The role of **biological controls** and **geospatial data** in the long-term protection of Hemlock ecosystems

UNG's Ecological Protection Lab

A program of the

UNG Environmental Leadership Center

History of the Ecological Protection Lab (formerly beetle lab)

Professor Emeritus

University of North Georgia

- Lab established in 2008 by Dr. Robert Fuller
- Realized we needed to respond to the rapid decline of the eastern hemlock (*Tsuga Canadensis*) due to HWA infestation.
- What are our options?
  - Chemical treatment
  - Biological controls
  - Genetic resistance

UNG's Ecological Protection Lab – ie. "BUG HOUSE"

- **Biological control agents** of lab reared predatory beetles have been released at over 100 sites on the Chattahoochee-Oconee National Forest in north Georgia.

To date UNG has released 194,531 of 392,688 beetle releases in GA (~ 50%)

Biological Control Beetle Rearing Partners

Young Harris College EST. 1886

University of Georgia 1785

UNG University of North Georgia

These three labs have focused on rearing as many beetles as possible.

Three College and University Rearing Labs

FUNDERS & Community Partners

Georgia Forestry Commission

GFC has provided resources to

- track HWA spread
- Release beetles
- Collect food resources for reared beetles

Lumpkin Coalition

Forest Service U.S. Department of Agriculture

State of Georgia 1776

Save Georgia's Hemlocks – Educate • Enable • Engage

Why use Biological Control?

The threat to eastern Hemlocks is a story about **co-evolution** of species.

Pests and Hosts
Predator and Prey

Develop complex traits and defenses, and interdependent relationships with other species over millions of years.

HWA **lack predators** to limit its population growth.
Hemlock's **lack natural chemical defenses** to HWA.

OPTIONS

1. **Chemical defenses** - deployed through our application of pesticides. **High costs, non-target species**
2. **Chemical defenses** - breeding or biotechnology. **Loss of genetic diversity, decades if not longer process**
3. **Predator controls** – establish new ecological equilibrium. **Predators may not be as adaptable. May not be enough of predators to suppress tree mortality**

What is Biological Control?

Biological Control is
"the utilization of natural enemies to reduce the damage caused by noxious organisms to tolerable levels."[1]

In natural ecosystems very few organisms occupy a niche without competitors, chemical defenses or predators. Natural enemies are the best ecosystem approach to achieving long-term stability.

Can Biological Controls work?

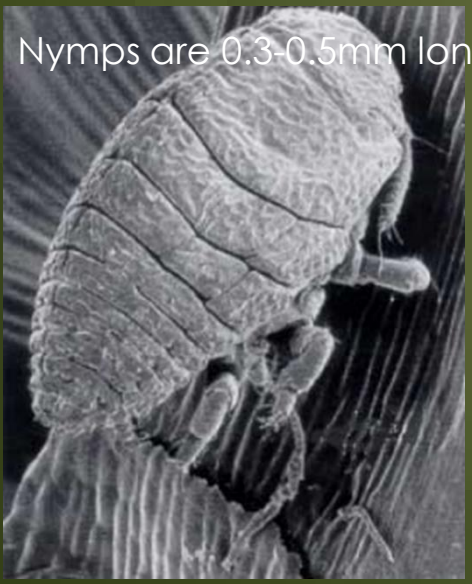
Cottony-cushion scale in California was discovered in CA citrus in 1868. USDA went to Australia looking for natural enemies. Brought back 514 ladybird beetles. By 1890 all infestations of scale had been wiped out.

Can it work here?

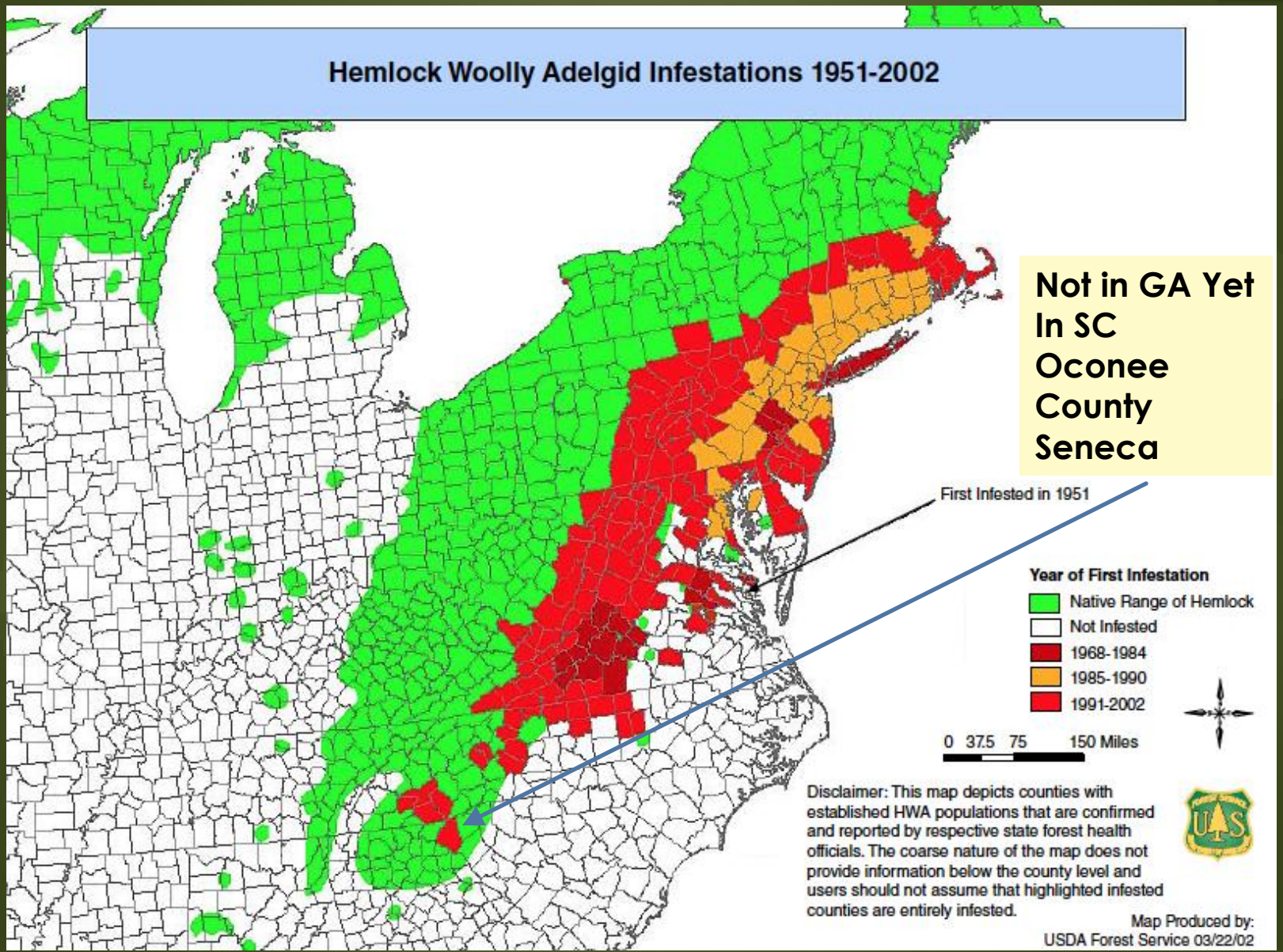
Won't know unless we try. Will likely require more than one type natural enemy. Natural enemies won't eliminate HWA but they may repress to levels that greatly reduce tree mortality.

Hemlock Woolly Adelgid (Adelges tsugae)

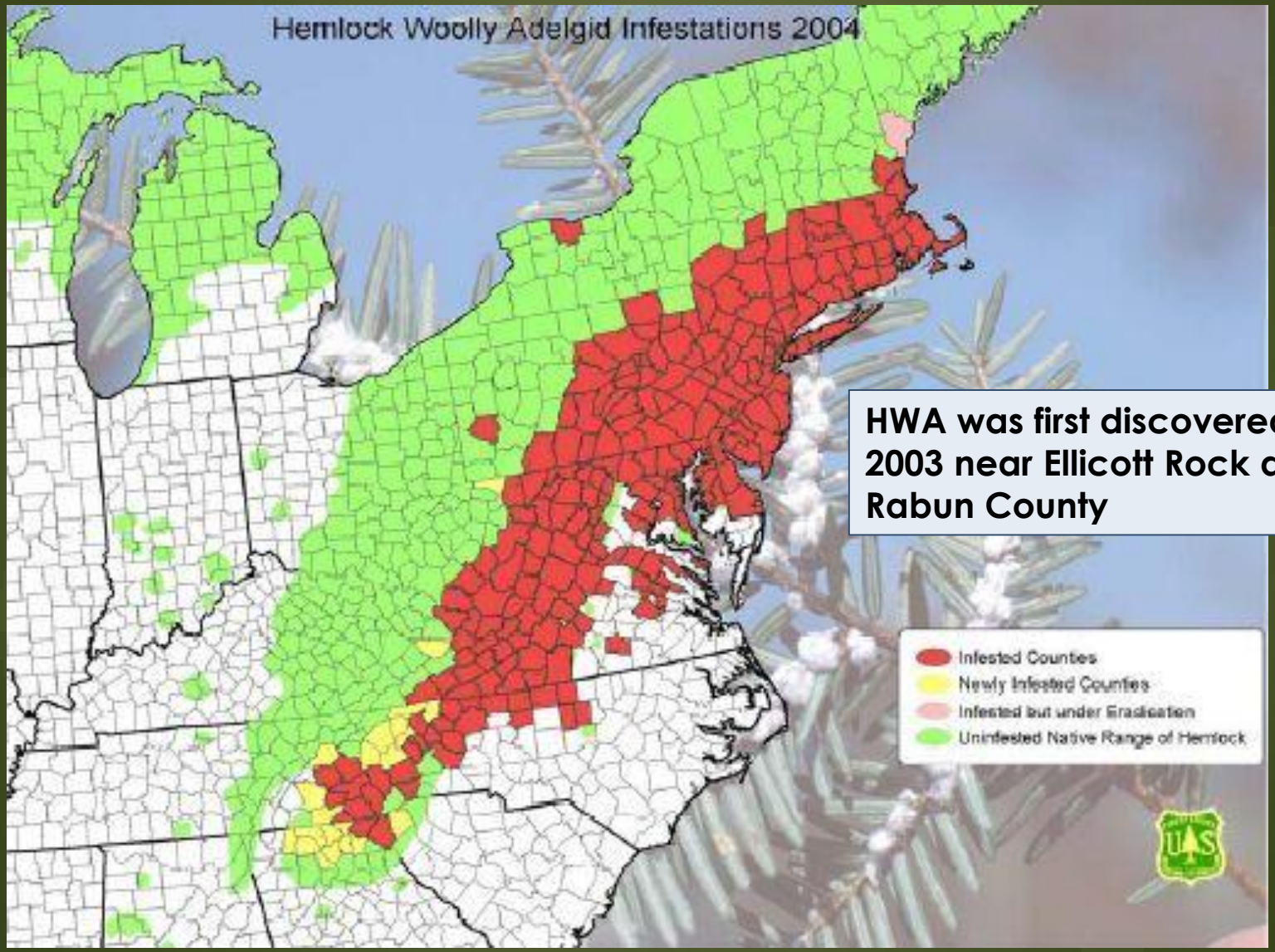
- History
  - Non-native invasive species from Southern Japan
  - Arrived northwestern United States around the 1920's presumably via ornamental plants
  - Migrated to the eastern United States around 1950



