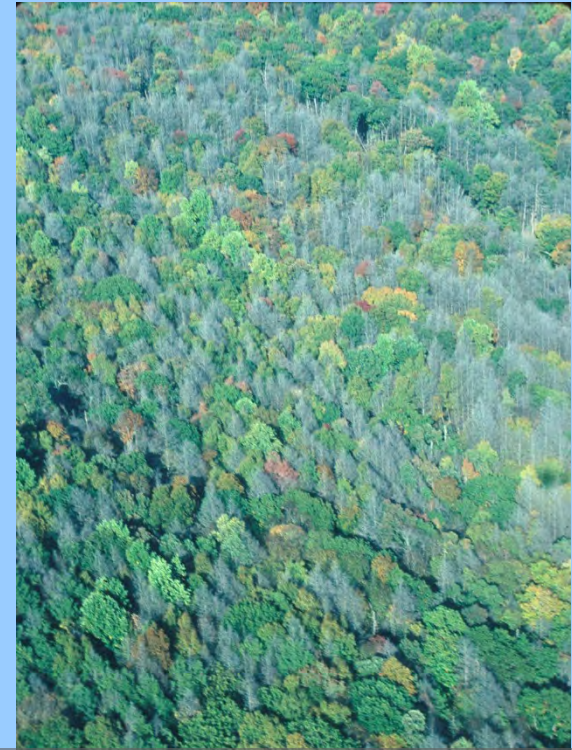




Hemlock Woolly Adelgid and its Impacts on Forest Ecosystems

David A. Orwig

Imported forest pests are the most pressing & under-appreciated forest health issue in US today



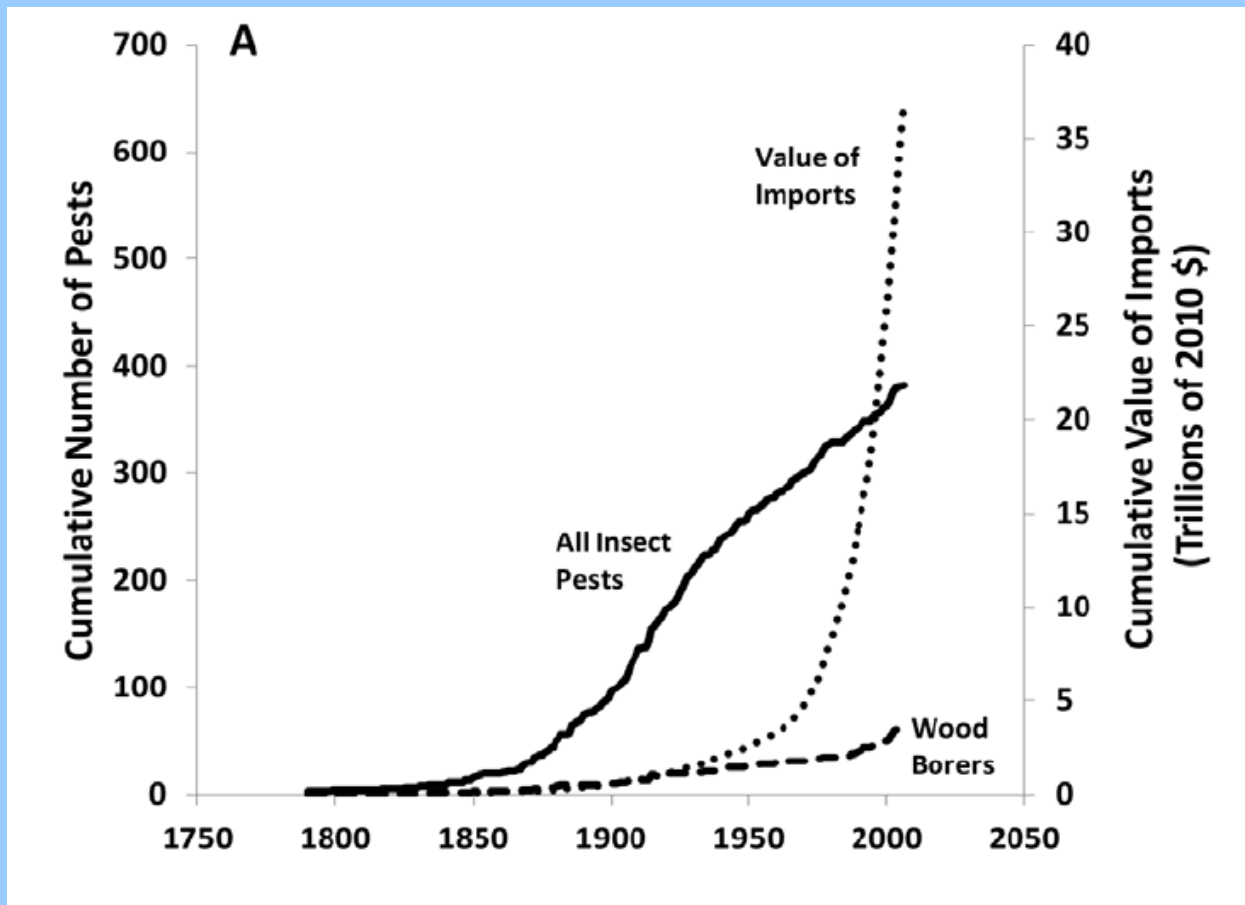
The only threat that can decimate species in just decades.
Cost billions annually

Invasive pests and pathogens

Pre-1850 a dozen or so insects damaging trees

Post 1850: > 400 – virtually all insect orders

Important component of global change - > \$ 4 Billion annually



2.5/yr

Damaging one every 2-3 years

Pests and pathogens arrive in a variety of ways:

- 1) nursery related materials (plants, seeds)
- 2) pallets, crates, packing material
- 3) Lumber

