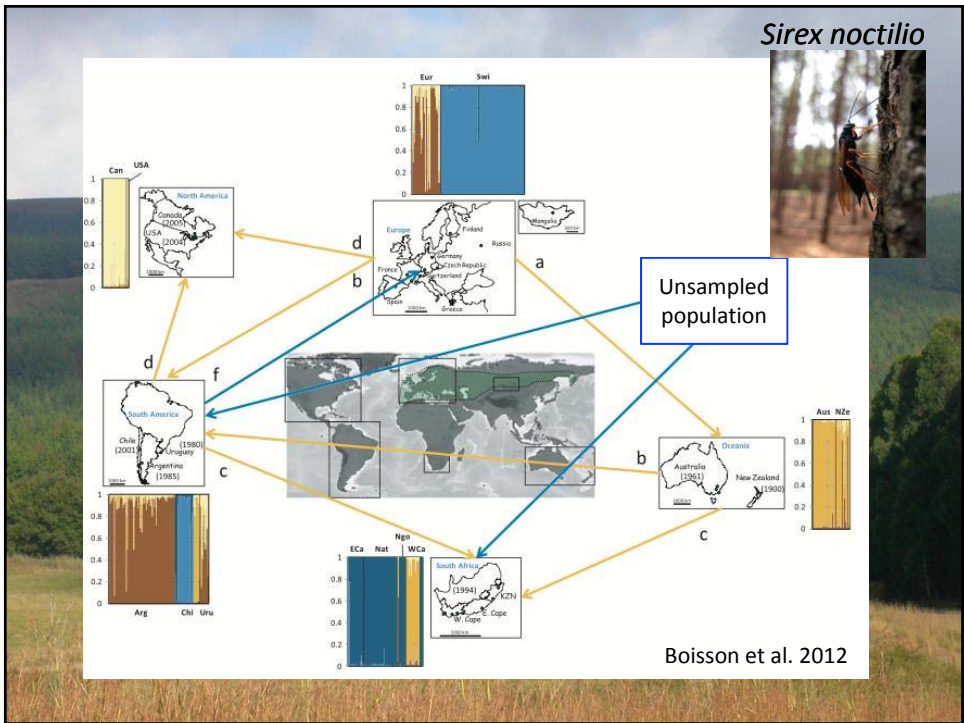
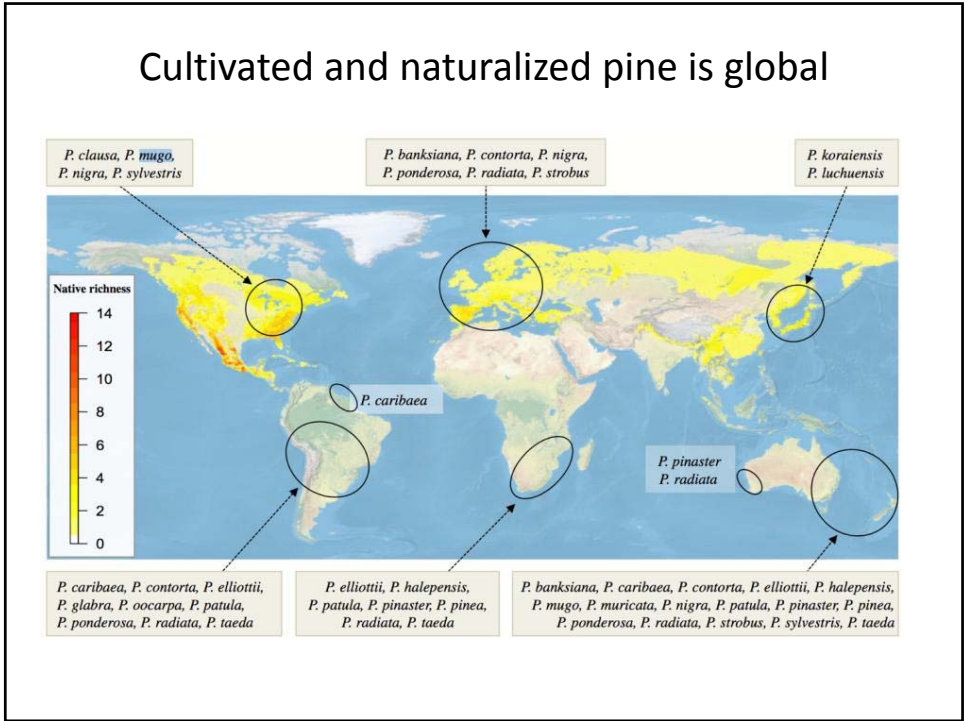
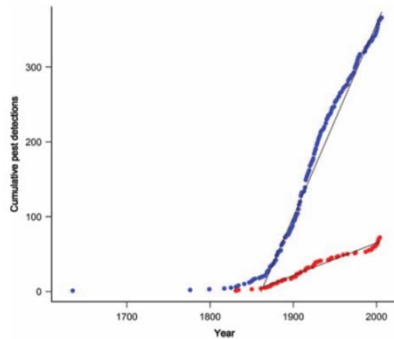


Cultivated and naturalized pine is global



Historical accumulation in US forests



2.2 new insects

0.9 new pathogens

(since 1850)

Figure 1. Cumulative detections of established forest pests over time with line fitted for the years 1860–2006. Nonindigenous insects (blue) were detected at a rate of approximately 2.5 insects per year ($y = 2.58x - 4802$; $y =$ cumulative number of insects, $x =$ year; $r^2 = 0.988$). High-impact insects and pathogens (red) were detected at a rate of at least 0.43 pests per year ($y = 0.43x - 804.3$; $r^2 = 0.977$).