HWA SPREAD 1951-2002

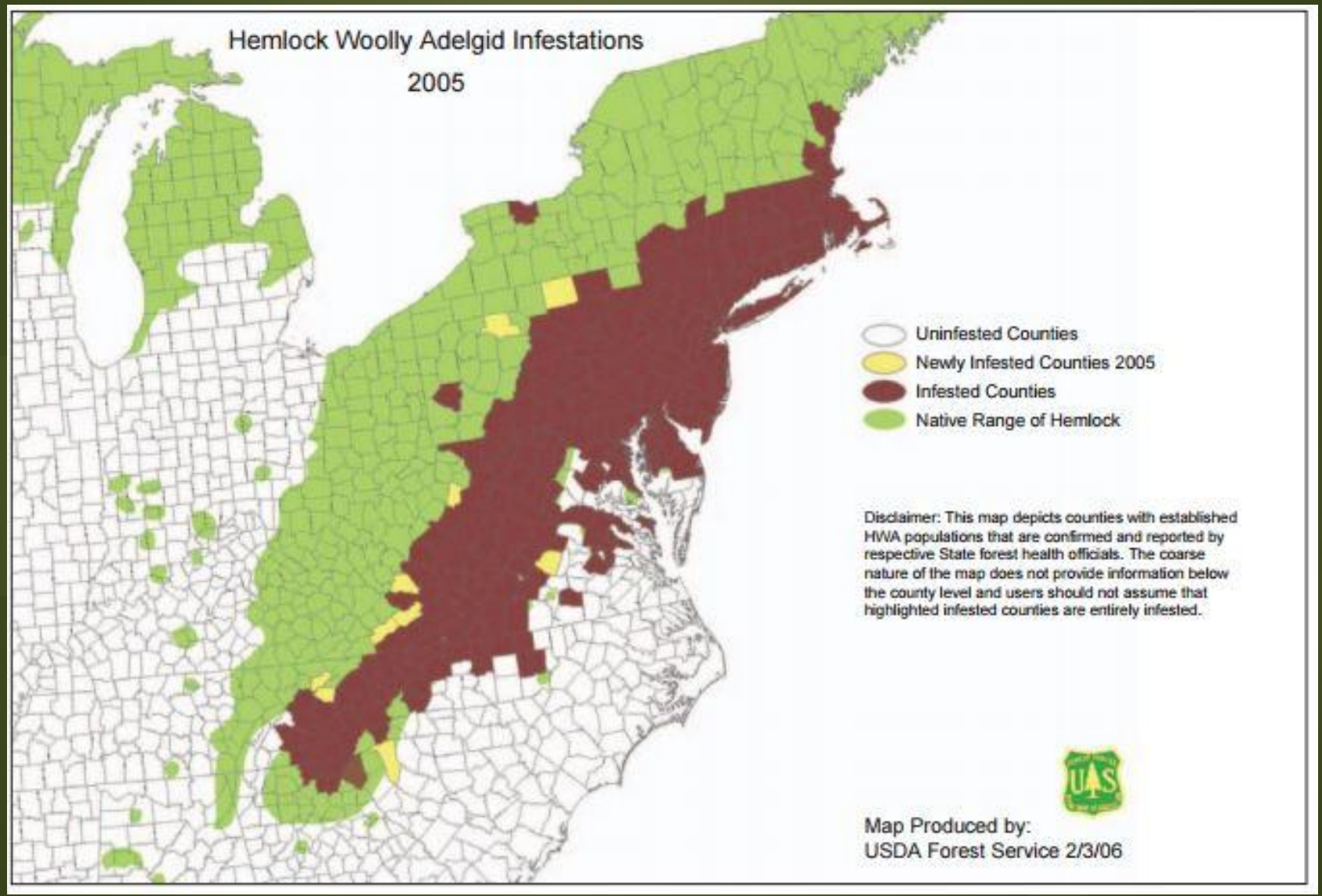


HWA SPREAD 2004

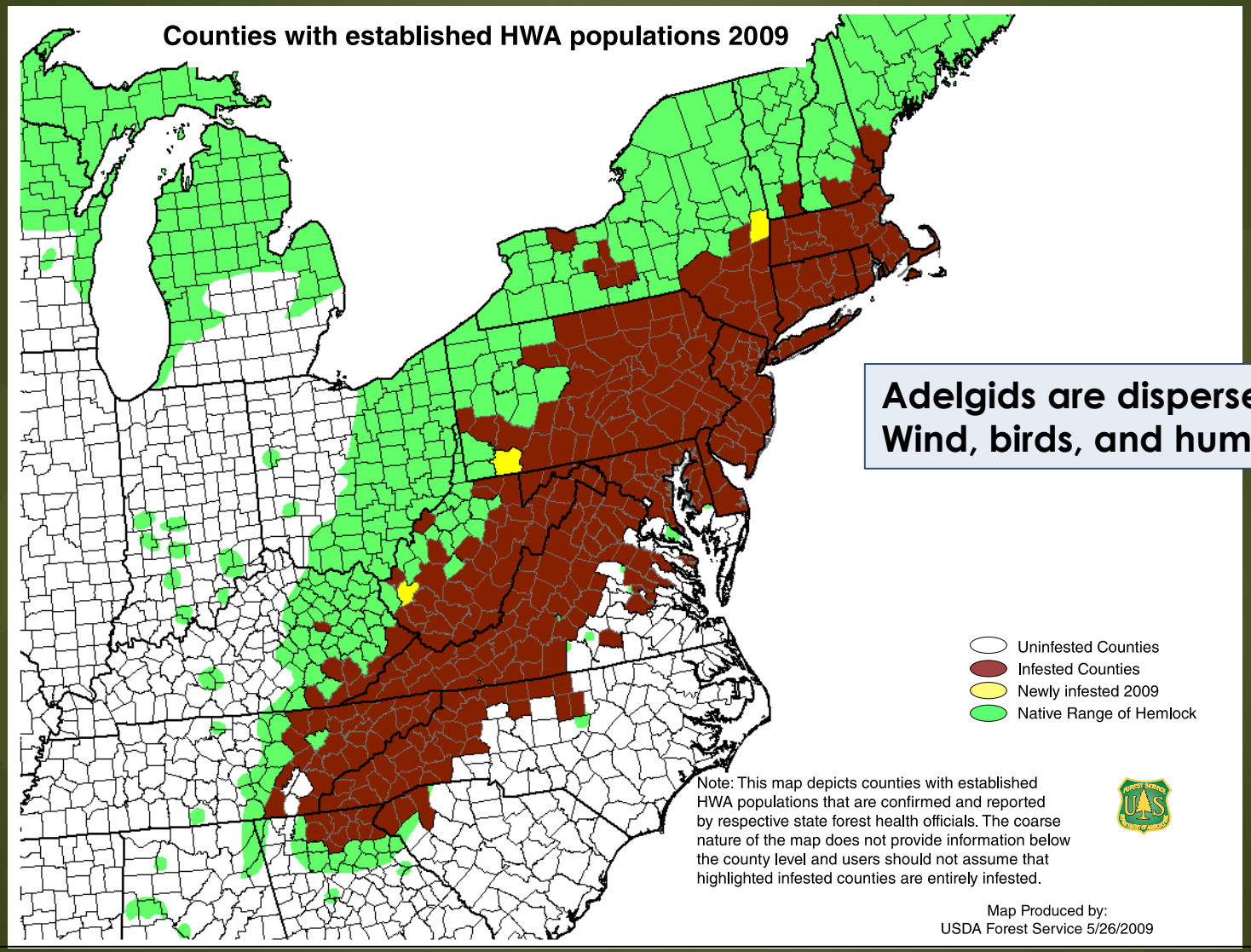


HWA was first discovered in GA in 2003 near Ellicott Rock area of Rabun County

HWA SPREAD 2005

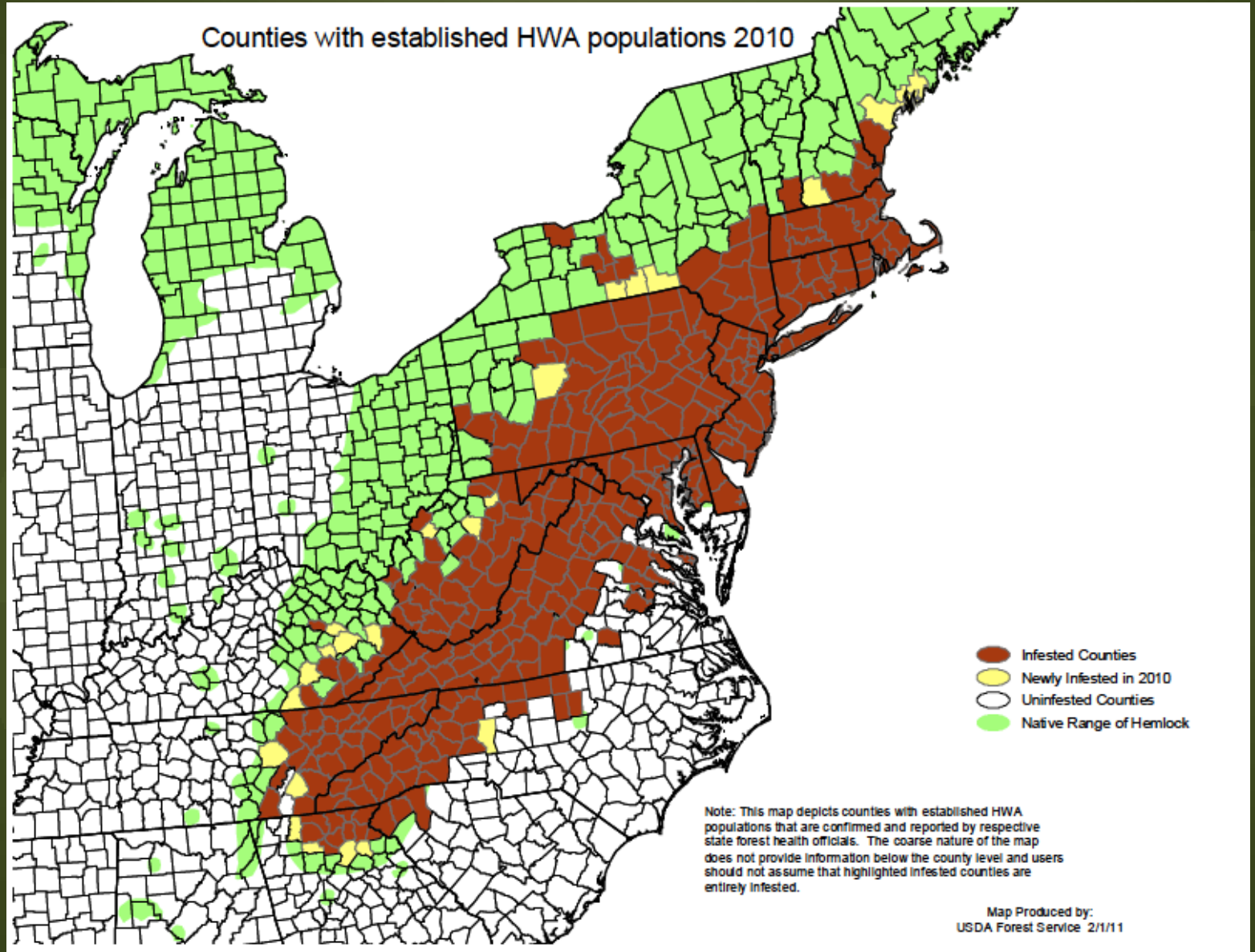


HWA SPREAD 2009

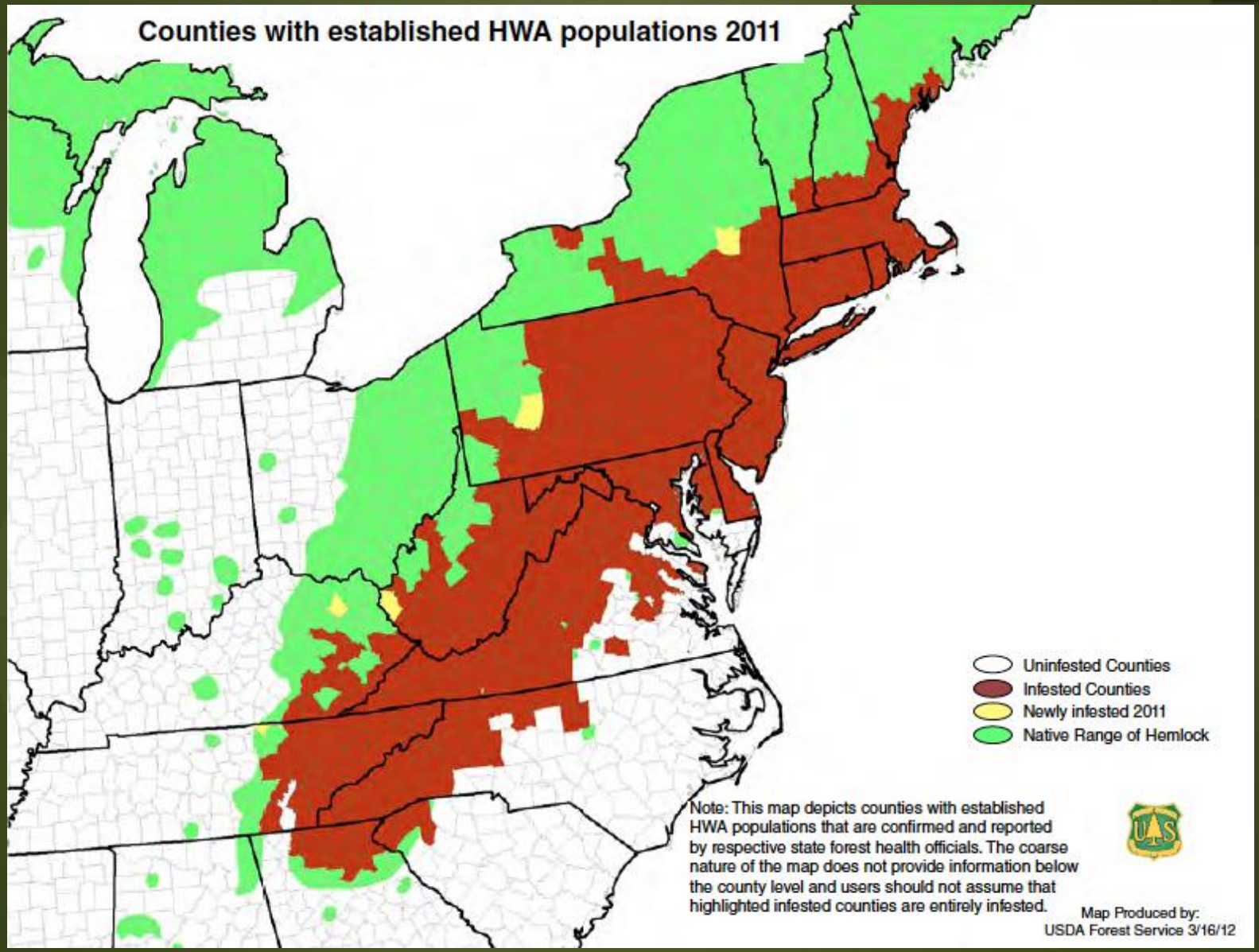


Adelgids are dispersed by Wind, birds, and human activity

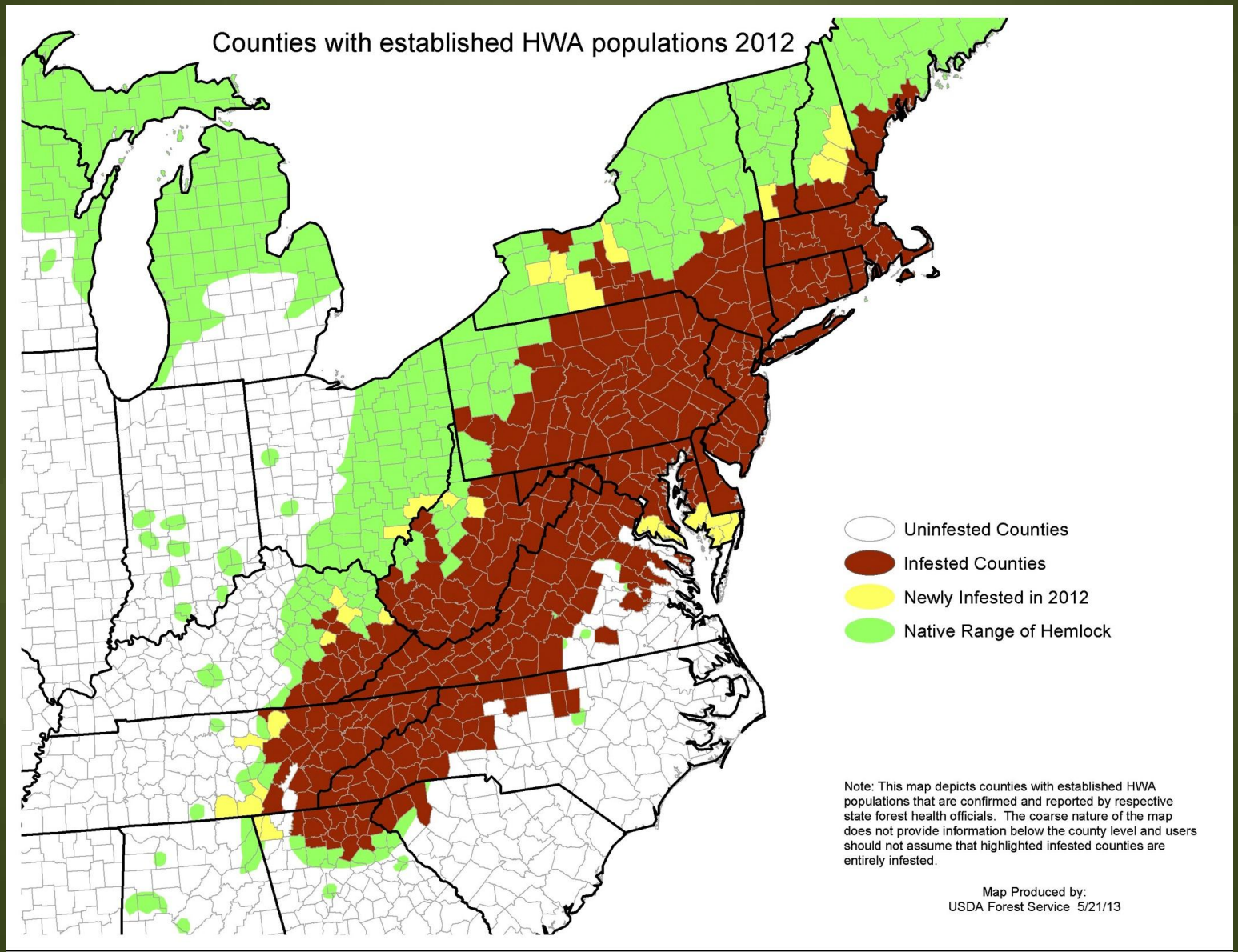