Trade volume leads to new introductions



Pathways



90% of recent wood-boring insects arrived in the US via **solid wood packaging**

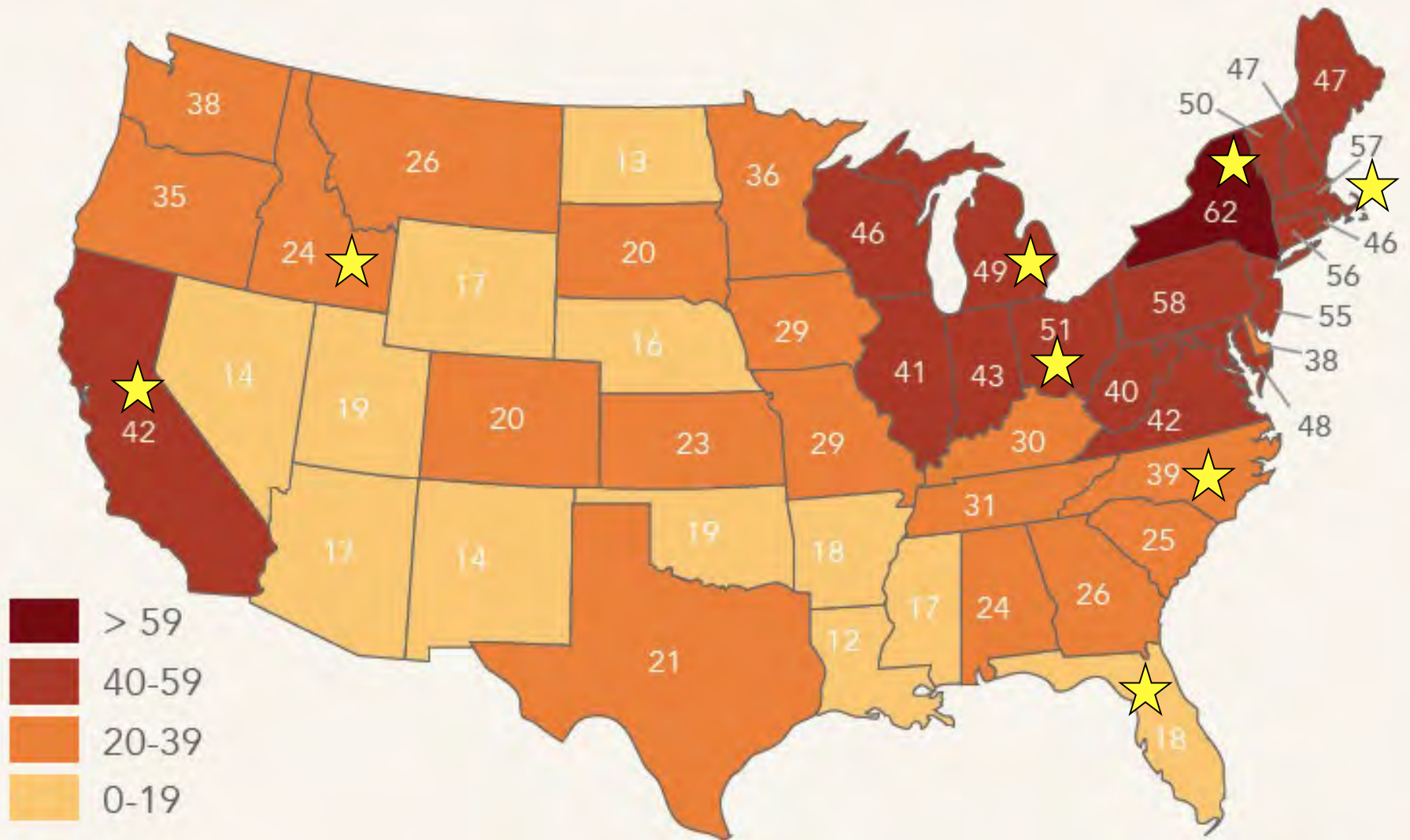
- (also spools, dunnage)
- *ALB, EAB*



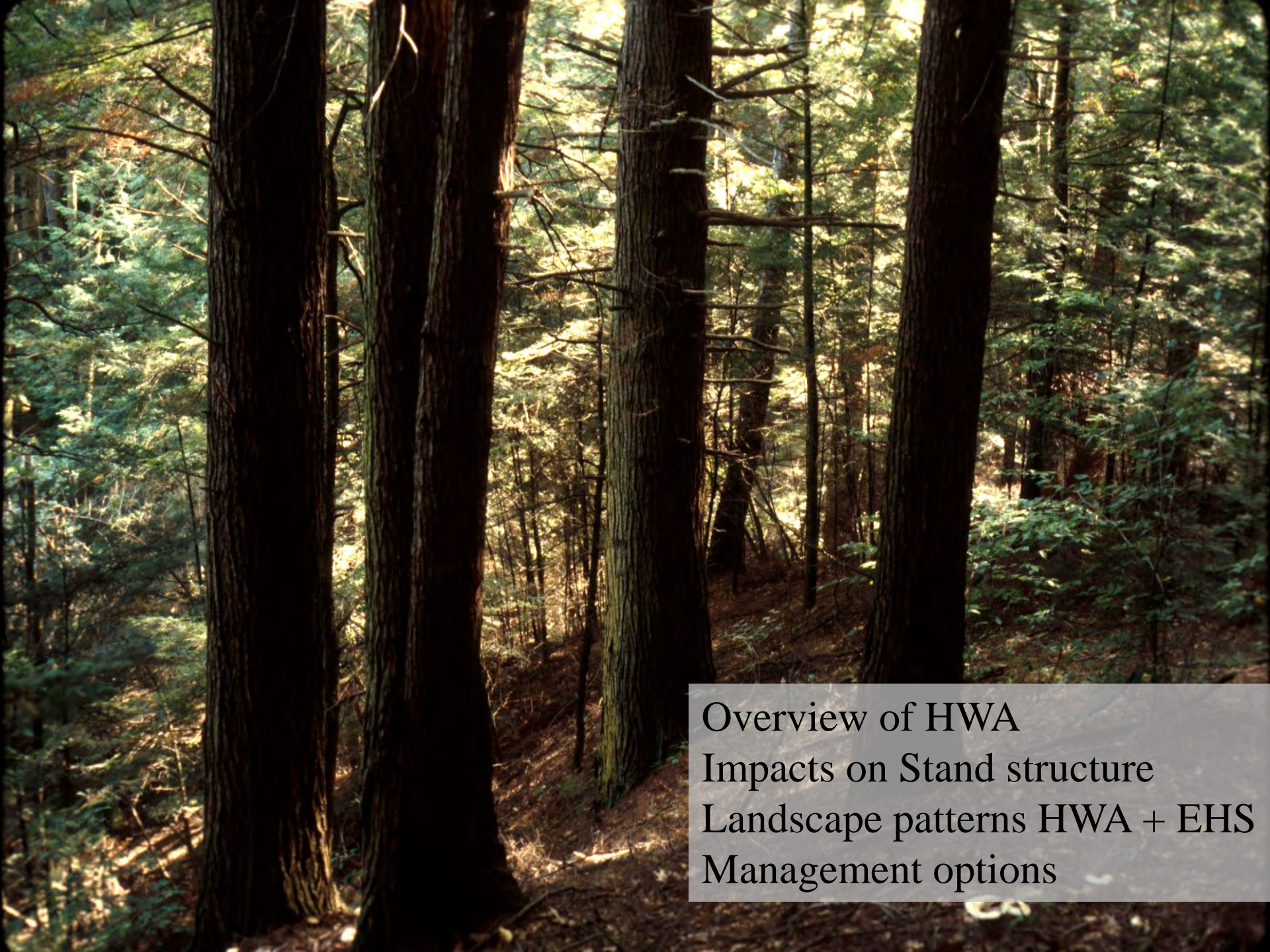
70% of all damaging forest pests arrived in the US via **imported plants**

Now > 3 billion/yr
Chestnut blight, BBD, HWA

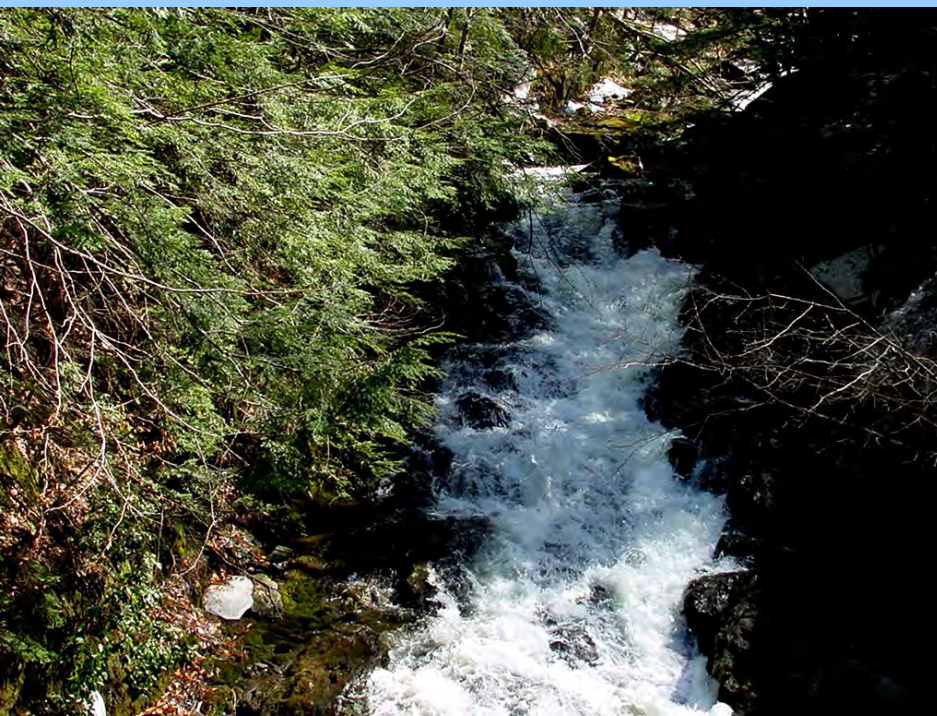
All states have many imported forest pests



Why do some states have such high numbers?



Overview of HWA
Impacts on Stand structure
Landscape patterns HWA + EHS
Management options



Hemlock is important for:

Old-growth forests

CWD to upland and streams

Moderation of stream temps
important for trout



Black-throated green warbler



Hemlock regeneration is limited by deer browsing.

Ward et al. 2004



Blackburnian warbler

Hemlock provides valuable habitat for a variety of wildlife species





USDA Forest Service

Hemlock woolly adelgid (*Adelges tsugae*)

2 generations /year

Parthenogenetic

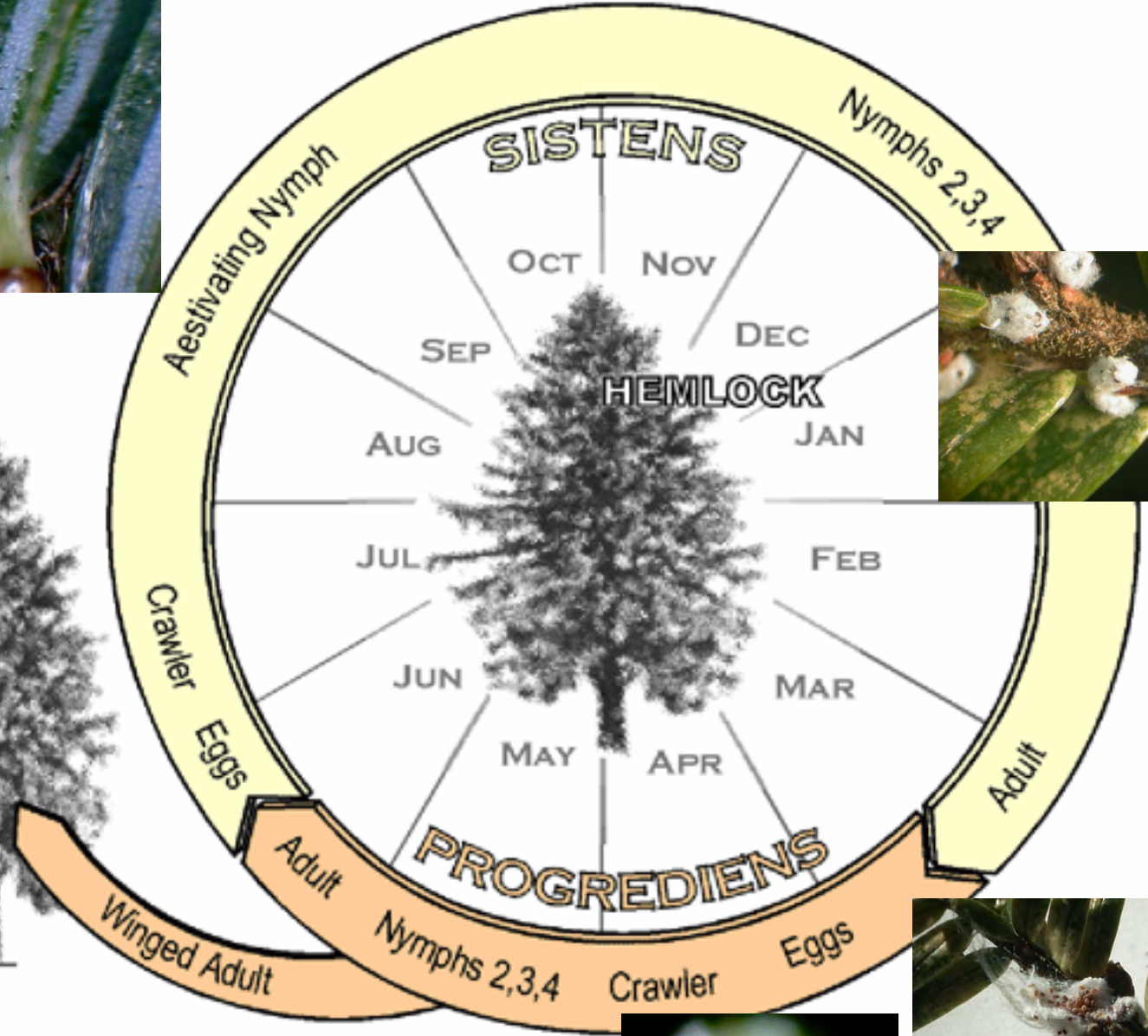
rapid dispersal

feed and kill all sizes and ages

hemlock resistance?