Aukema et al. 2010

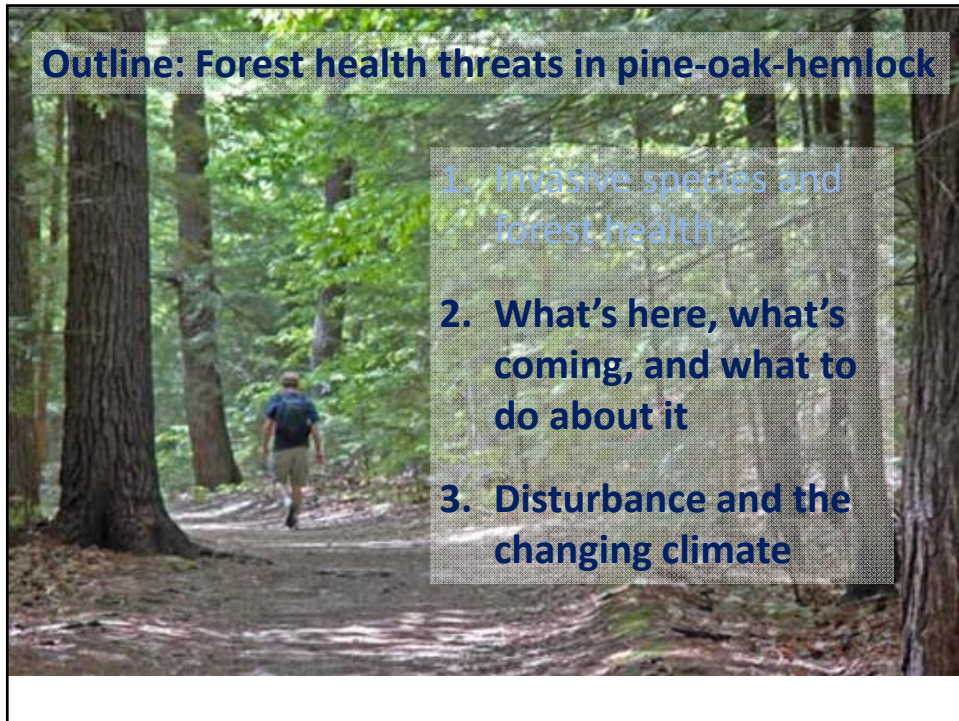
Cryptic diversity = population or species-level diversity in the absence of morphological differences

local adaptation
ecotype
cryptic species
biotype
geographic race
species complex
host race
genetic diversity
rapid evolution
species swarm

• **Cryptic species**



Photo: Hebert 2004, PNAS



Outline: Forest health threats in pine-oak-hemlock

1. Invasive species and forest health
2. What's here, what's coming, and what to do about it
3. Disturbance and the changing climate



Old *hemlock - beech - oak - pine forest* at UNH's College Woods (photo by Ben Kimball)

PINE-OAK-HEMLOCK (BEECH)

Pine	core
Oak	core
Hemlock	core
Beech	core
Paper birch	frequent/abundant
Red maple	frequent/abundant
Striped maple	frequent/abundant
White ash	occasional
Black cherry	occasional
Black birch	occasional
Sugar maple	occasional
Grey birch	occasional

WHITE PINE**Insects**

White pine weevil	<i>Pissodes strobi</i>
Pine aphids	<i>Cinara spp.</i>
Pine bark adelgid	<i>Pineus strobi</i>

Pathogens

White pine blister rust	<i>Cronartium ribicola</i>
Caliciopsis canker	<i>Caliciopsis pinea</i>
White pine needle cast	Multiple pathogens

White pine weevil, *Pissodes strobi*



White pine weevil, *Pissodes strobi*



White pine weevil, *Pissodes strobi*

Management:

- Grow young pine in stands with 40-50% crown closure
- Grow in high competition environments (inc. with hardwoods) to encourage rapid height growth with minimal diameter growth in terminal leader
- Prune quickly to establish new leader once affected

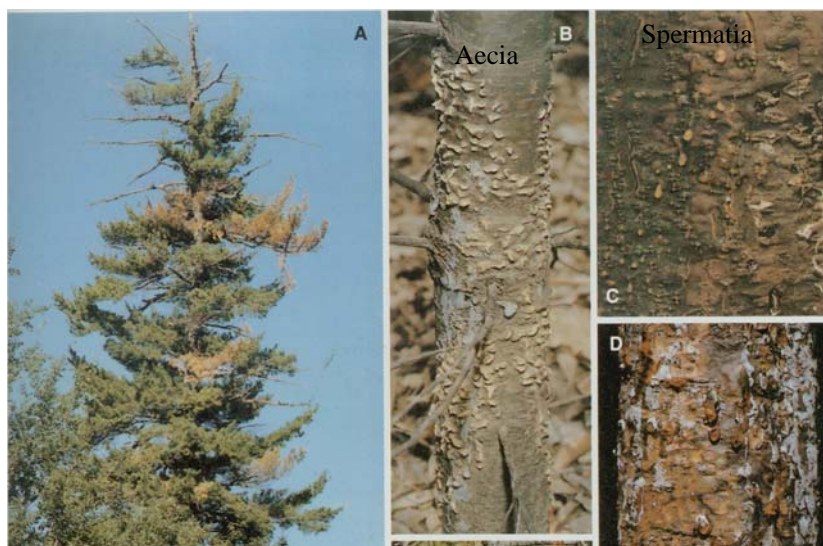
Pine aphids (*Cinara* spp.)



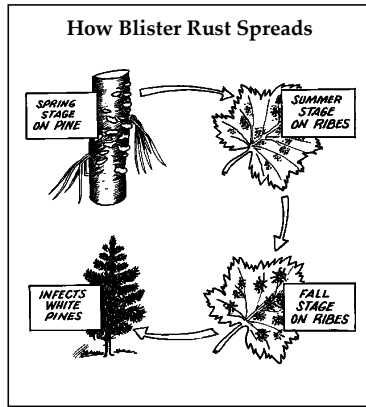
Pine bark adelgid (*Pineus strobi*)



White pine blister rust (*Cronartium ribicola*)



WPBR (*Cronartium ribicola*)



Simplified life cycle showing the importance of an alternate host

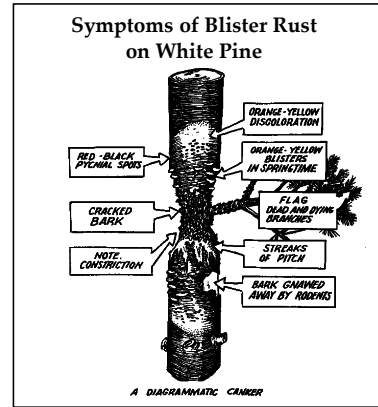


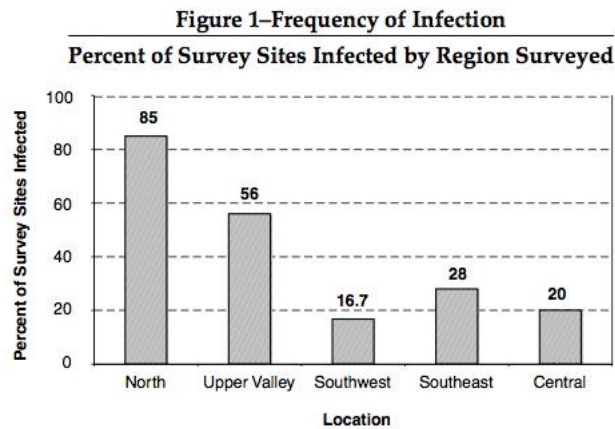
Diagram denoting common symptoms of blister rust on a white pine

by Kyle Lombard and Jennifer Bofinger

NH Division of Forests and Lands
Department of Resources and Economic Development