HWA SPREAD 2010



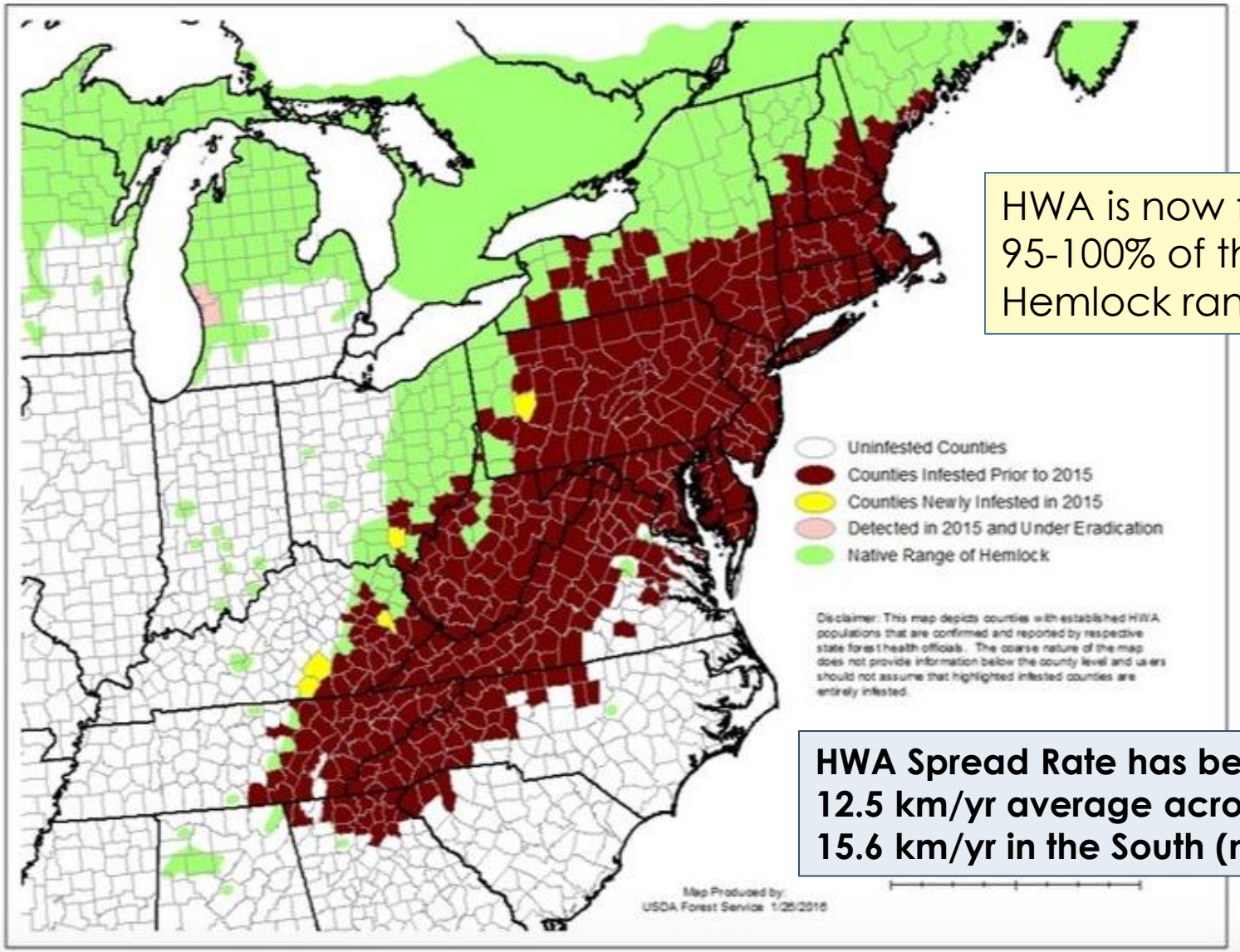
HWA SPREAD 2011



HWA SPREAD 2012



HWA SPREAD 2015



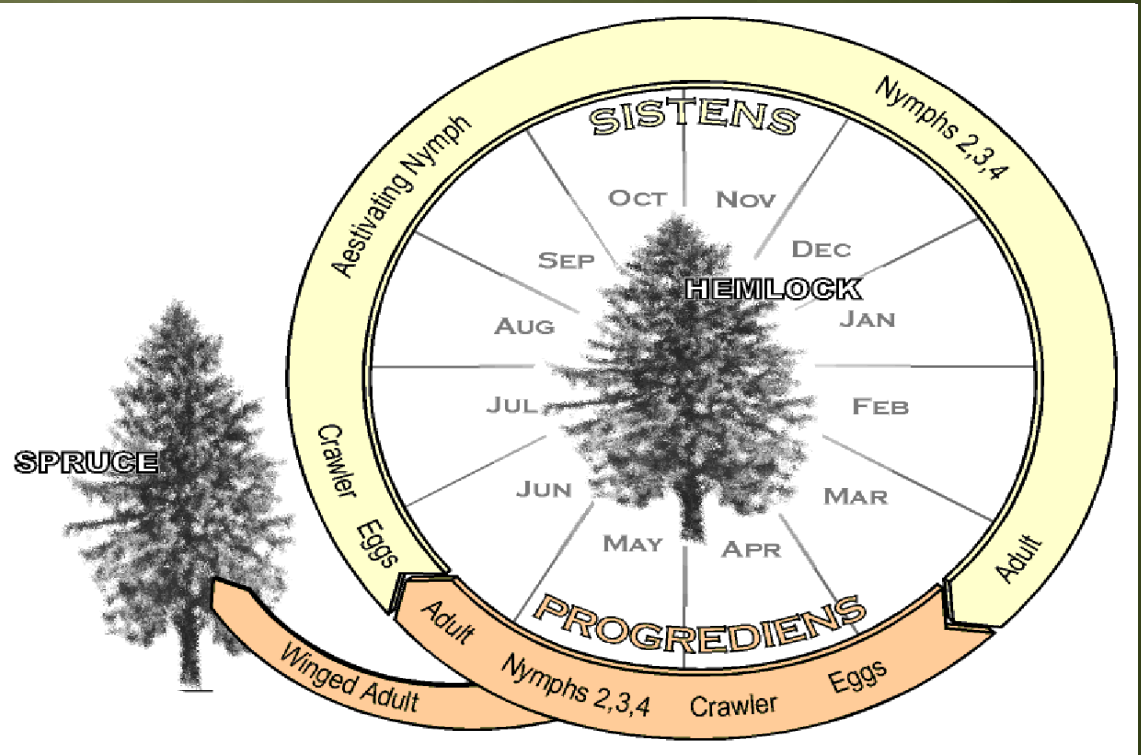
HWA is now found in 95-100% of the native Hemlock range in GA.

HWA Spread Rate has been
12.5 km/yr average across all ranges
15.6 km/yr in the South (much faster)

Why are HWA so destructive?

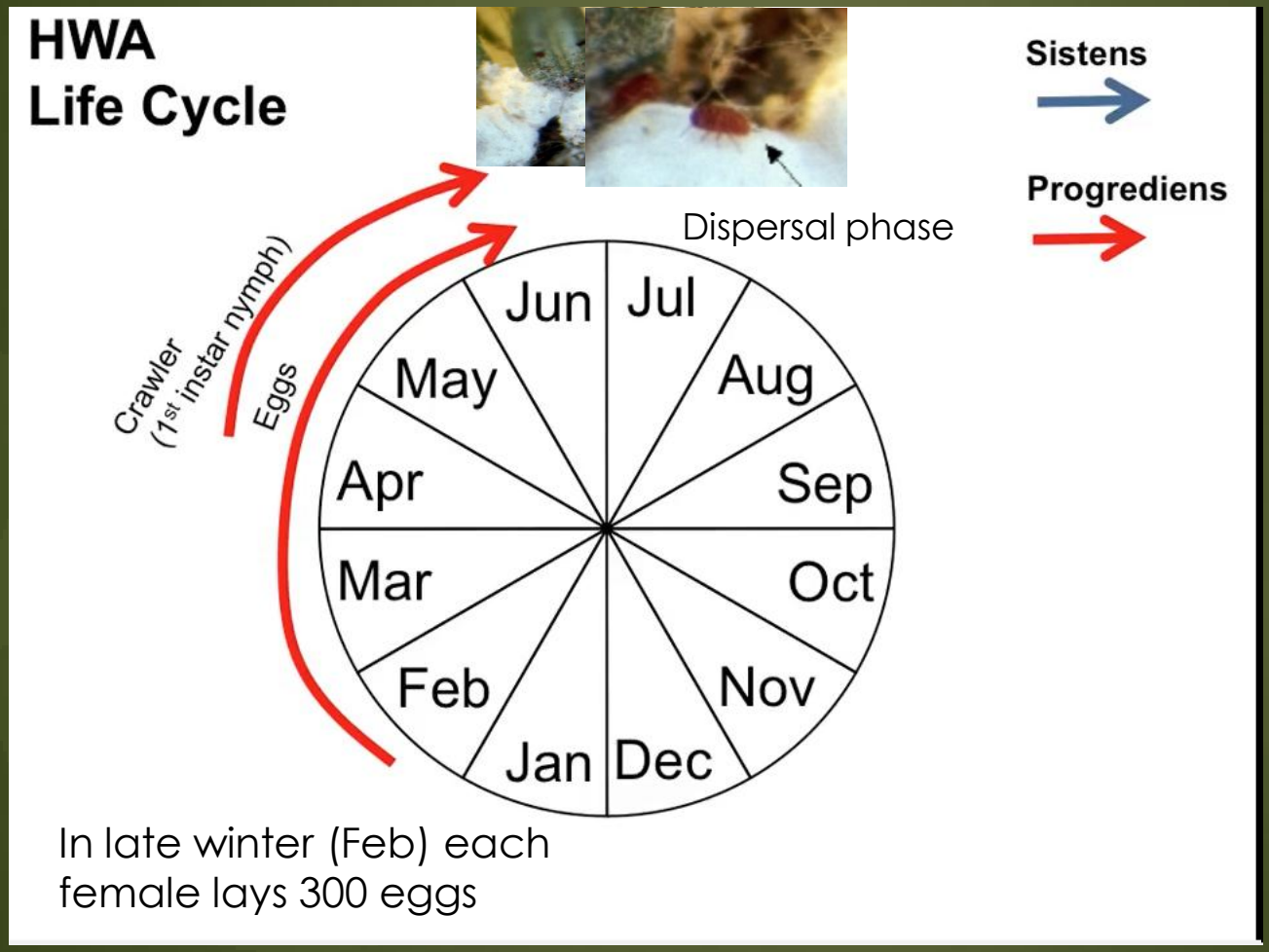