No effective native predators

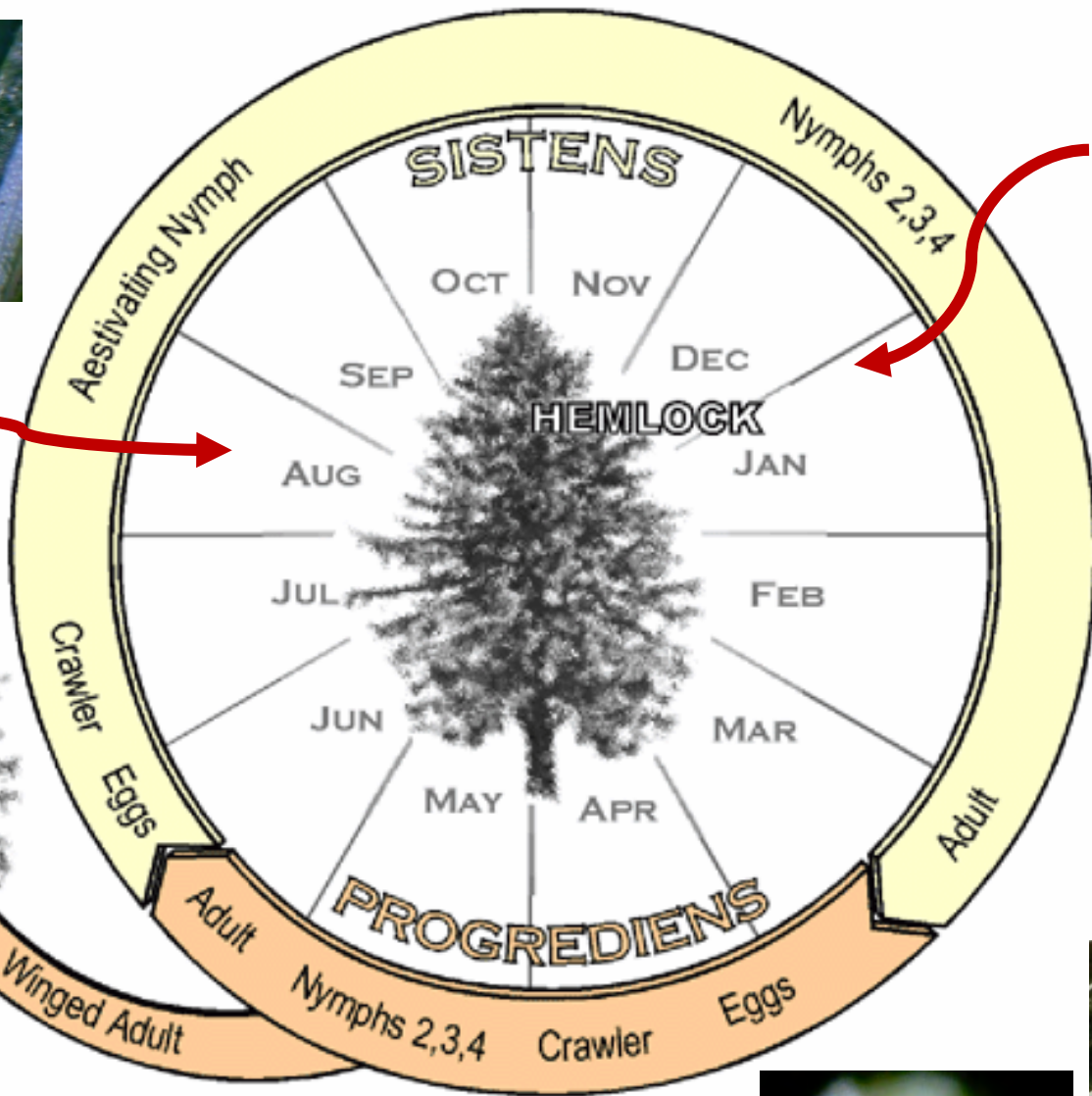




HWA life cycle in E. North America (USDA)



Still seeing
Adults
2019



Recent work
Shows egg
Laying as early
As Dec/Jan!!



HWA life cycle in E. North America (USDA)

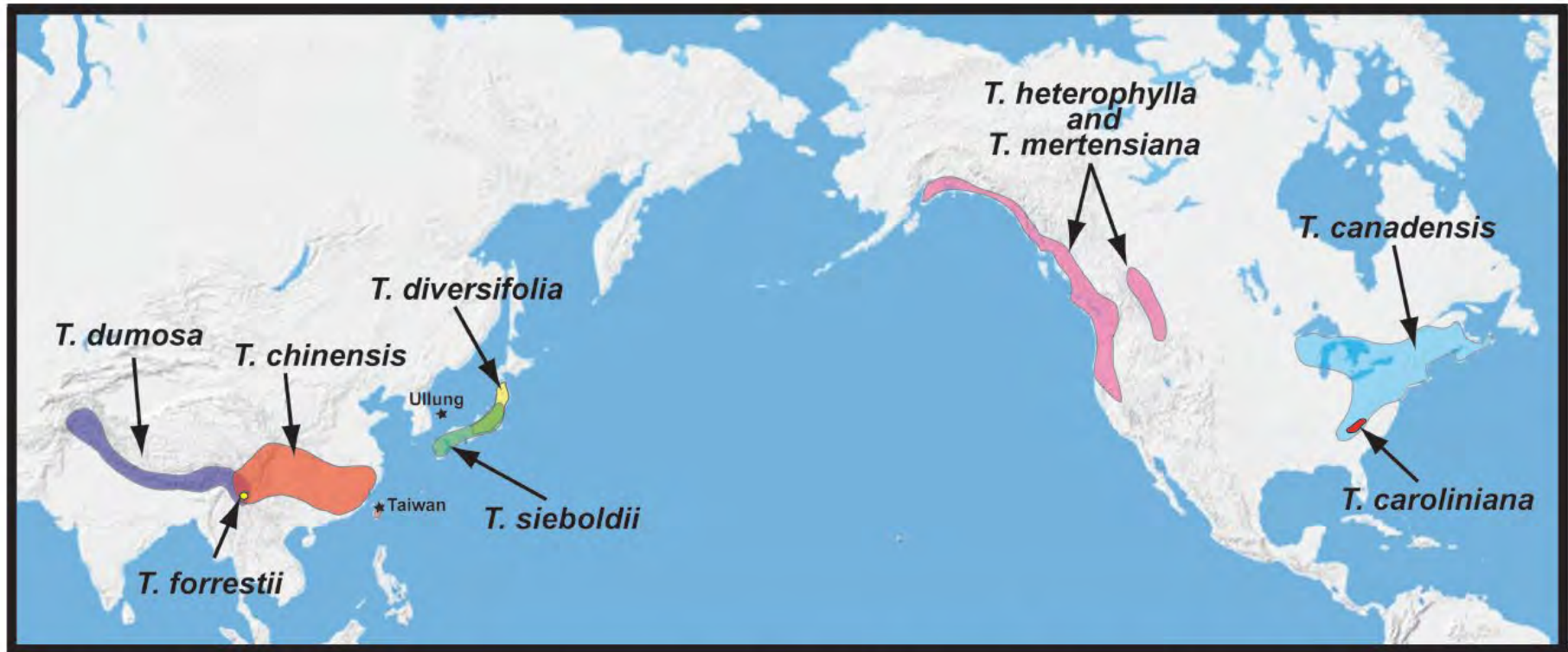
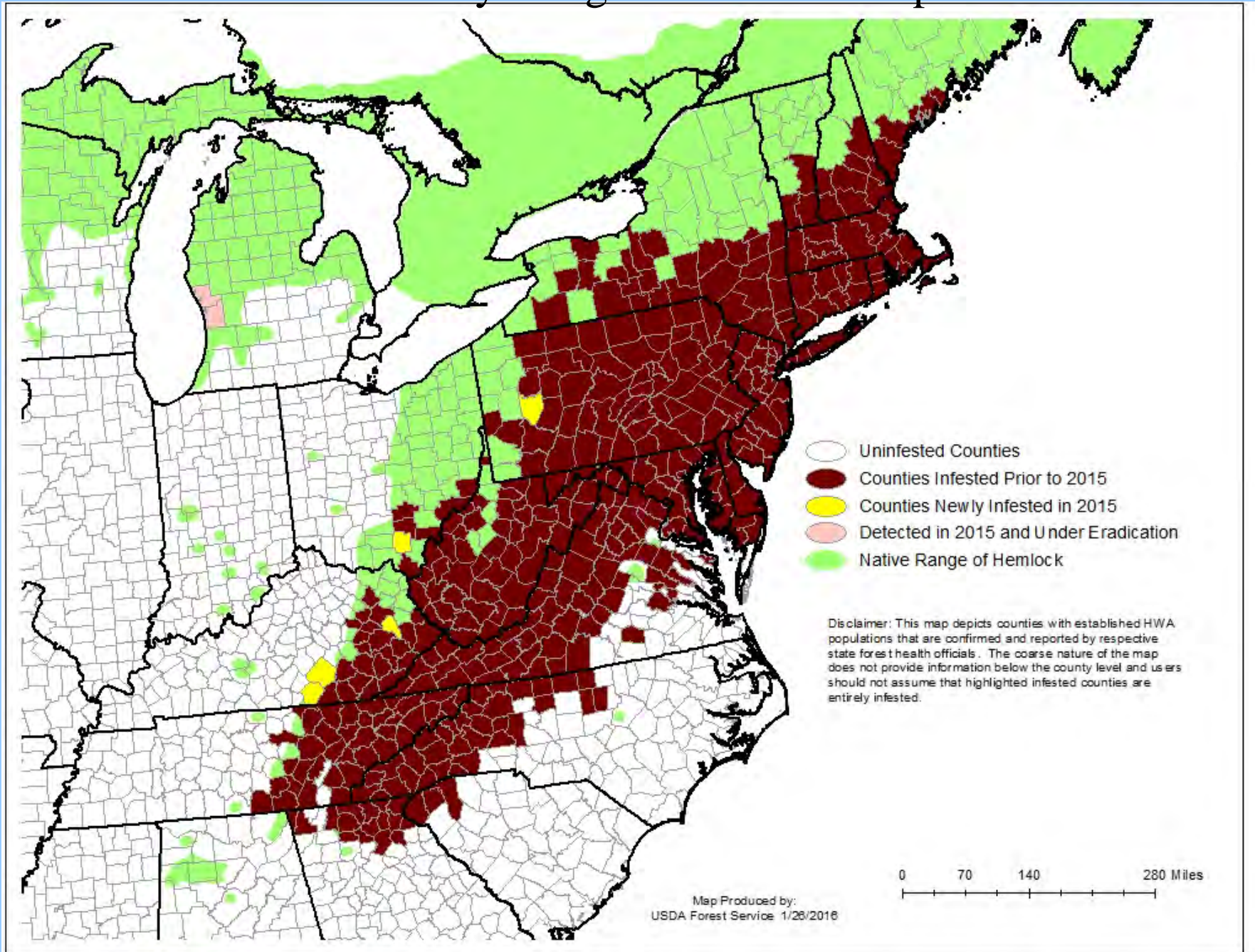