1999

WPBR (*Cronartium ribicola*)



But, only 2.4% of trees were infected

by Kyle Lombard and Jennifer Bofinger

NH Division of Forests and Lands
Department of Resources and Economic Development

1999

WPBR (*Chronartium ribicolola*)

Management:

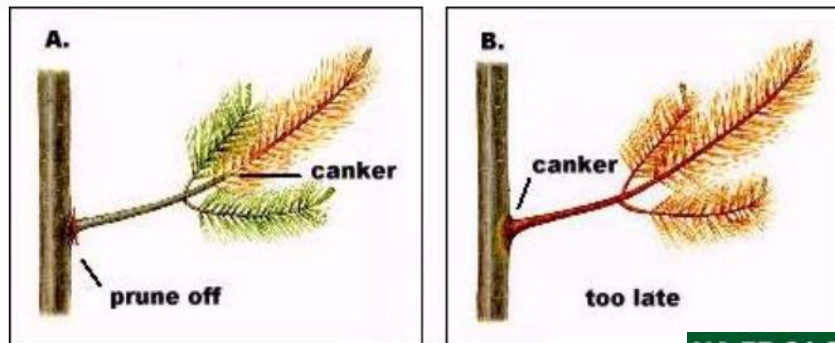
- SIMILAR TO PISSODES - grow young pine in stands under existing overstory to reduce moisture buildup
- HISTORICAL: Ribes removal
- Prune infected branches



WPBR (*Chronartium ribicolola*)

Management:

- Prune infected branches



NA-FR-01-93

Caliciopsis canker (*Caliciopsis* spp.)



Caliciopsis canker (*Caliciopsis* spp.)

Figure 3.

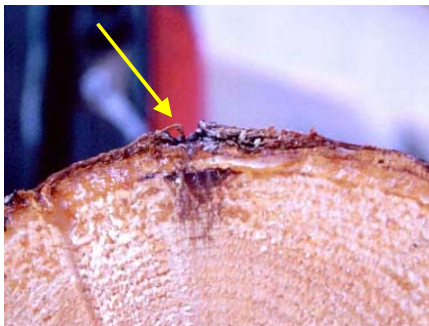


Figure 4.



Caliciopsis canker (*Caliciopsis* spp.)

Management:

- Currently most ignore these infections (Impacts on vigor unclear, mortality is rare)
- Increased temperature/sunlight in upper bole may reduce spore production
- Tree removal unlikely to reduce spore load

White pine needle cast

Figure 1. Eastern white pines exhibiting symptoms of foliar damage: chlorosis (A), and necrosis (B).



Munck et al. 2012

White pine needle cast

Figure 4. Necrotic needles (A) from Mast Yard, New Hampshire infected with *Bifusella linearis*, fruiting bodies (B) are shiny and black (x7.5) and the ascospores (C) are constricted in the middle (X400). Spores stained with methyl blue.



Figure 5. Needles (A) with chlorosis and necrosis from Sangerville, Maine infected with *Canavirgella banfieldii*, fruiting body (B) is embedded in the needle (x20) and ascospores (C) are not constricted in the middle (x200). Spores stained with methyl blue.



Figure 6. Sample (A) with defoliation and chlorosis from Waterbury, Vermont infected with *Mycosphaerella dearnessii* (anamorph *Lecanosticta acicola*), asexual fruiting body (B) (x35) and spores (C) (x200).



Pathogen complex

Mycosphaerella dearnessii
(*Lecanosticta acicola*)

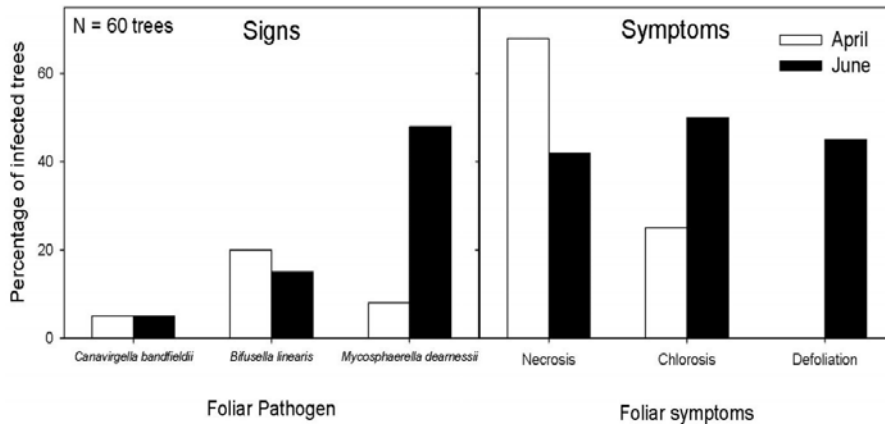
Canavirgella banfieldii

Bifusella linearis

Munck et al. 2012

White pine needle cast

Figure 11. Frequency of foliar disease signs and symptoms on infected trees.