- No natural predators
- They are **all female** and can reproduce asexually. This is called **Parthenogenesis**
- They have two reproductive cycles (two generations) each year

Near constant feeding and rapid reproduction doesn't allow trees enough **recovery time**



HWA Lifecycle

2 generations

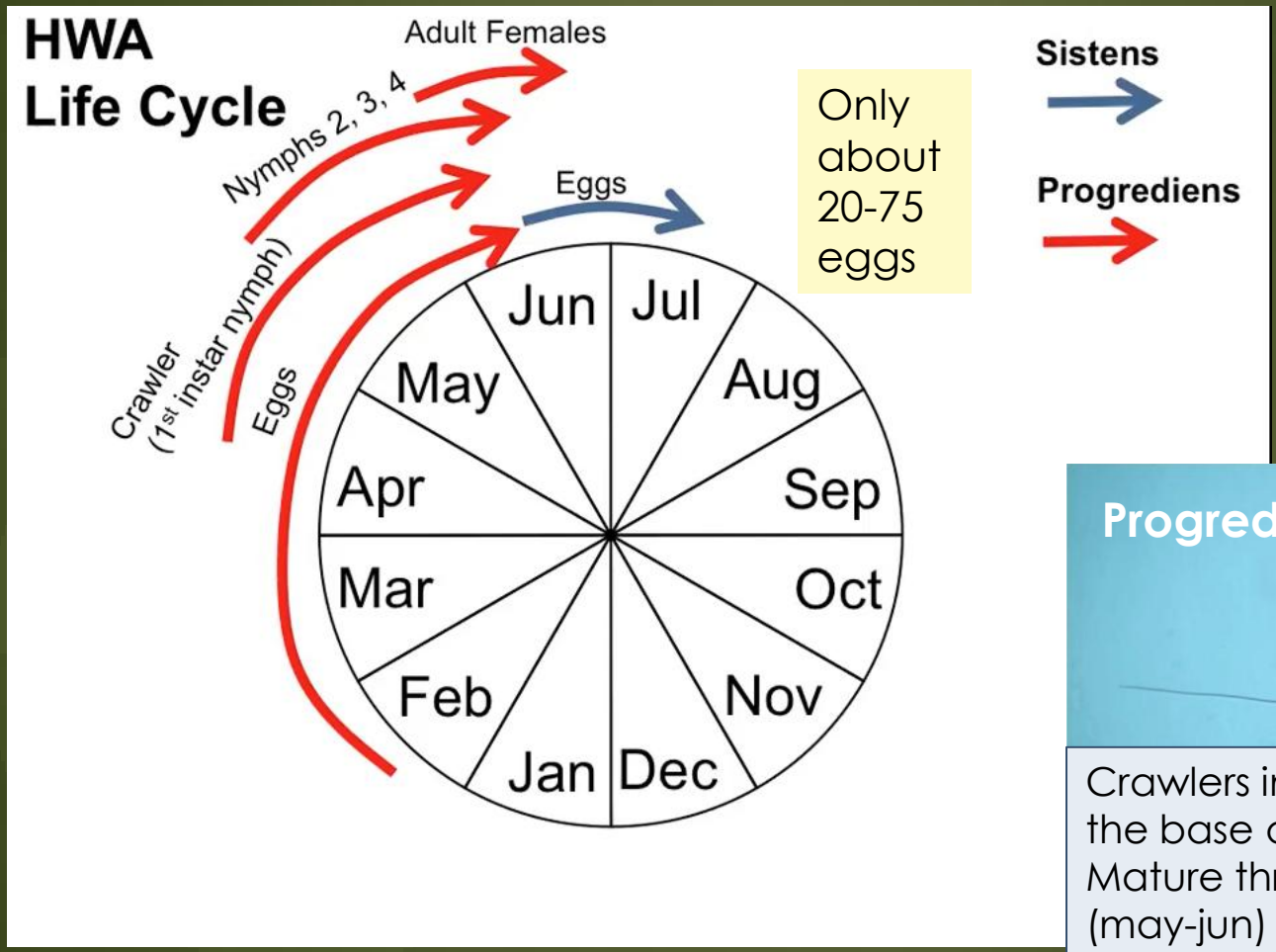


In Latin means "to halt"
Has a Dormant phase

In Latin means "to proceed"