FIG. 1. Map showing the ranges of extant *Tsuga* species based on Little (1971), Hirokawa (1972; 1976), and Farjon (1990). The distributions of *T. mertensiana* and *T. heterophylla* are shown as sympatric for graphical simplicity although *T. mertensiana* generally occurs at higher elevations and in some regions such as the Sierra Nevada where *T. heterophylla* is not present. The islands of Ullung and Taiwan are indicated with stars.

Nathan Havill, Yale University

***Adelges tsugae* documented on all 9 hemlocks worldwide**
Recent genetics: from So. and low elevations in Japan
Serious pest only in Eastern U.S.

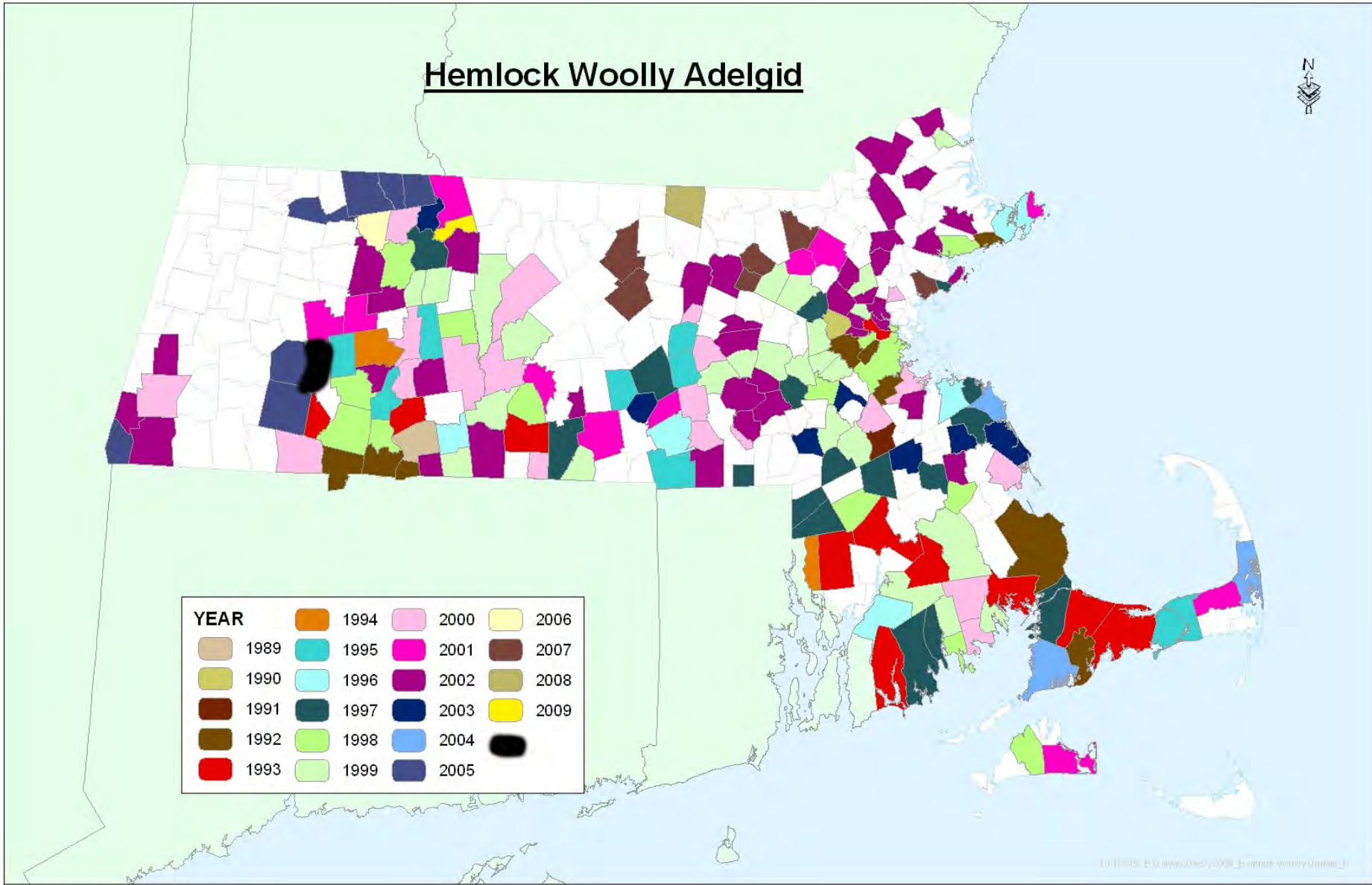
Hemlock woolly adelgid infestation map 2016