Munck et al. 2012

White pine needle cast



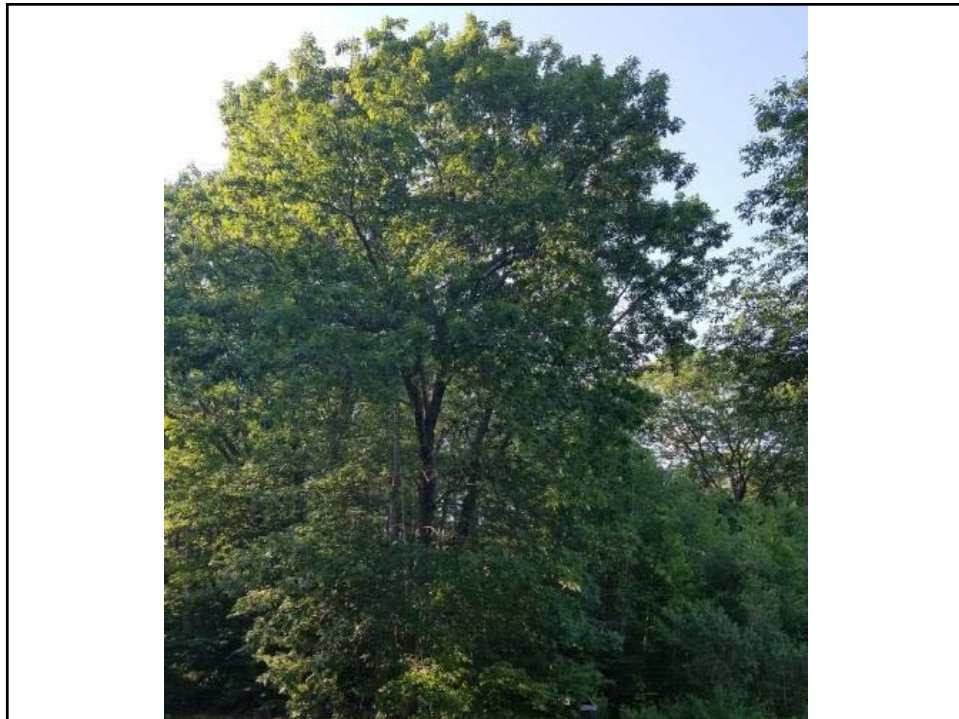
Prognosis

Disease is widespread and common

Wet springs favor spore production

Drought may favor disease expression

Munck et al. 2012



OAK		
Insects		
Red Oak Borer	<i>Enaphalodes rufulus</i>	Coleoptera: Cerambycidae
Gypsy moth	<i>Lymantria dispar</i>	Lepidoptera: Lymantriidae
Twolined Chestnut Borer	<i>Agrilus bilineatus</i>	Coleoptera: Buprestidae
Goldspotted Oak Borer	<i>Agrilus auroguttatus</i>	Coleoptera: Buprestidae
Oak Skeletonizer	<i>Bucculatrix ainliella</i>	Lepidoptera: Bucculatricidae
Red Oak Clearwing Borer	<i>Paranthrene simulans</i>	Lepidoptera: Sesiidae
Fall Cankerworm	<i>Alsophila pometaria</i>	Lepidoptera: Geometridae
Elm Spanworm	<i>Ennomos subsignarius</i>	Lepidoptera: Geometridae
Winter Moth	<i>Operophtera brumata</i>	Lepidoptera: Geometridae
Forest Tent Caterpillar	<i>Malacosoma disstria</i> Hübner	Lepidoptera: Lasiocampidae
Pinkstriped Oakworm	<i>Anisota virginensis</i>	Lepidoptera: Saturniidae
Orangestriped Oakworm	<i>Anisota senatoria</i>	Lepidoptera: Saturniidae
Browntail Moth	<i>Euproctis chrysorrhoea</i> L.	Lepidoptera: Lymantriidae
Variable Oak Leaf Caterpillar	<i>Lochmaeus manteo</i>	Lepidoptera: Notodontidae
Fall Webworm	<i>Hyphantria cunea</i>	Lepidoptera: Arctiidae
Pathogens		
Armillaria root rot	<i>Armillaria sp.</i>	
Oak wilt	<i>Ceratocystis fagacearum</i>	
"Oak decline"		
***Sudden oak death	<i>Phytophthora ramorum</i> ***	*** West coast only ***

OAK	
Insects	
Red Oak Borer	<i>Enaphalodes rufulus</i>
Gypsy moth	<i>Lymantria dispar</i>
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Pathogens	
Armillaria root rot	<i>Armillaria sp.</i>
Oak wilt	<i>Ceratocystis fagacearum</i>
"Oak decline"	
***Sudden oak death	<i>Phytophthora ramorum</i> ***
*** West coast only ***	

Red oak borer, *Enaphalodes rufulus*



University of Arkansas Forest Entomology Lab, Bugwood.org

Red oak borer, *Enaphalodes rufulus*

Photo#681348



Copyright © 2012 [tom murray](#)

Native insect

Most common on stressed trees (drought)

Outbreaks in AR around 2000, now crashed

University of Arkansas Forest Entomology Lab, Bugwood.org

Gypsy moth (*Lymantria dispar*)



Gypsy moth (*Lymantria dispar*)




“Slow the Spread”

80 species introduced to control (11 establ.)

Aerial sprays,
Gypcheck (NPV)

Oak wilt (*Ceratocystis fagacearum*)




Vascular pathogen

Transmission via interconnected roots or by beetles

No known control measures

Oak wilt (*Ceratocystis fagacearum*)



Not known in NE

Vectored by sap-feeding beetles (Nitidulidae) or oak bark beetles (*Pseudopityophthorus* spp.)

Oak wilt (*Ceratocystis fagacearum*)

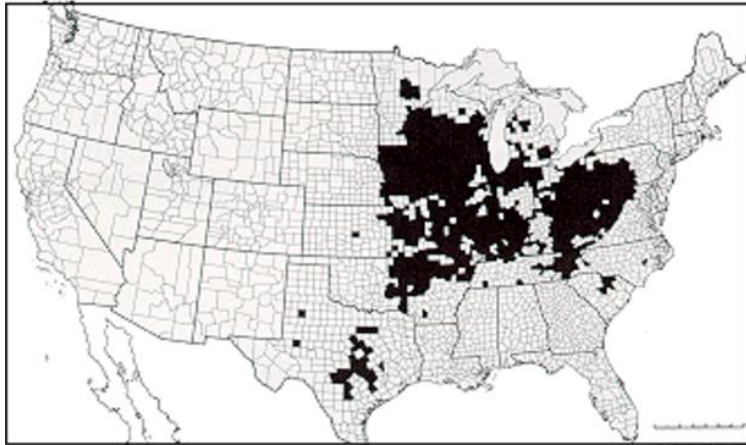
Bark crack/nitidulid beetles

Pseudopityophihorus spp.



Oak wilt (*Ceratocystis fagacearum*)

Figure 1. - *Distribution of oak wilt, 1980*



“Sudden oak death”



Figure 5. Mortality of overstory coast live oak in a typical mixed-evergreen forest in Marin County, CA.