HWA Lifecycle

2 generations



Only about 20-75 eggs

Sistens

Progrediens

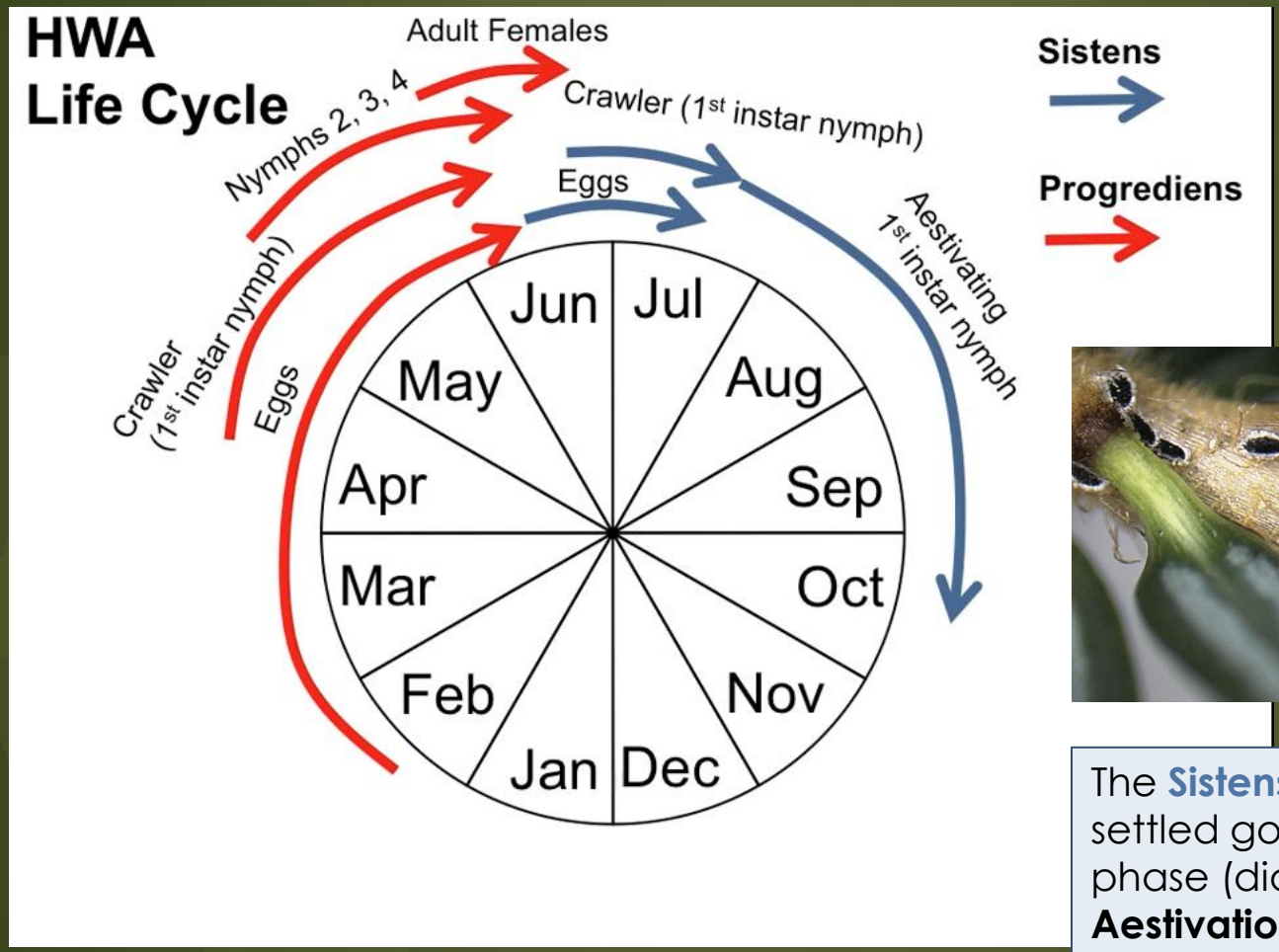
In Latin means "to halt"
Has a Dormant phase

In Latin means "to proceed"

Crawlers insert their stylet into the base of new needles. Stay. Mature thru 3 nymph phases (may-jun) become adults. Lay **eggs** in **June**

HWA Lifecycle

2 generations



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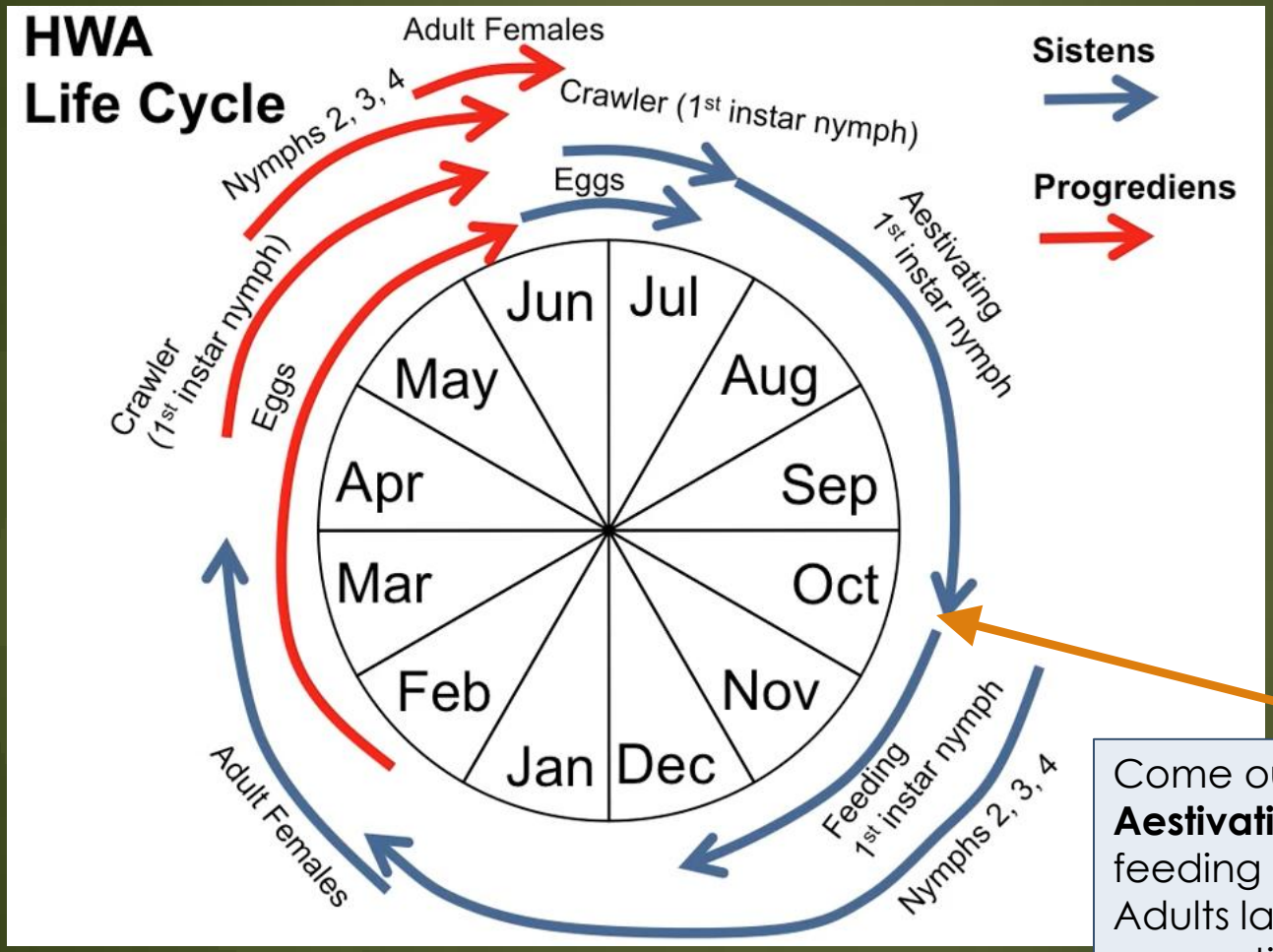
The **Sistens** generation once settled goes into a dormant phase (diapause) called **Aestivation**. Many don't survive.

HWA Lifecycle

2 generations



In Latin means "to halt"
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Come out of diapause or **Aestivation** in **October**. Longer feeding period ~3 months. Adults lay **eggs** for Progrediens generation in **February**.