Hemlock Woolly Adelgid



YEAR			
1989	1994	2000	2006
1990	1995	2001	2007
1991	1996	2002	2008
1992	1997	2003	2009
1993	1998	2004	
	1999	2005	



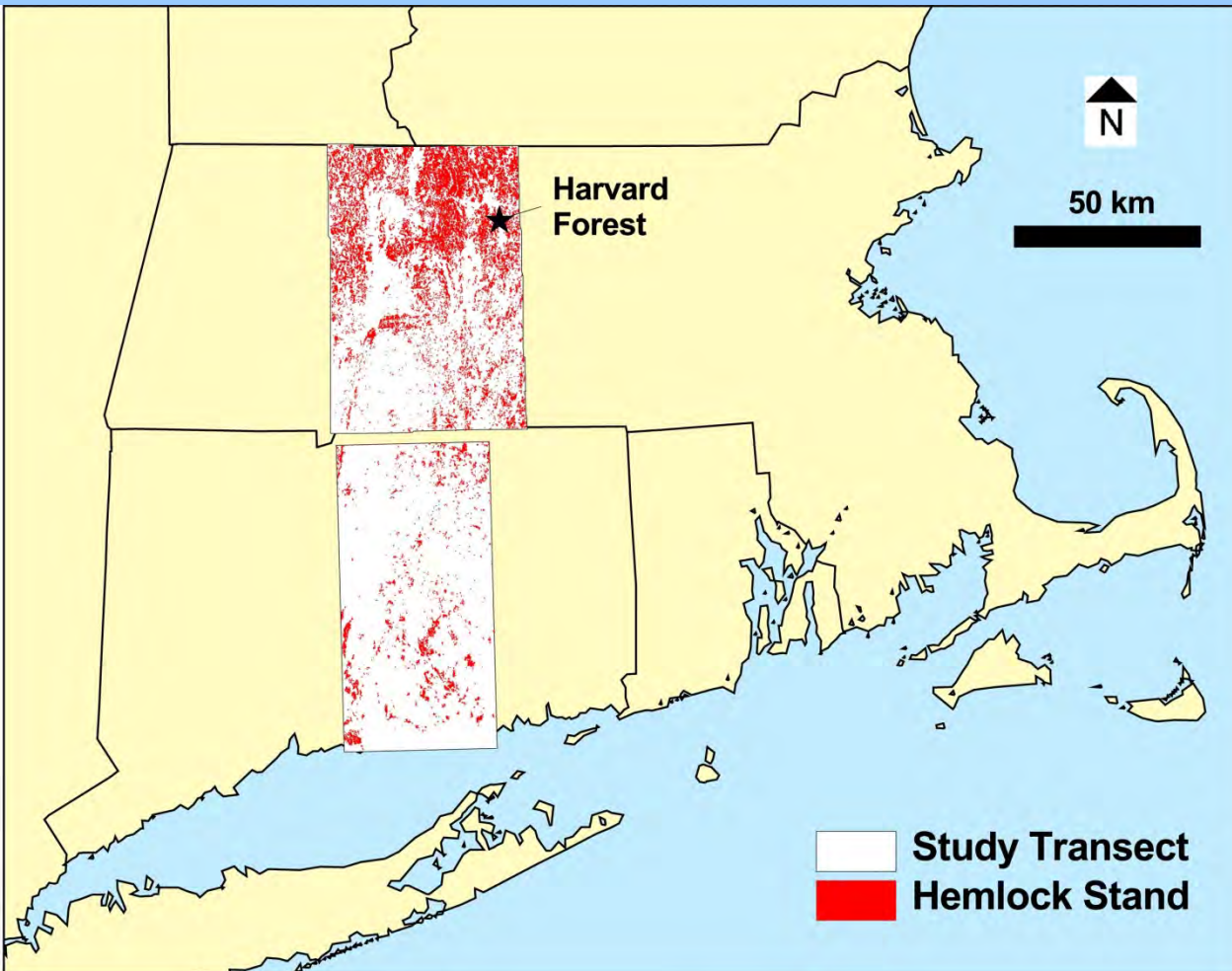
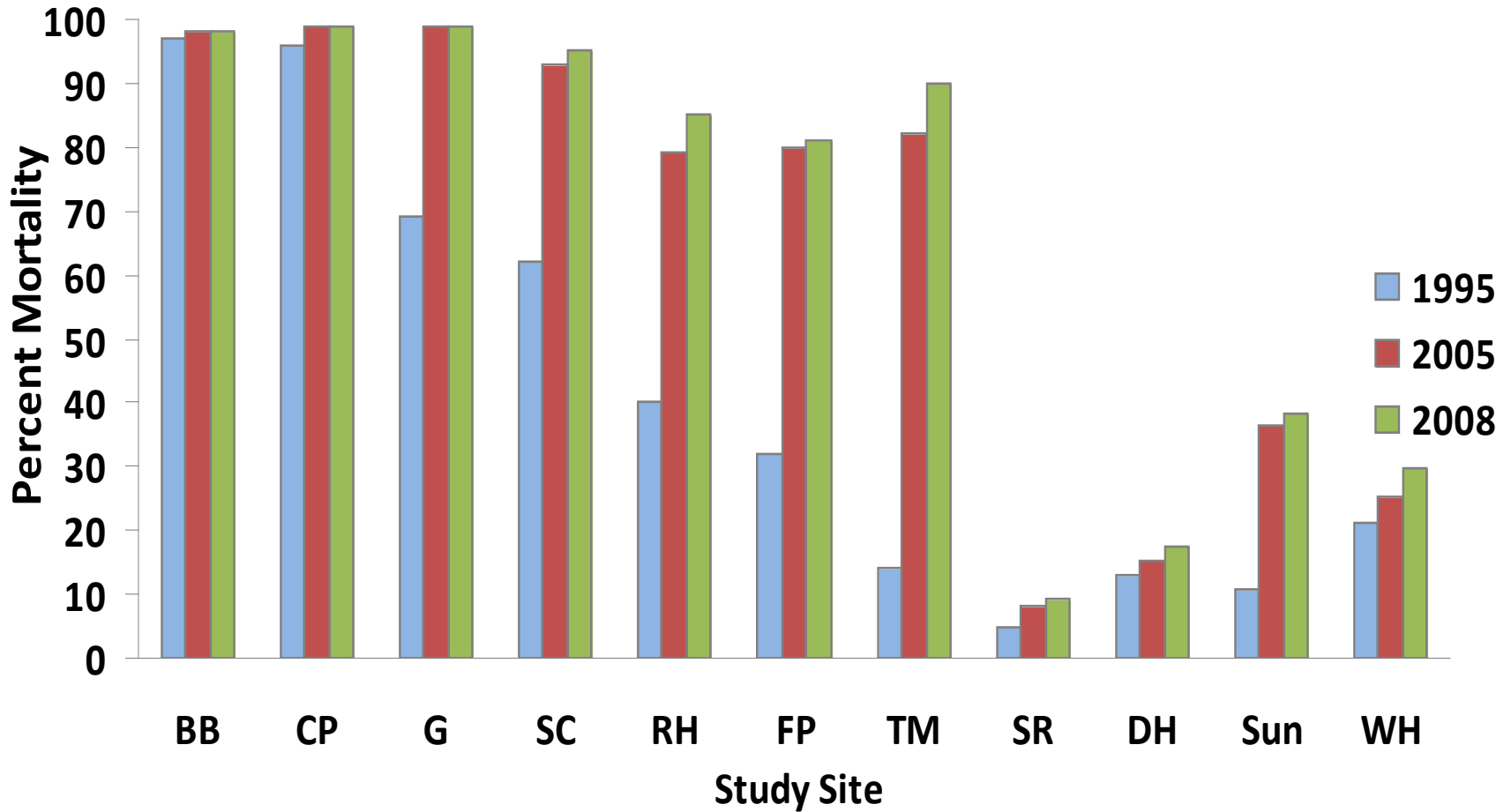


Figure 1. HWA space-for-time study area, representing 7500 km². Hemlock represents >86,000 ha or 21% of the mapped area in MA (up to 36% in northern MA), and 16,500 ha or ~5% of the mapped area of CT.

Harvard Forest HWA studies include:

- 1) Stand and community analyses
- 2) Landscape investigations of hemlock structure and HWA infestation patterns
- 3) Ecosystem analyses of HWA infestations including n cycling, decomp, throughfall chemistry
- 4) Comparisons of HWA vs. Hemlock Logging
- 5) Wildlife studies
- 6) Hydrological Investigations
- 7) HWA dispersal

Hemlock Overstory Mortality



Overstory mortality trends, high in many, but not all stands



Crowns continue to deteriorate, with no sign of recovery



Continuous feeding leads to progressive needle loss, interior branches



However, at some sites, decline is slower (cold temps.?)
Variability in winter temps important (esp. cold following warm)



**Rapid birch establishment
Occurs with canopy thinning**

Invasives and ferns can also increase tremendously





White pine establishing
In dry site in CT

Trees remain standing for 5-8 years; branches, then tops fall off; then boles.

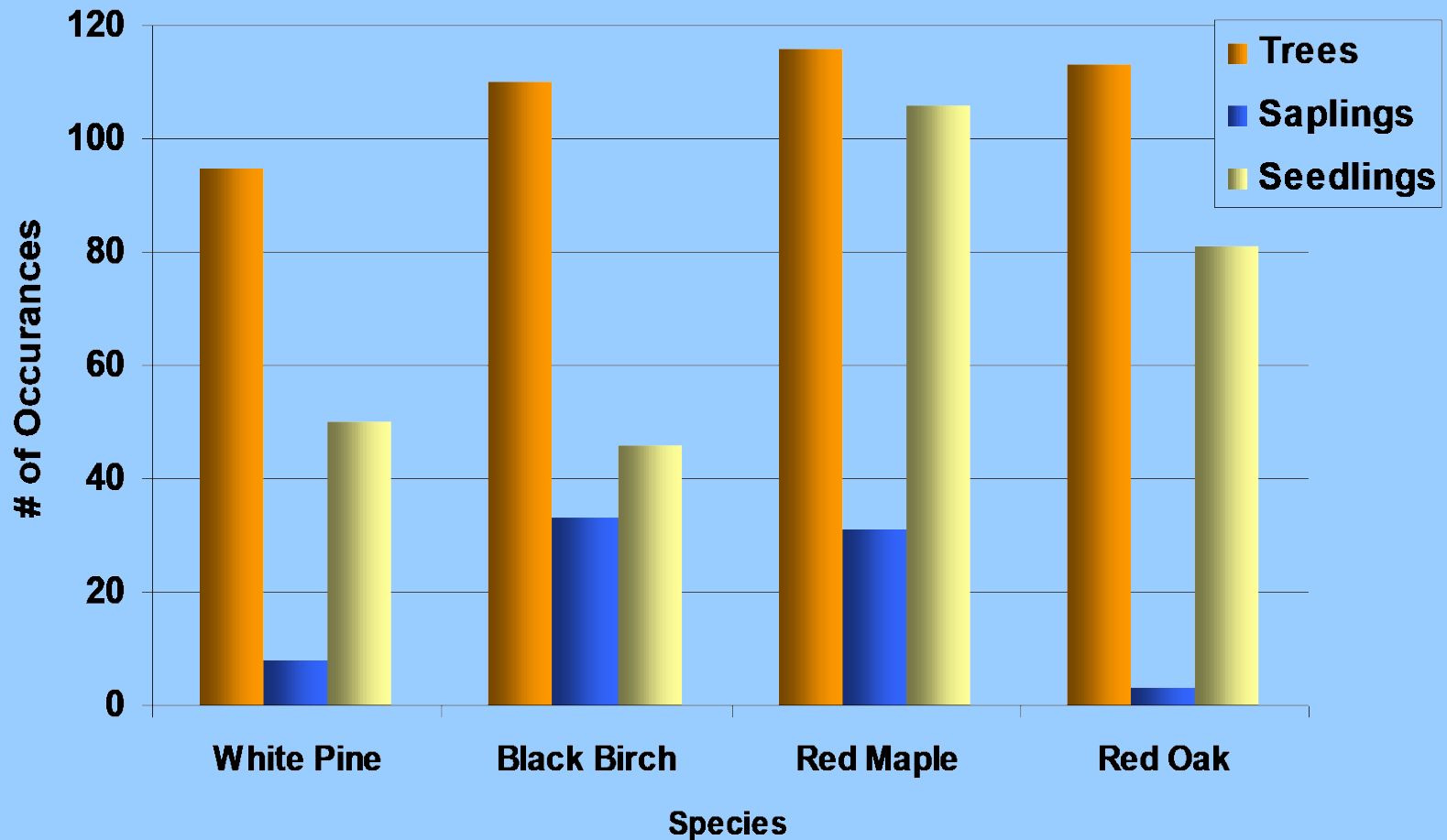


Birch forms the new forest



What will replace hemlock in Massachusetts?