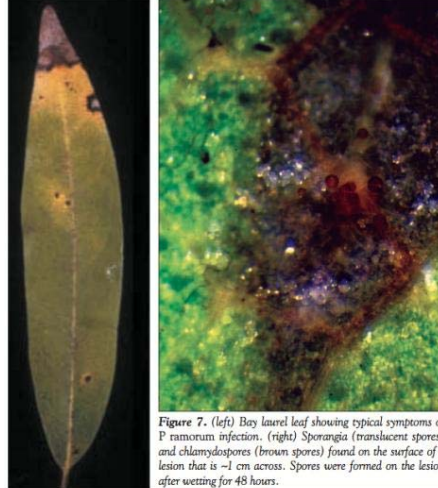


Figure 7. (left) Bay laurel leaf showing typical symptoms of *P. ramorum* infection. (right) Sporangia (translucent spores) and chlamydospores (brown spores) found on the surface of a lesion that is ~1 cm across. Spores were formed on the lesion after wetting for 48 hours.

Rizzo and Garboleto 2003

“Sudden oak death”



Figure 5. Mortality of overstory coast live oak in a typical mixed-evergreen forest in Marin County, CA.

Phytophthora ramorum

West coast, Europe

Oomycete (fungus-like organism, water mold)

Affects oaks and relatives

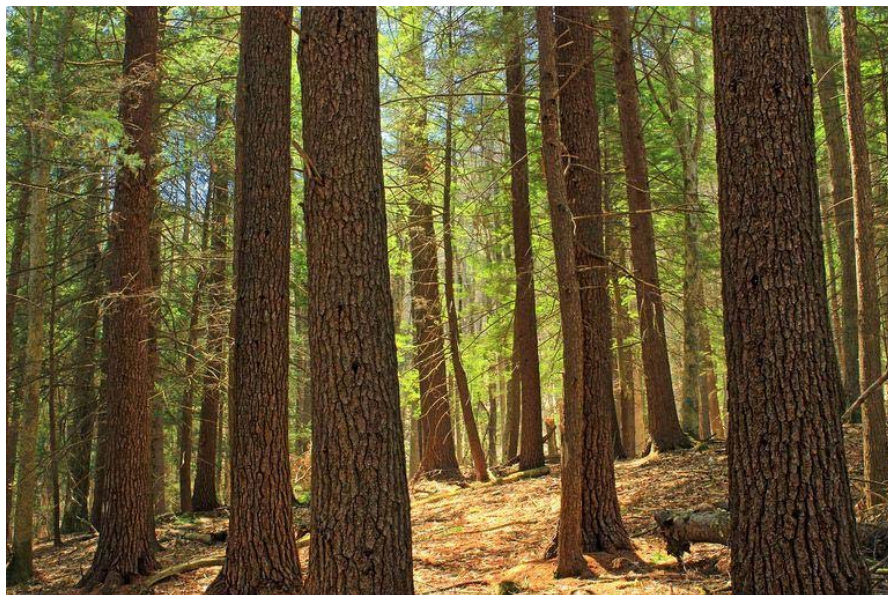
Transported on Rhododendron

Rizzo and Garboleto 2003

Powdery mildew (*Phyllactinia corylea*
and *Microsphaera alni*)



<https://extension.umd.edu/>



HEMLOCK

Insects

Hemlock wooly adelgid
Elongate hemlock scale
Circular evergreen scale
Eastern hemlock looper

Adelges tsugae
Fiorinia externa
Nuculaspis tsugae
[Lambdina fiscellaria](#)


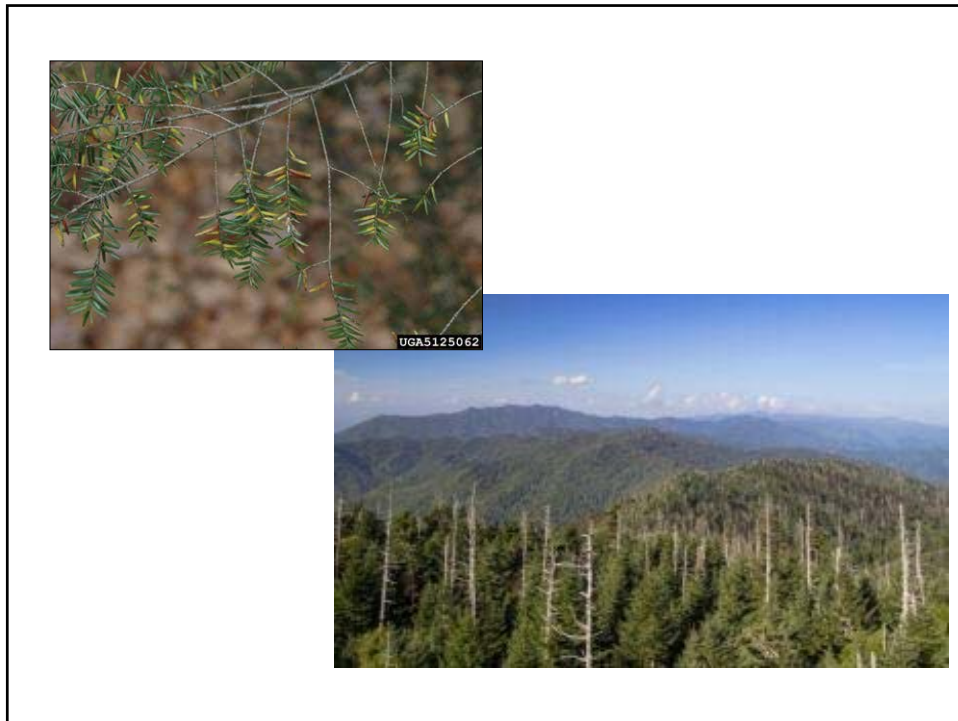
Pathogens

Hemlock tip blight
Needle rust

Sirococcus tsugae
[Pucciniastrum sp.](#)

Hemlock wooly adelgid (*Adelgid tsugae*)






UGA5125062

Massive problem in PA and NC (also MA)