The Beetles

Native to Asia

Sassajiscymnus tsugae

Native to the Pacific Northwest

Laricobius nigrinis

Scymnus coniferarum

Sasajiscymnus tsugae (St)

- Native to Japan
- Feed only on adelgids
- Active late spring – summer
- Only beetle released in Georgia between 2008-2011.
- Released continually thru 2017

Sasajiscymnus tsugae (St)

STRENGTHS

- Very Easy to Rear
- Life cycle well synced with HWA. They also have two generations (bivoltine)
- Highly mobile and feed on all life stages.
- A larva can consume 500 eggs and 50-100 nymphs
- Adults can live one year consuming 50 nymphs per week.
- Can Lay 300 eggs in a lifetime
- In Japan they kill 86-99% of adelgids. [2]
- In Connecticut beetles were recovered from 22% of release sites. Better success at older sites. [2]

Sasajiscymnus tsugae (St)

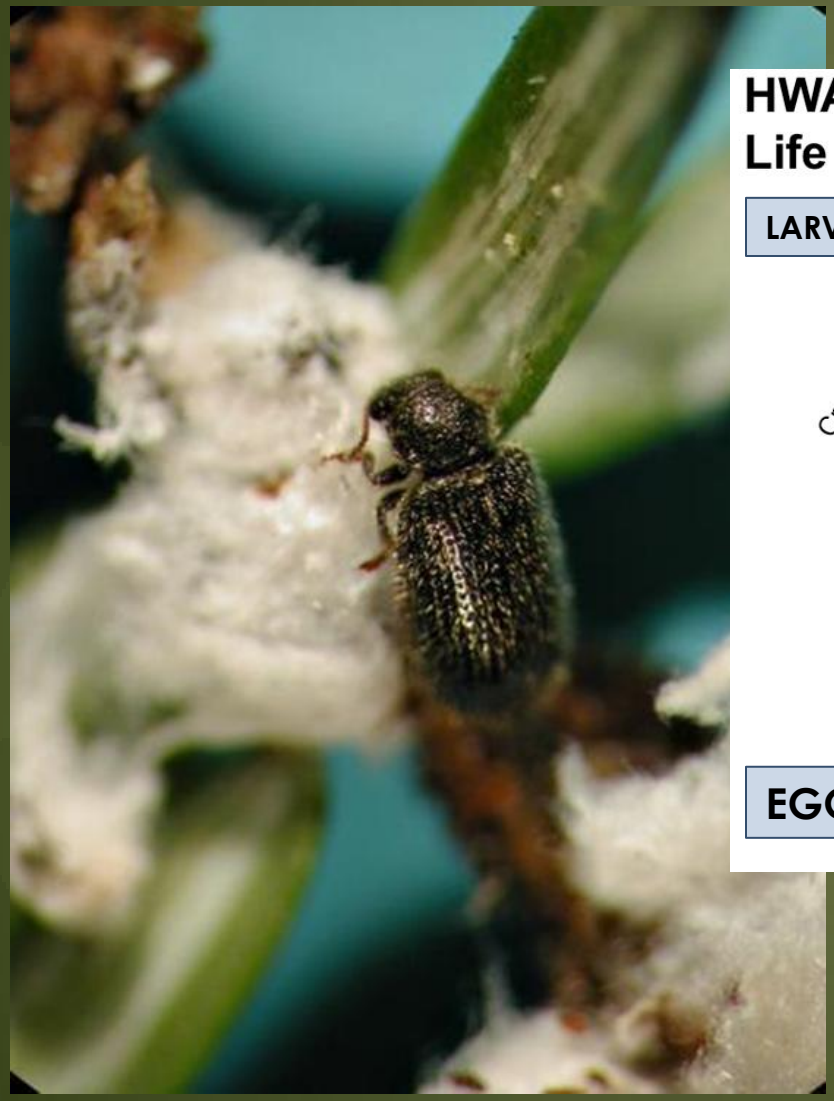
WEAKNESSES

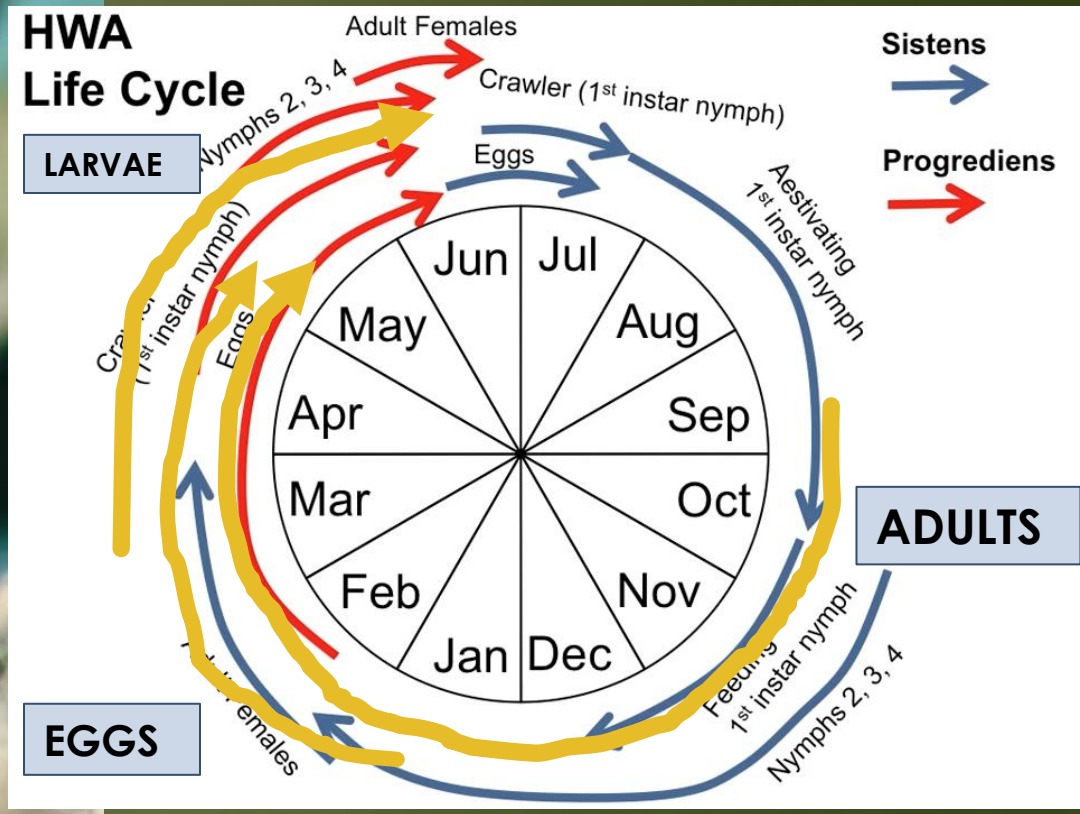
- **Susceptible to cold winters**
- Initial beetle population for rearing had limited genetic diversity
- Recovery of these beetles has been disappointing.
- Difficult to recover below 5m at ground level, much more successful from 5m-20m

Laricobius nigrinus (Ln)

- Native to Pacific North West
- Active during winter to spring
- Can only reproduce and finish its lifecycle with HWA
- Part of life cycle is in soil in the summer
- Single generation (univoltine)
- Began rearing in 2012 through current

Laricobius nigrinus (Ln)





Adults overwinter on Hemlock branches feeding on HWA Sistens. In late winter, Ln lay single eggs in HWA sisten ovisacs. Hatch and Ln larvae eat HWA eggs. 4 instars. Drop to ground and pupate in soil.

Laricobius nigrinus (Ln)

STRENGTHS

- Well synced with HWA (oviposition of Sistens)
- Not easily lab reared

WEAKNESSES

- Does best (larval development) in specific temperature ranges. Greater than 12°C (53.6°F), best at 18°C (64°F), no development at 21°C (69.8°F)
- Limited in #'s of wild caught beetles to begin rearing each year.

Scymnus coniferarum (Scw)

- Also native to the Pacific Northwest of the United States
- Feeds during the late fall to winter season
- Larval stage will feed on HWA progredians generation from May to June
- Pupates near the host or under tree bark
- Is currently unavailable for use due to a differentiation between species that allows it to also feed on pine adelgid

TOTAL BEETLE RELEASES

2008 - 2017

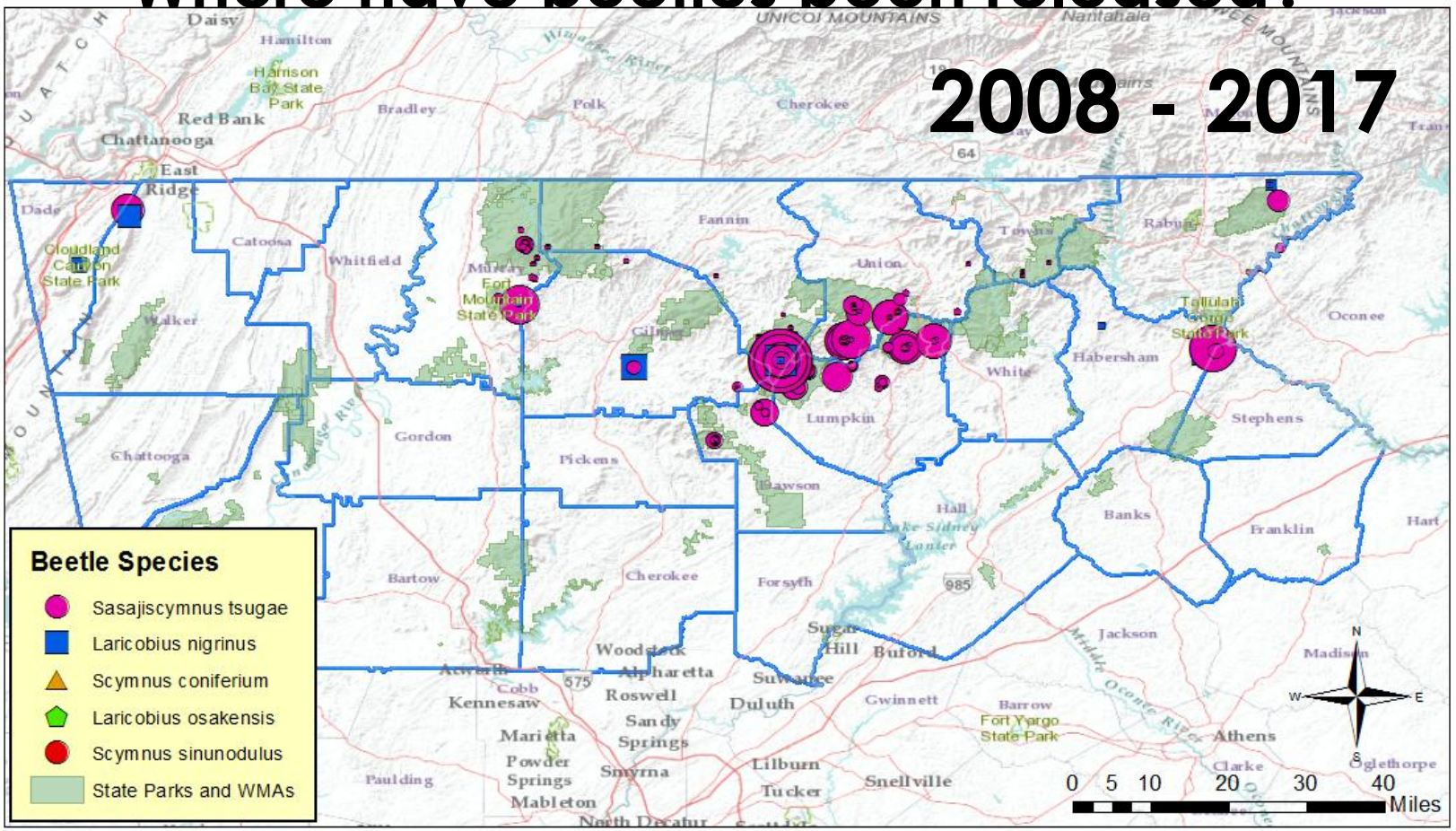
Beetle Species	2017	2016	2015	2012	2011	2010	2009	2008	Total	% of Total
St	8399	31173	10889	28058	48118	83570	65497	55033	**330737**	84.22%
Ln	22256	3922	19155	722					**46055**	11.73%
Scw		8794	5948						**14742**	3.75%
Lo		322	322						**644**	0.16%
Ss						510			**510**	0.13%
Total	**30655**	**44211**	**36314**	**28780**	**48118**	**84080**	**65497**	**55033**	**392688**	
Percentage of Total	7.81%	11.26%	9.25%	7.33%	12.25%	21.41%	16.68%	14.01%		