Secondary Species # of Occurances in 123 Hemlock Stands



LANDSCAPE PATTERNS

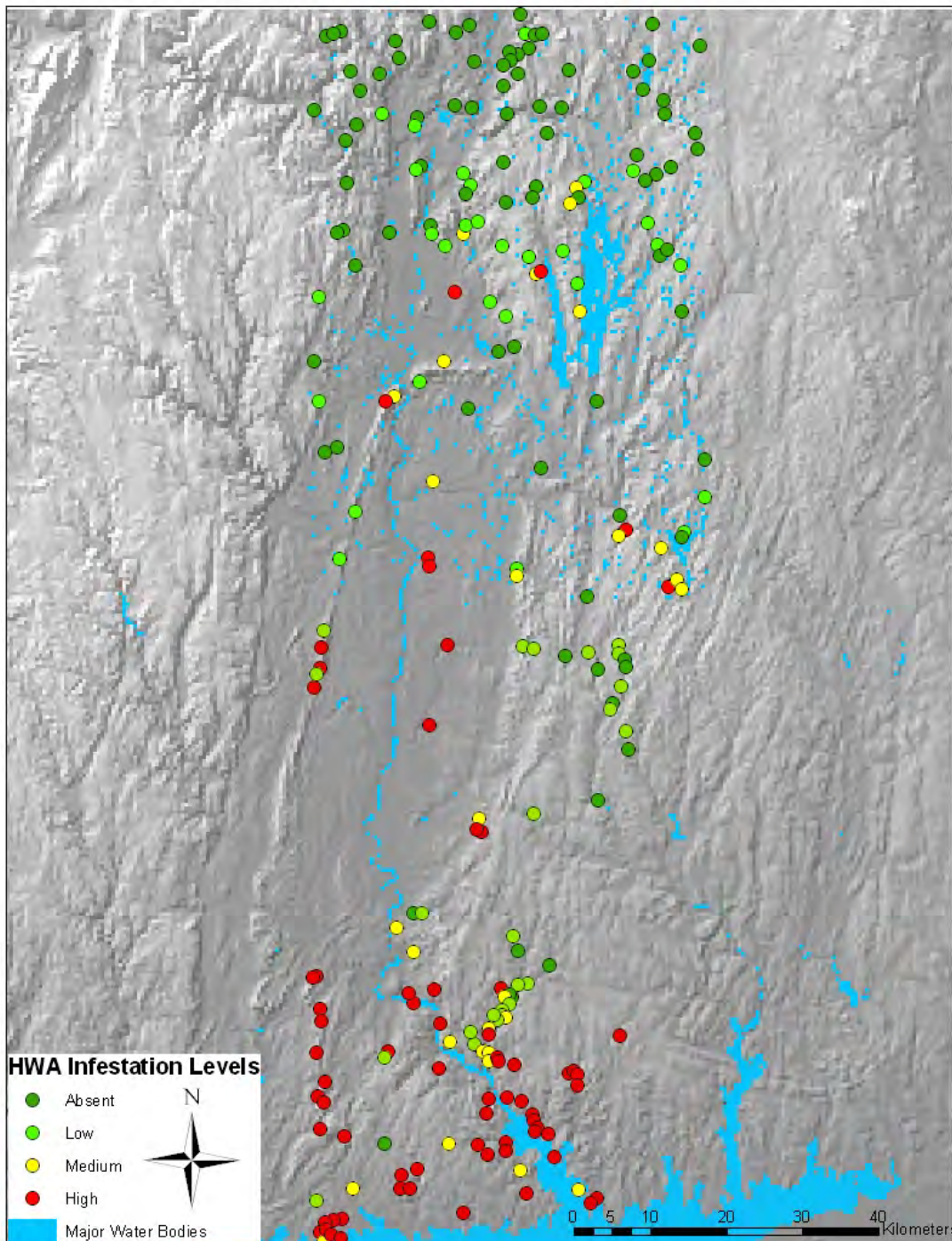
CT: 114 stands

MA: 123 stands

HWA found within a few
km of Vermont (2004)!
[now 1/3 way up VT & NH]

Latitudinal pattern present
But damage not as rapid

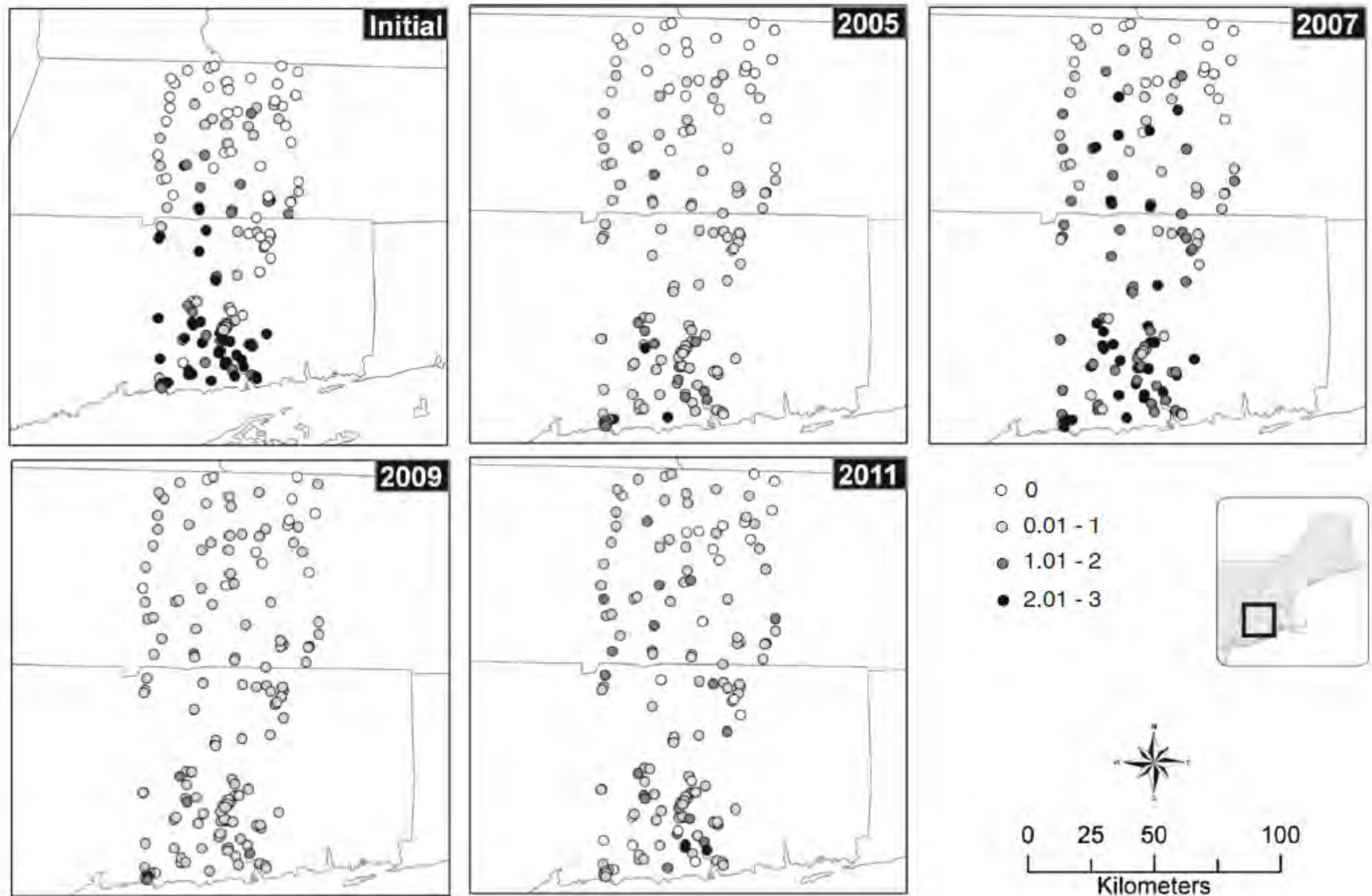
Only 2 stands > 50%
Overstory mortality in MA