Present in NH but currently not a massive problem



Control by native (West Coast) and introduced *Laracobius*

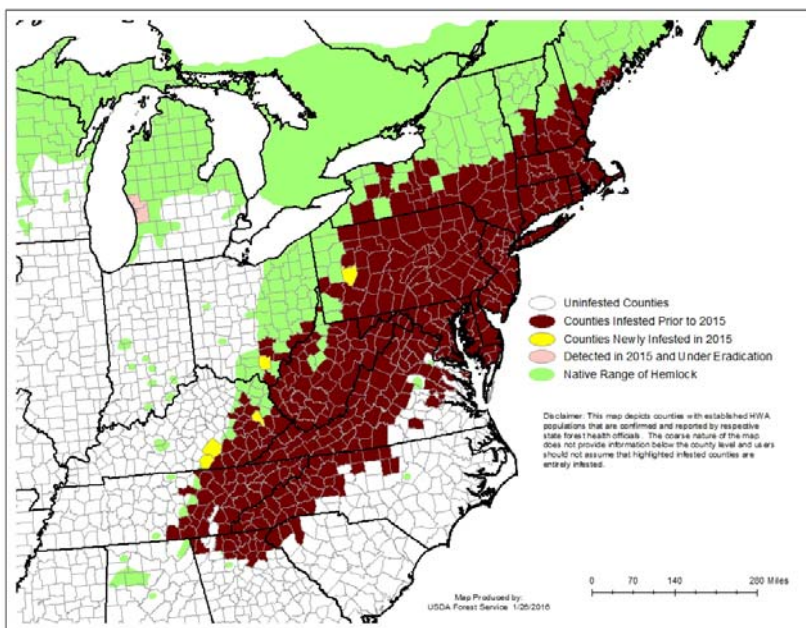
A composite block within a black border. On the left, there is a close-up photograph of a tree branch with green, needle-like leaves and small, yellowish-brown cones, identical to the one in the top slide. A small black box with the white text 'UGA5125062' is at the bottom right of this image. To the right of this image is the text 'Massive problem in PA and NC (also MA)'. Below this is the text 'Present in NH but currently not a massive problem'. At the bottom left of the block is a landscape photograph of a forested mountain range, identical to the one in the top slide. To the right of this image is the text 'Control by native (West Coast) and introduced *Laracobius*'.



Laricobius nigrinus (a.k.a. "Lari" beetle) feeds on HWA egg sacs on a stem.

Photo by: John D. Simmons

Hemlock Woolly Adelgid Infestation



Elongate hemlock scale (*Fiorinia externa*)



Circular hemlock scale (*Nuculaspis tsugae*)



Nymphs and adults of circular hemlock scale, *Nuculaspis tsugae*, on the lower surface of hemlock needles.

Hemlock tip blight (*Sirococcus tsugae*)



Hemlock needle rust (*Pucciniastrum* spp.)



Hemlock borer (*Melanophila fulvoguttata*)



a. Infestations by HEMLOCK BORER are often accompanied by sloughing bark and woodpecker activity.

www.forestpests.org

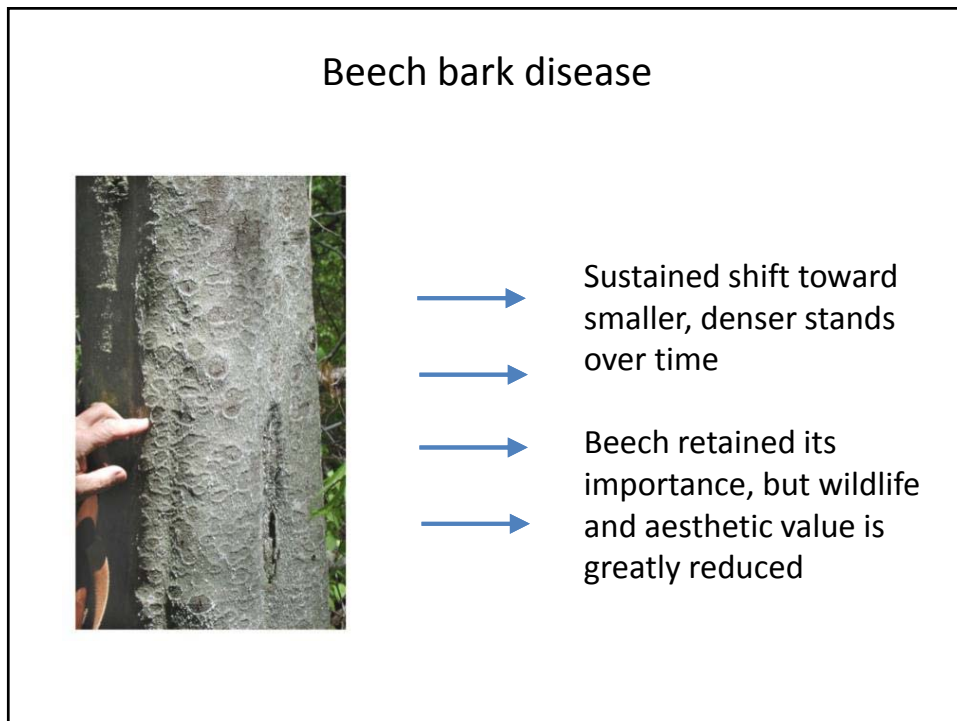
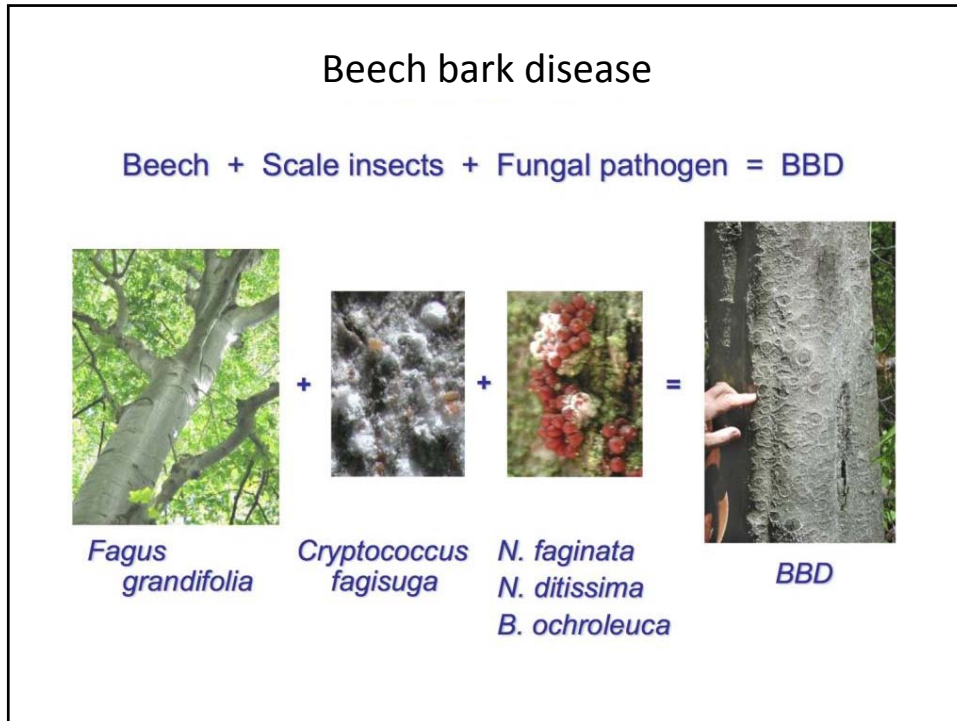


b. Larvae of the HEMLOCK BORER construct frass-filled galleries as they bore into the cambium.



c. HEMLOCK BORER adults are metallic black with six orange or yellowish spots on their elytra.