Working to compile a complete Biological Control database for all labs

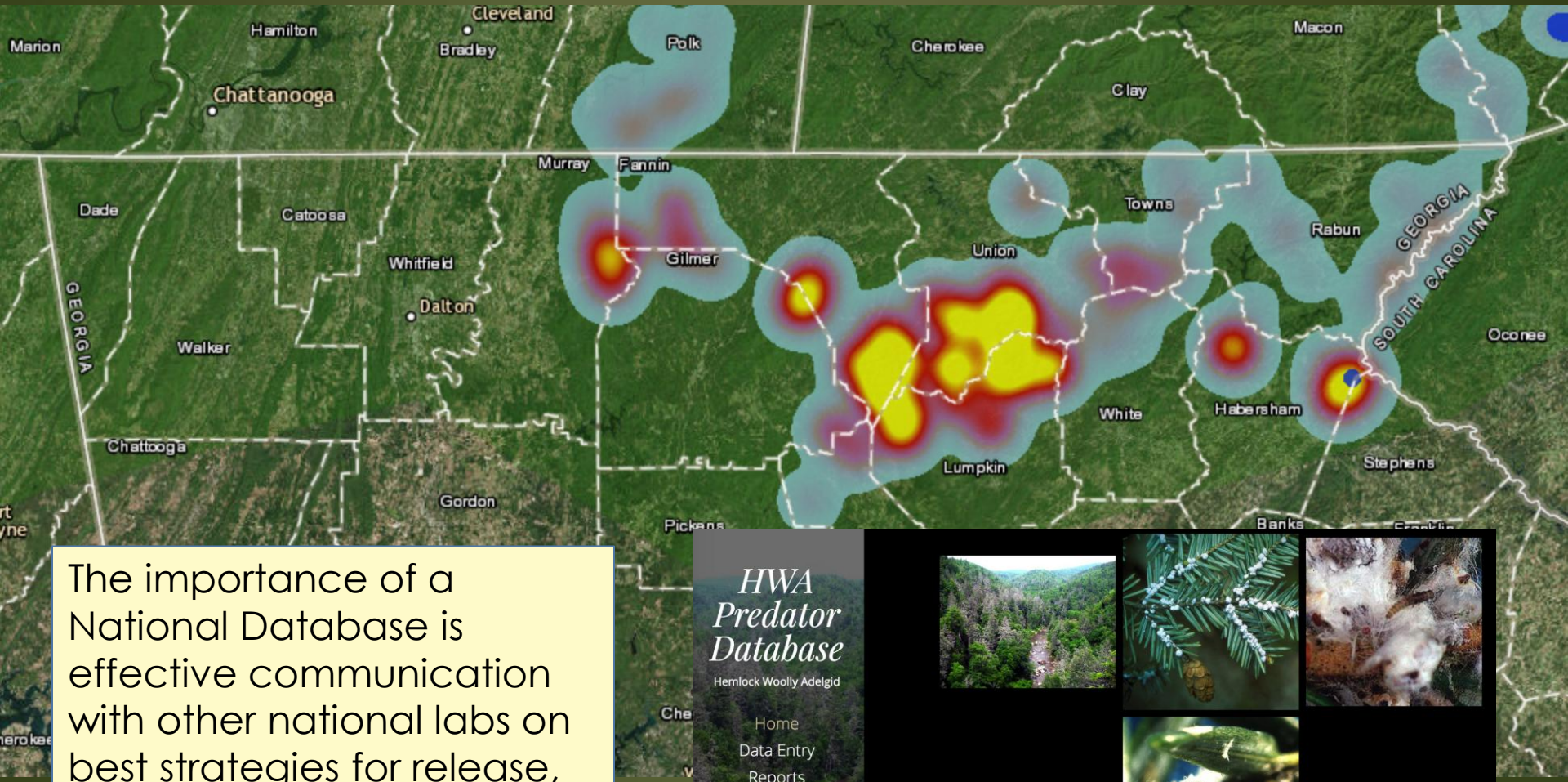
soon to complete 2013-2014

Developing our Geospatial database

Where have beetles been released?

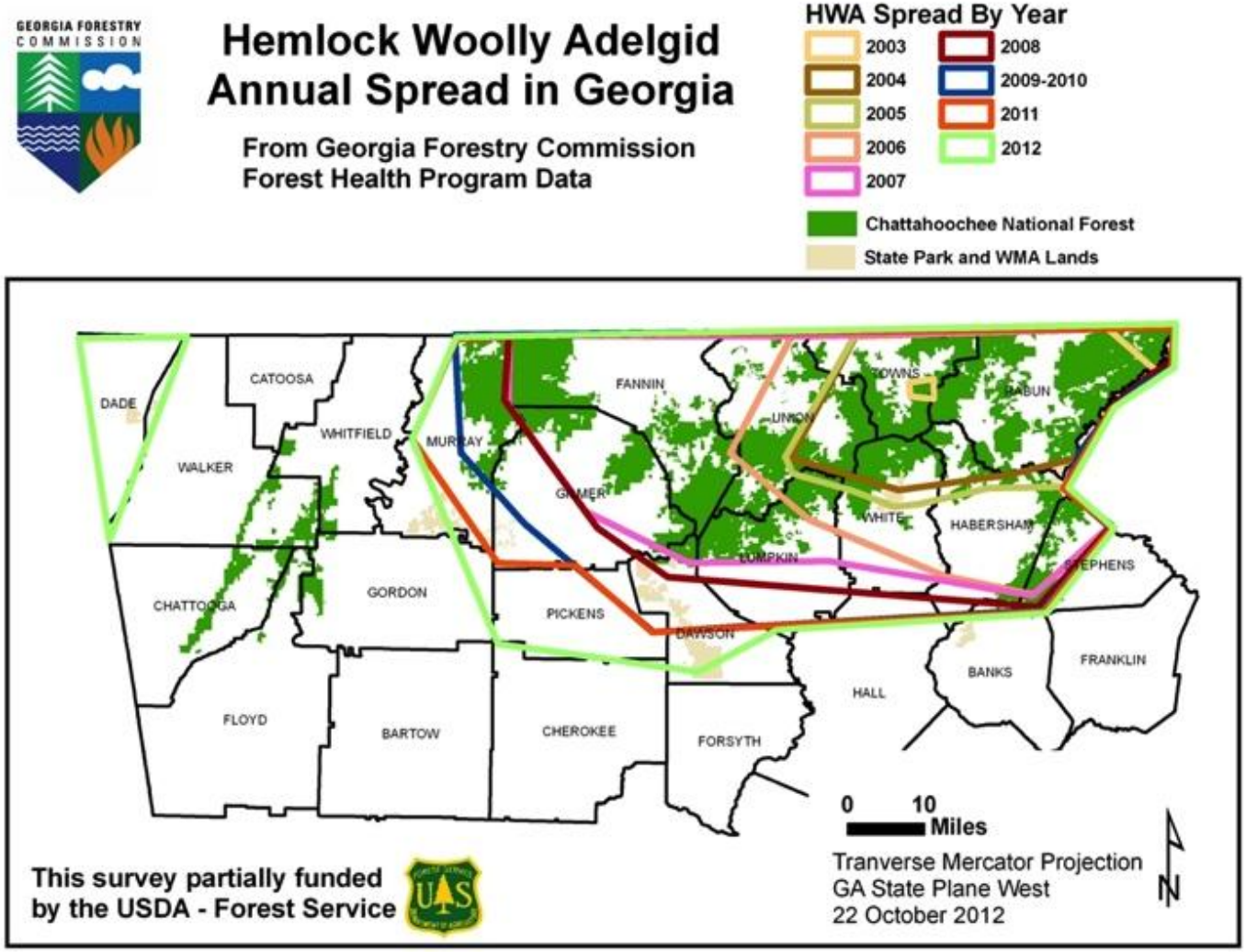


Updates to National HWA Predator Database



The importance of a National Database is effective communication with other national labs on best strategies for release, beetle types, and recapture efforts.

Time series maps that depict both the spread and the response



A geospatial database will allow for better communication of the evolving problem with the public.

- Interpretive signs
- Podcasts with USFS

Goal moving forward

- Develop a twenty year strategy to optimize the effectiveness of Georgia's **Biological Control Plan**.

STRATEGY

Develop a Geospatial Database to

- Correlate beetle release location data (by year and type) with variables that influence their effectiveness
- Revise Bio Control Management Plan in collaboration with all partners

What are the Big Questions?

RELEASES

- **Where should we focus future releases?**
  - **Which environmental factors influence** greatest **success** for each beetle type (established through research and recovery efforts).
  - Which **areas are optimum** for the success of each beetle type?

RECAPTURE

- **Where should we focus recapture efforts?**
  - Limited resources requires us to be strategic in where we assess beetle effectiveness.

Factors influencing Hemlock health

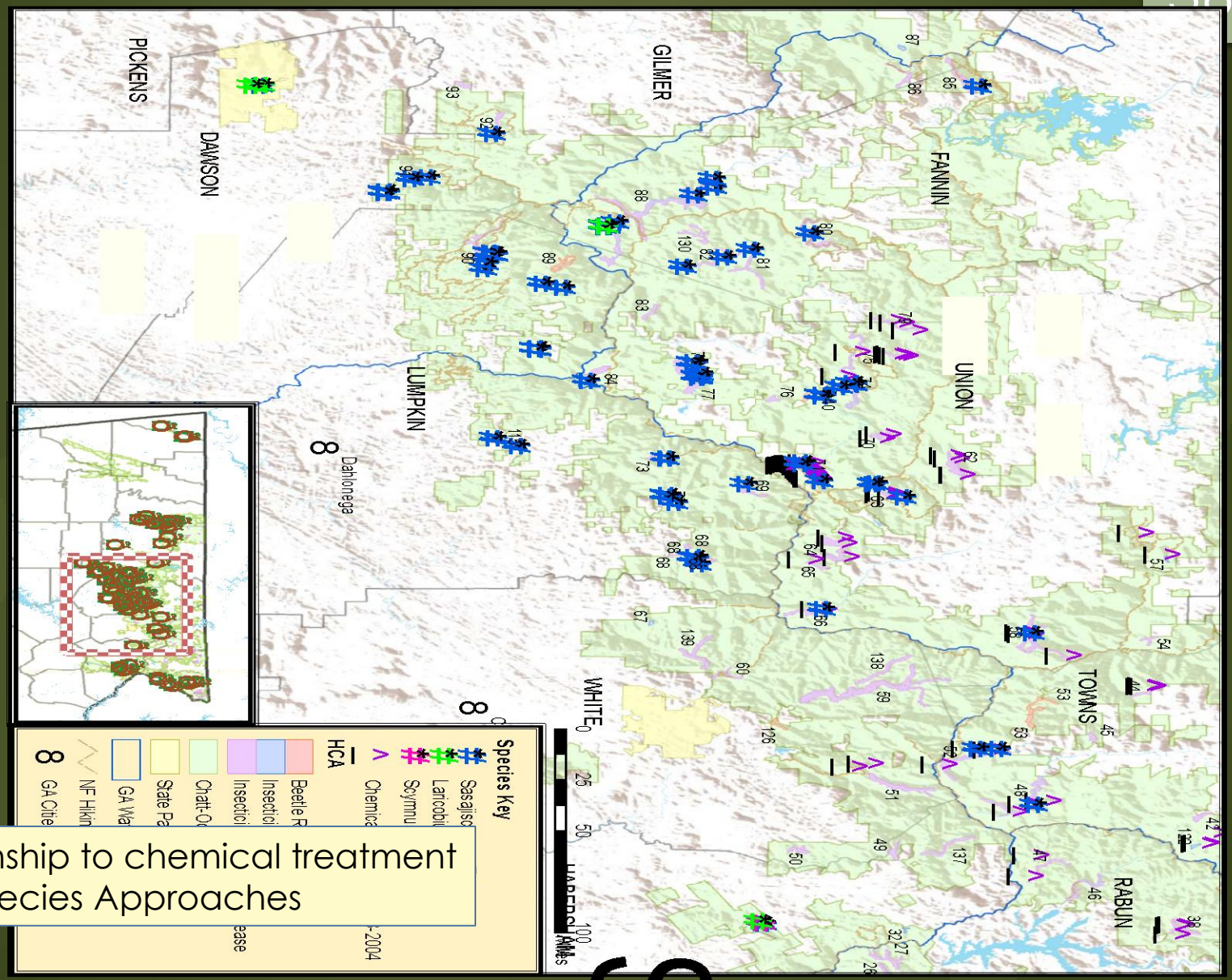
Table 1.—Characteristics of sites where the most hemlocks, the best hemlocks, and the worst hemlocks were located.