HWA change in abundance over time

668

S. Gómez et al. 2015



Northern Massachusetts Sites with major infestation- 2013



Along Swift River, Petersham MA



Bernardston, MA

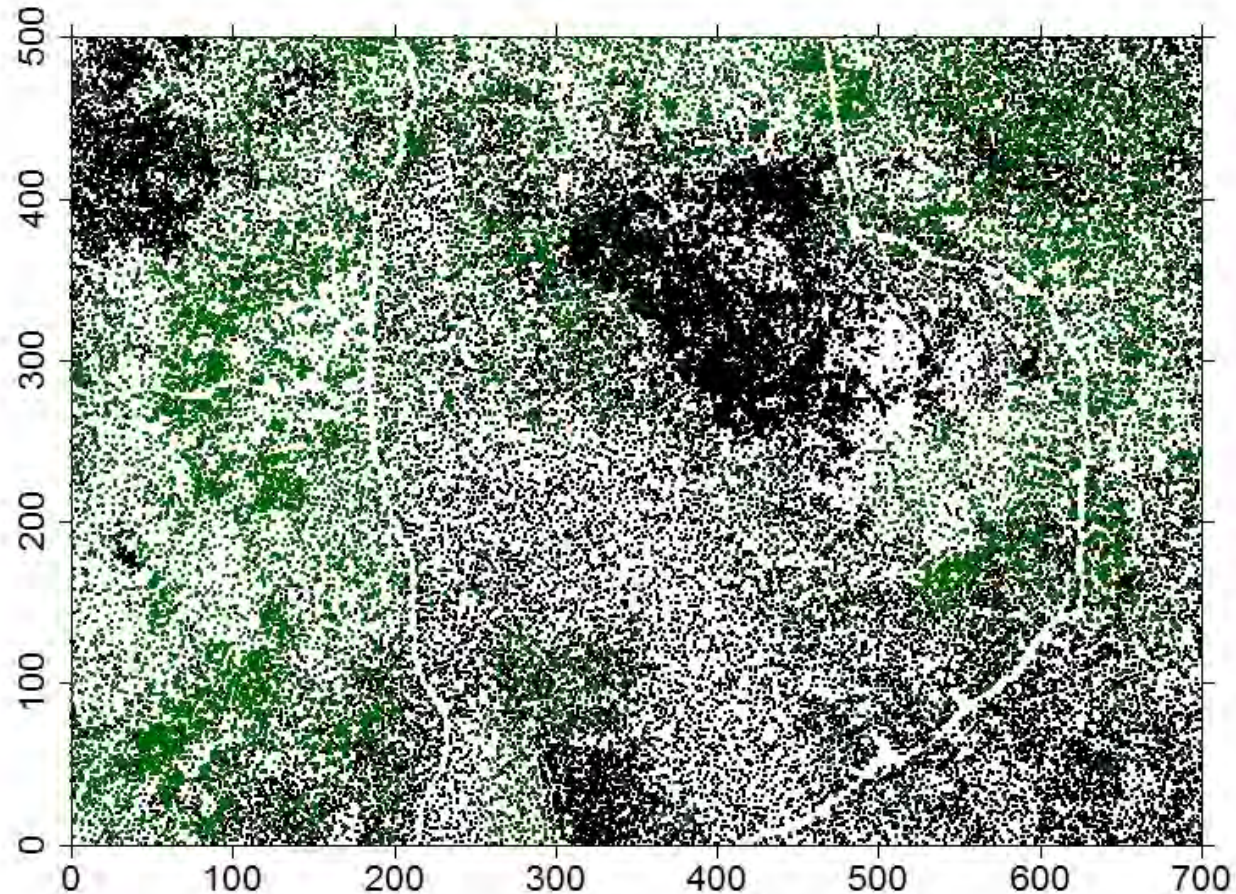
Harvard Forest 2016

Overstory and understory thinning

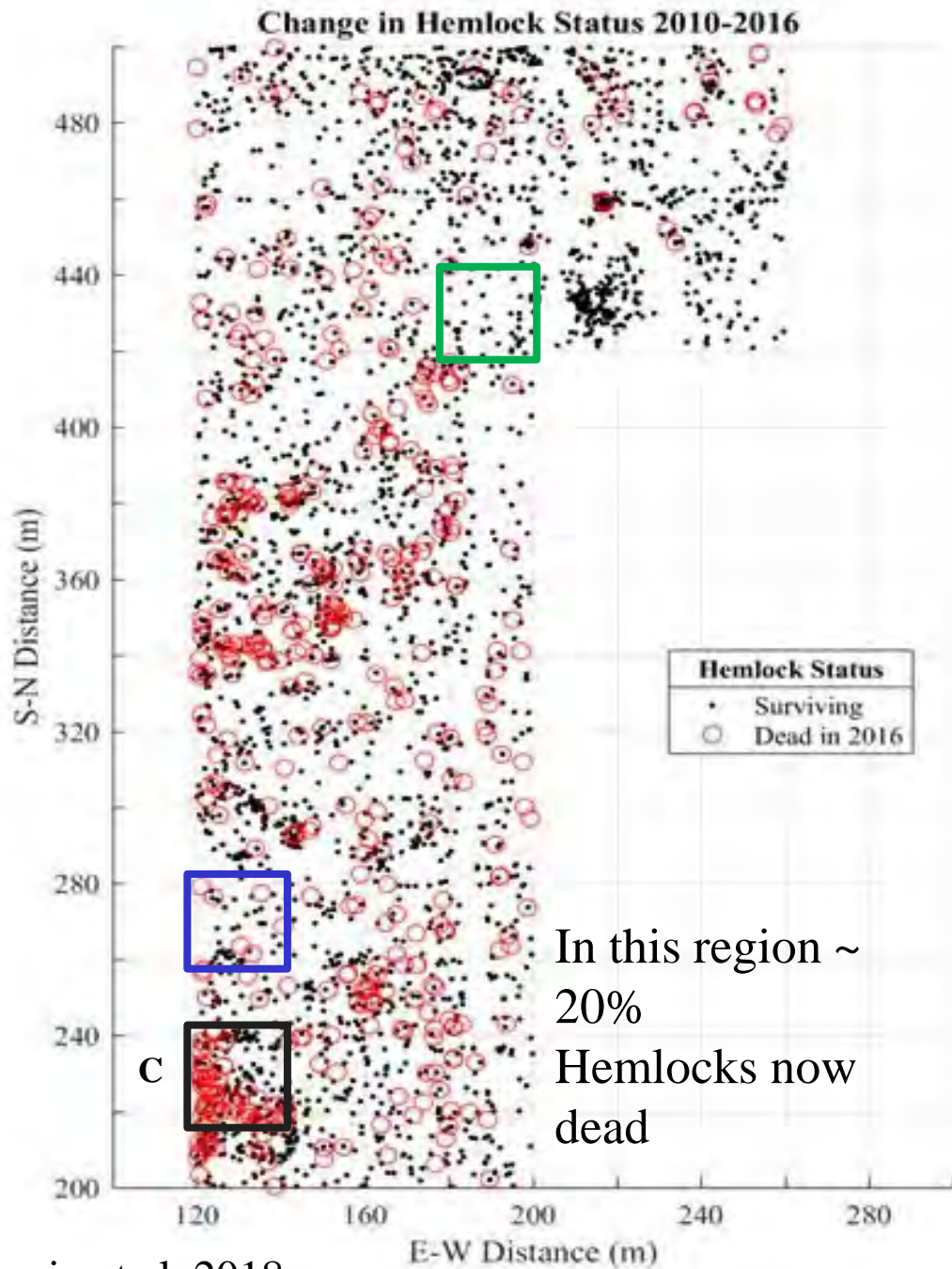
7 years after initial infestation



Distribution of 116,226 stems (live and dead > 1cm dbh)
Eastern hemlock (green) and all other species



Resampling this plot has begun this summer



2018-2019: widespread decline in HWA populations: still investigating

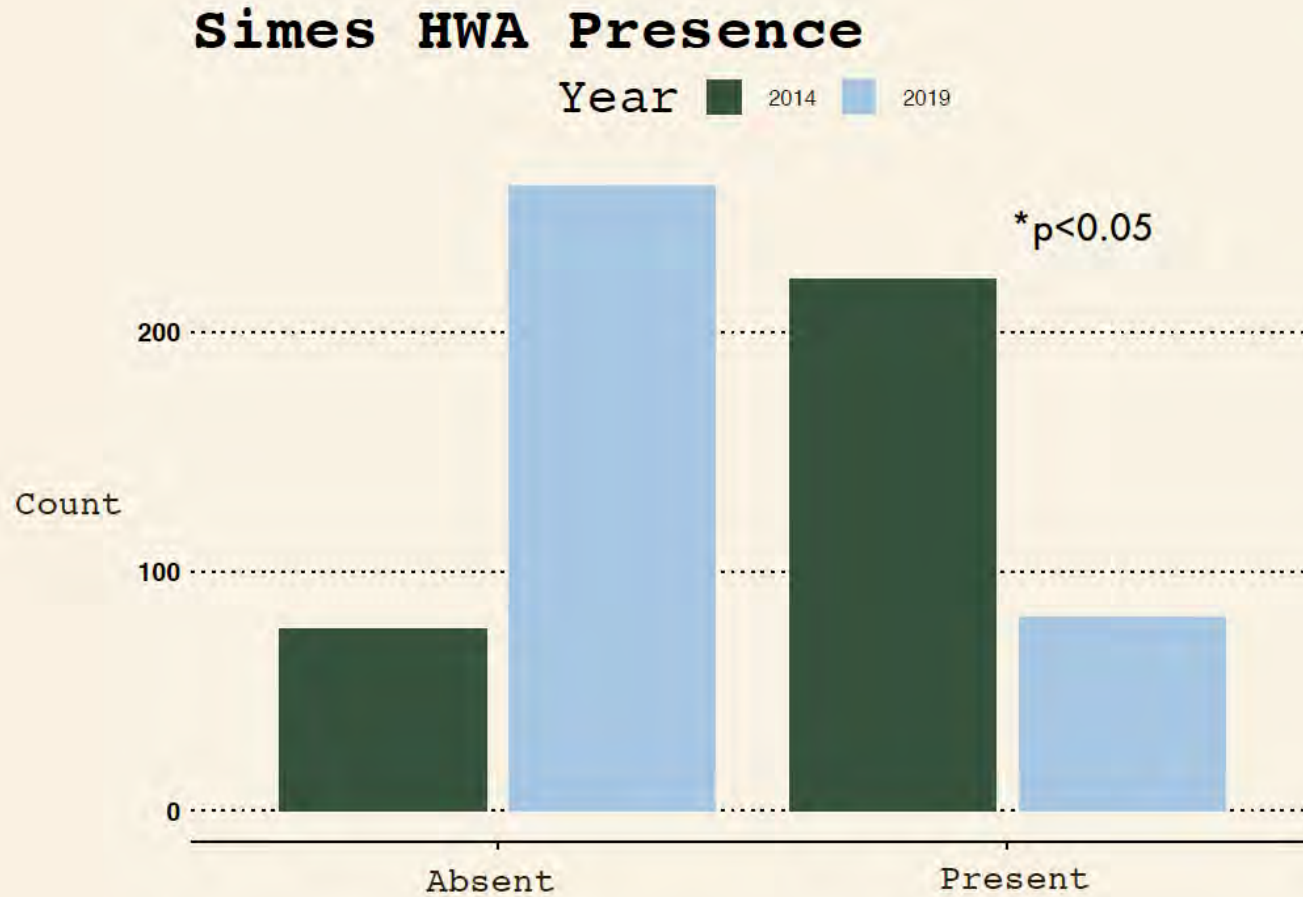




Photo: David Foster

**So, what can
be done?**



Imidacloprid (Merit) pesticide of choice:

Tree I.V.