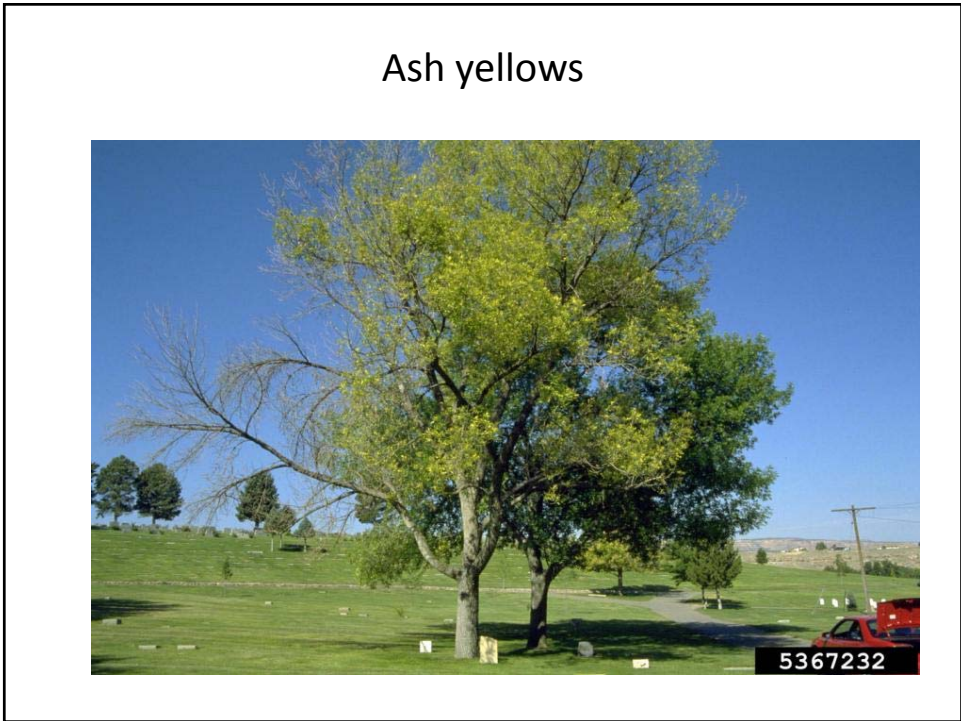




Target canker (*Neonectria ditissima*)



Ash yellows



Ash yellows



Causal agent: MLO
(mycoplasma-like
organism) -- a kind of
wall-less bacterium

Vectored by leaf hoppers
and other piercing/
sucking insects

Resembles Emerald ash
borer symptoms

Management: harvest
infected trees

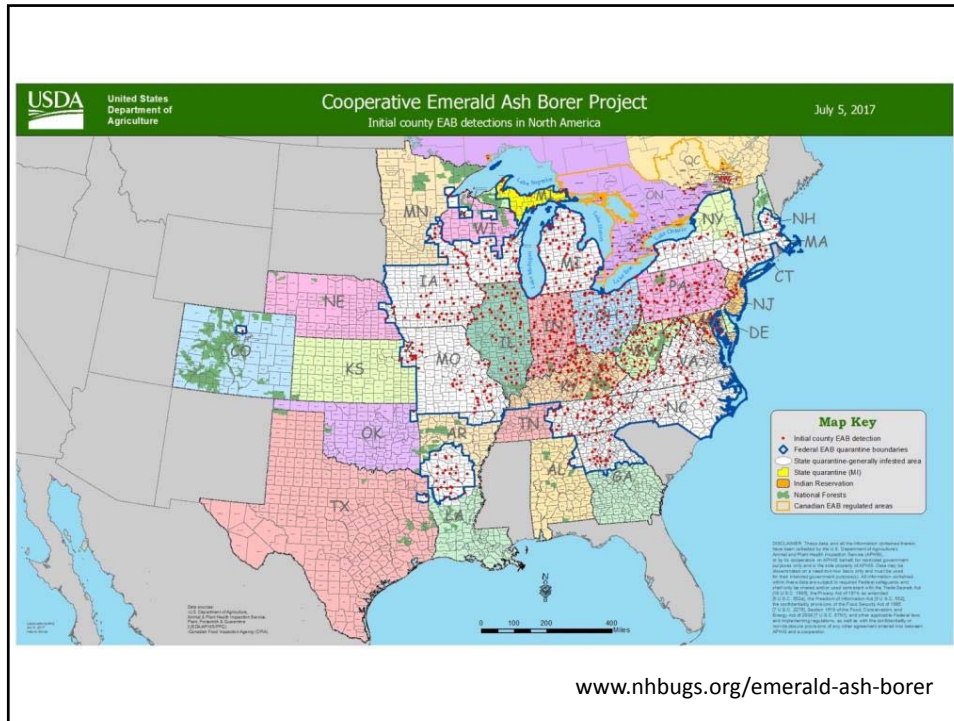
Emerald ash borer (EAB; *Agrilus planipennis*)



Vectored by leaf hoppers
and other piercing/sucking
insects

Resembles Emerald ash
borer

Management: harvest
affected trees



Signs of EAB

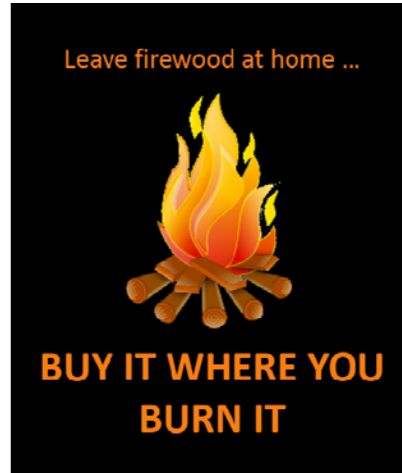
- Serpentine galleries
- D-shaped exit holes
- Woodpecker "blonding"

www.nhbugs.org/emerald-ash-borer



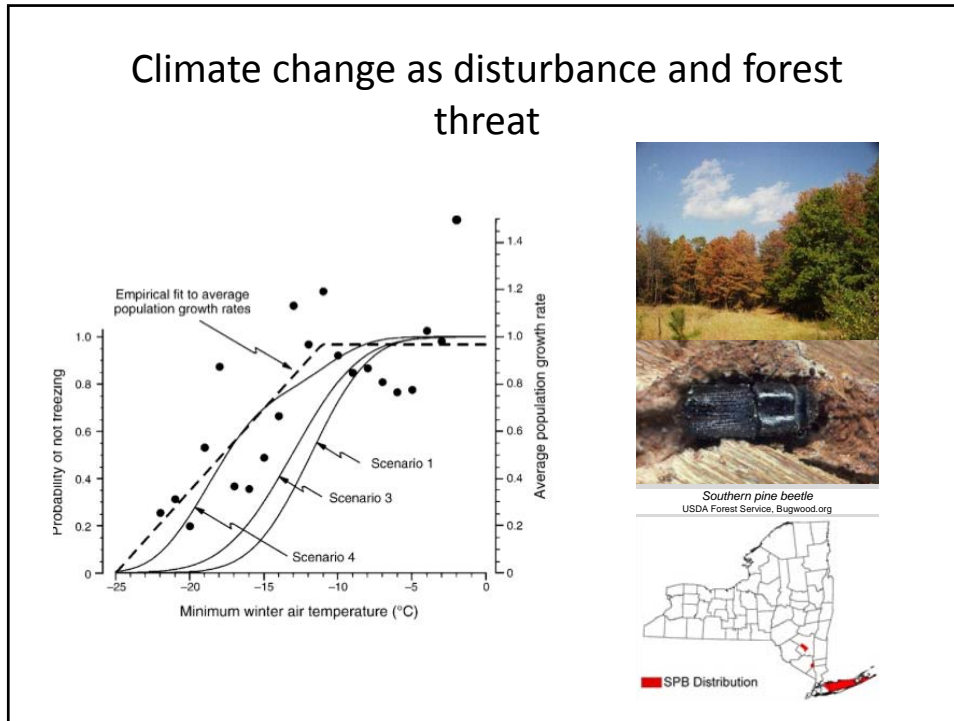
EAB management

- “Slow the spread”
- Biological control
- Tree breeding
- Systemic insecticides for high value trees



Outline: Forest health threats in pine-oak-hemlock

1. Invasive species and forest health
2. What's here, what's coming, and what to do about it
3. Disturbance and the changing climate

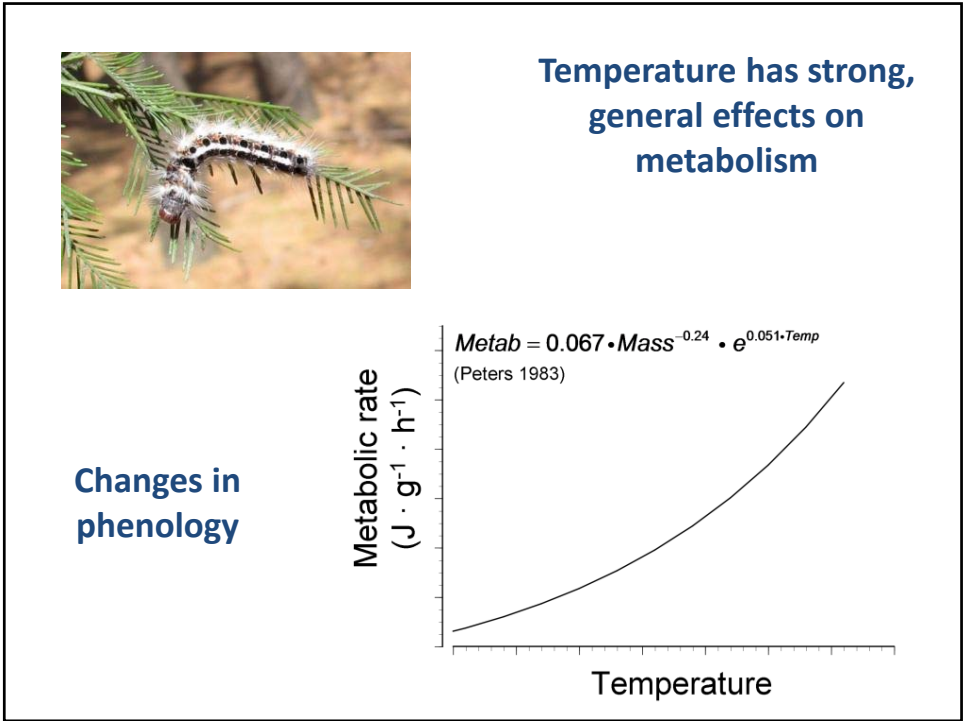


Climate change as disturbance

Southern pine beetle
USDA Forest Service, Bugwood.org

SPB Distribution

- Native species are moving (mostly north in New England)
- Increased developmental rates and # of generations
- Local maladaptation in forest trees can lead to stress-induced susceptibility
- Disruption of insect biocontrol systems



201

REVIEW / SYNTHÈSE

Responses of insect pests, pathogens, and invasive plant species to climate change in the forests of northeastern North America: What can we predict?¹

Jeffrey S. Dukes, Jennifer Pontius, David Orwig, Jeffrey R. Garnas, Vikki L. Rodgers, Nicholas Brazeel, Barry Cooke, Kathleen A. Theoharides, Erik E. Stange, Robin Harrington, Joan Ehrenfeld, Jessica Gurevitch, Manuel Lerdau, Kristina Stinson, Robert Wick, and Matthew Ayres

Conclusions



Photo#140419
 Copyright © 2007 Peter Cristofani
 Introduced Pine Sawfly larva - *Diprion similis*

Pine-oak-hemlock forests in New England are generally healthy, but serious threats loom

Biological invasion and climate change are serious threats

Vigilance is key!