Kioritz soil injection

Soil drench

Stem injection-important near streams

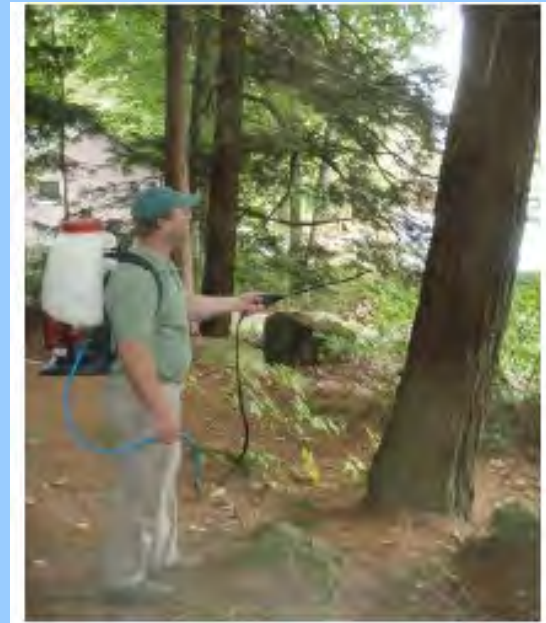
CoreTect time-release tablet

often provides 2 to 4+ years protection

Soil application widely used



There is also
a time-release
tablet



Safari (Dinotefuran) Fast-acting
systemic, spring applications
Effective, not persistent, often used
first, then Merit
There will be other casualties!

Biological Controls

From Japan, over 1.5 million have been Released in over 100 sites in 15 Eastern sites including MA



Carol Cheah

Sasajiscymnus tsugae

Native to British Columbia, over 7000 Adults have been released at 19 sites In 8 eastern states-recovery 2 years later



USDA

Laricobius nigrinus

Others being evaluated:
Scymnus sinuanodulus
Tetrableps galchanoides
Pathogenic fungi
Uncertain success, impact

So, how can we incorporate the study of invasive species into a school curriculum?

what can students do to add to this body of work?



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© Beth Reynolds/basecampphoto.com



Student research can provide:

year by year assessments of HWA densities

year to year branch growth, related to HWA

important data at the northern extent of HWA range

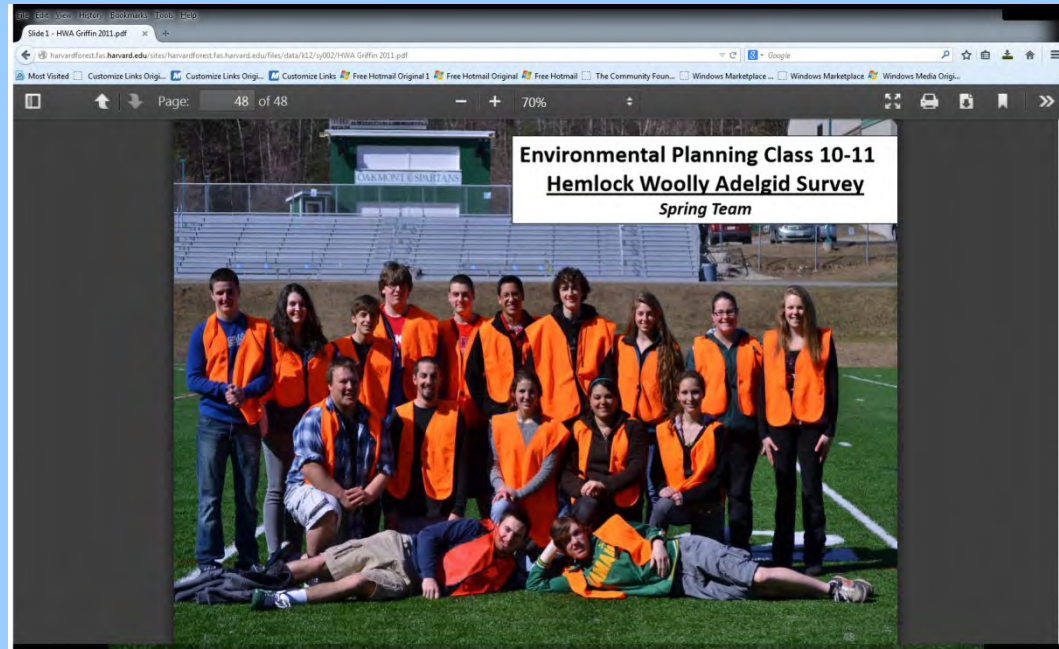
new discoveries of HWA at their homes, schools, towns



Katherine Bennett's 5th Grade class



Measuring snow depth



A co-occurring pest on the rise! Students can also contribute here

**Elongate Hemlock Scale
(EHS; *Fiorinia externa*)**

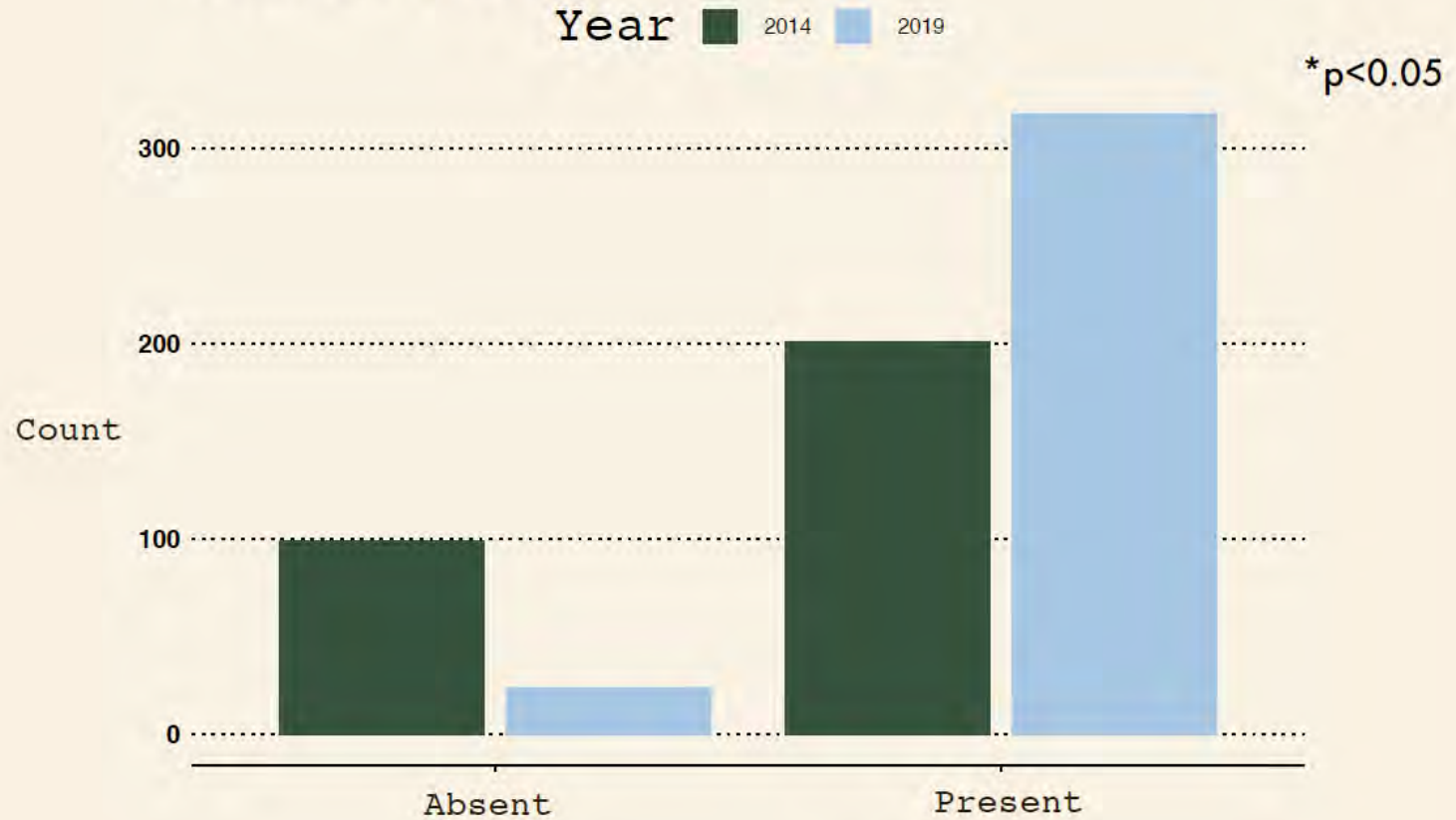
**Also from Japan, introduced in
NYC in 1908**

**Now located in 14 eastern states,
range overlaps with HWA**

**Often co-occur with HWA on same
tree: uncertain consequences**

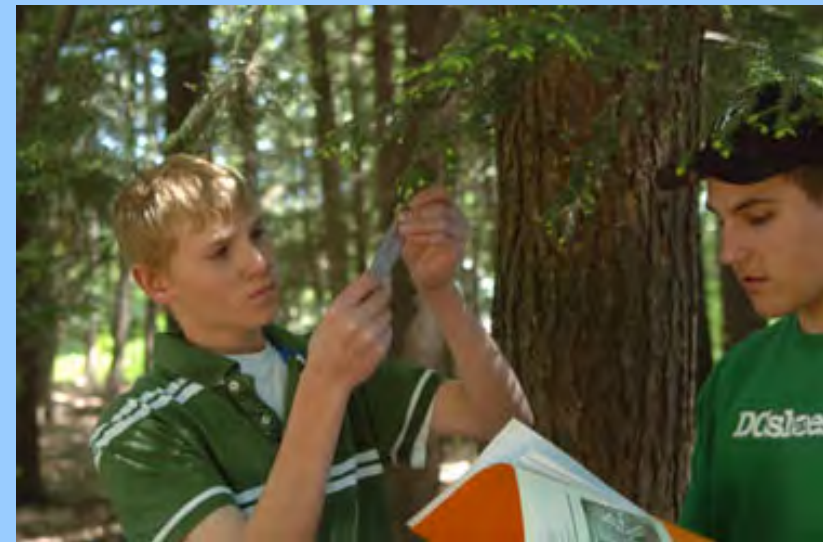


Simes Scale Presence



Woolly Bully Protocol revolves around 2 measurements:

1) Measurement of new branch growth in early Autumn



Core measurements:

Spring counts of HWA egg sacs
along outer 10 cm

HF provides data sheets, protocols