Site Characteristic	Most Hemlock	Best Hemlock	Worst Hemlock
Aspect	SW through NW	NW & N	SW & W
Hydrology Group (Infiltration Rate)	Moderate	High	Very Slow
Depth to Bedrock	60 inches	60 inches	One inch
Soil Order	Inceptisols	Entisols	Inceptisols
Drainage Class	Well Drained	Excessively	Well Drained
Surface Texture	Coarse	Medium/Moderately Coarse	Coarse

Also:
TEMPS
PRECIP
ELEVATION

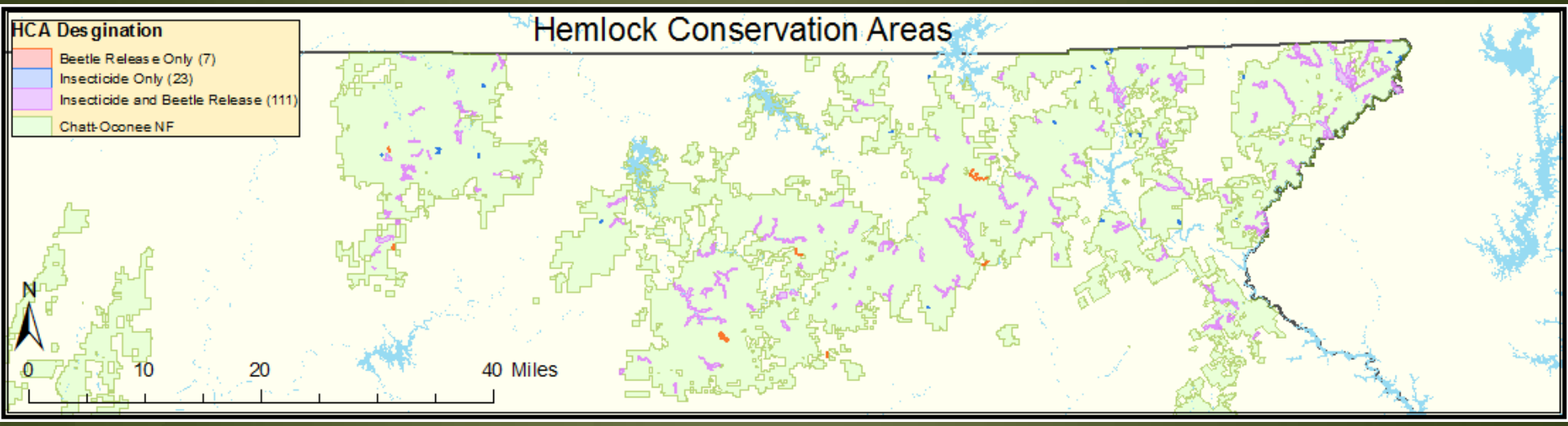
Using a Geospatial database we can start organizing, processing and analyzing environmental factors that are predictive of Hemlock canopy health and beetle effectiveness.

Beetle Success Factors



Relationship to chemical treatment
Multi-species Approaches

Hemlock Conservation Areas



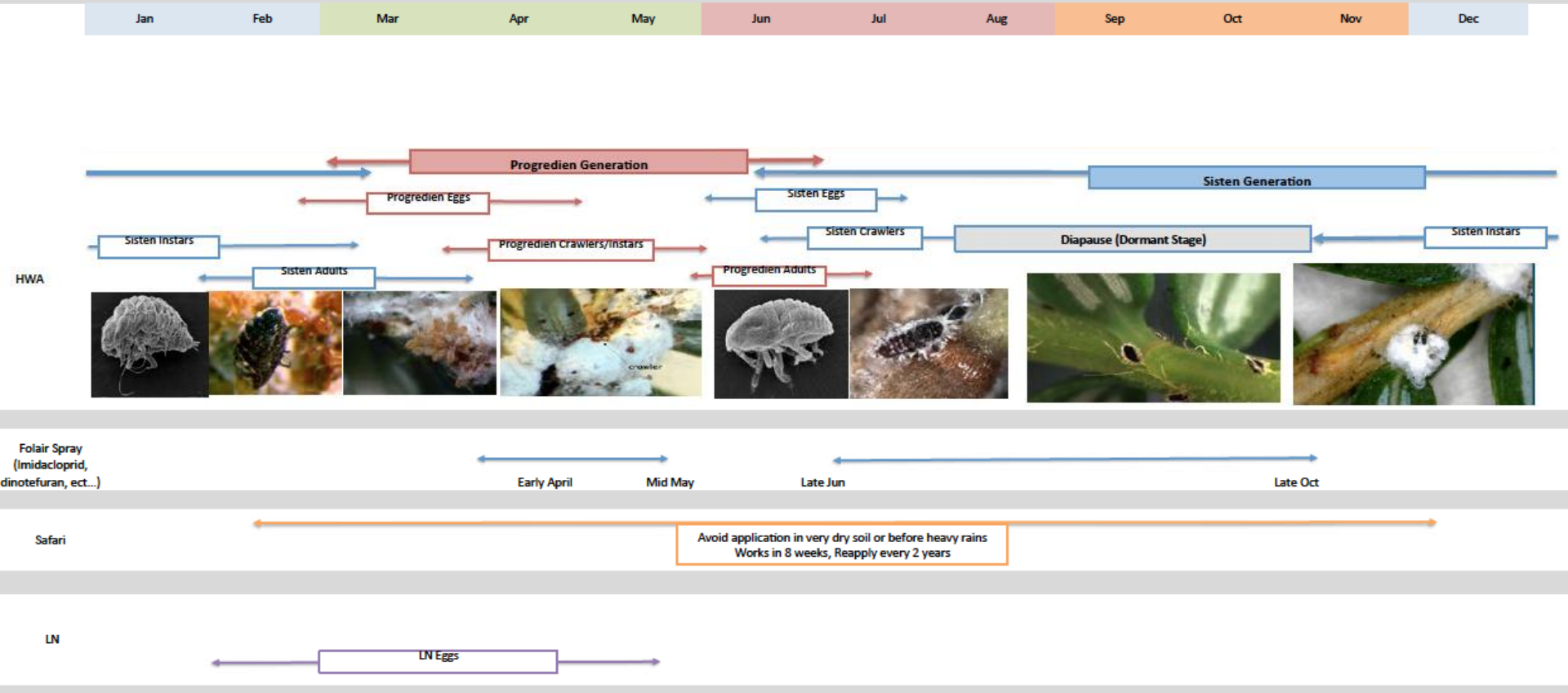
Hemlock Conservation Areas

- Chosen due to high density
- To preserve Biological Diversity

Findings may revise / add to HCAs

Phenology

Phenology is the study of plant/animals cycles as they relate to one another and to climate and habitat variations



Using the Spatial Geodatabase we can start analyzing environmental factors such as precipitation,

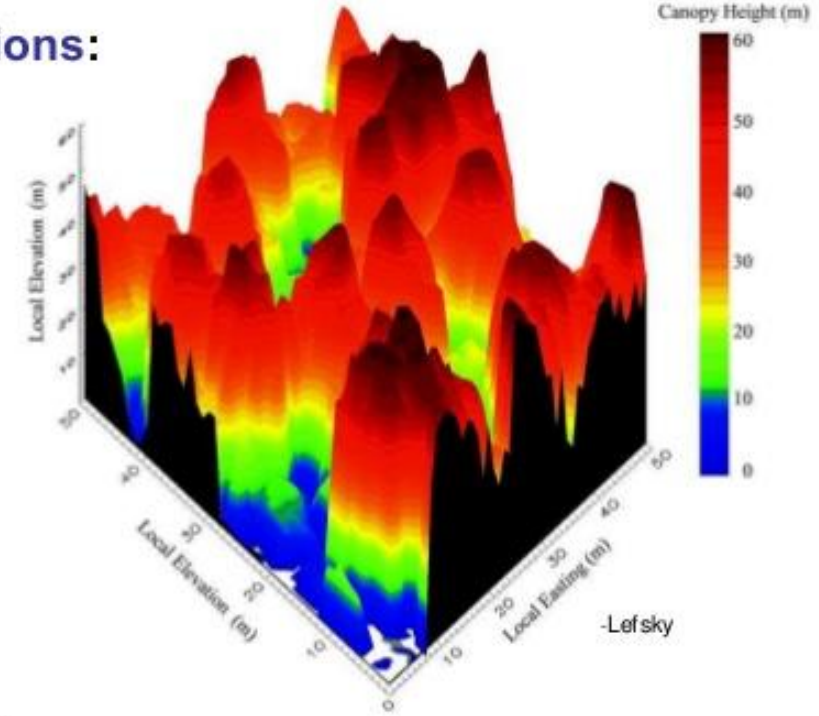
LIDAR

Light Detection and Ranging - remote sensing method that uses a pulsed laser to measure ranges (distances)

Modeling Forests

Other Forest Applications:

- Vertical and Horizontal distribution of:
  - Individual trees
  - Branches
- From this:
  - Canopy density
  - Species Identification and Classification
  - Stand Structure
  - Successional state
  - Forest health
  - Habitats
  - With time: Change detection



We are examining the potential to use LIDAR and other remote sensing data as a tool for assessing and predicting **changes in Hemlock canopy health**.

Additional Predators

- The Silver Fly or Leucopis argenticollis is currently being researched in its native range in the Pacific Northwestern U.S.
- In that part of the country Silver Flies are 2nd only to Laricobius nigrinus in abundance as an HWA predator. And HWA is their preferred food source when available.
- One of the objectives of the research is to begin releases of western silver flies in the eastern U.S. to determine the most effective release strategies.

What can you do?

- Share your knowledge
- Attend Hemlock Fest, other volunteer days
- Don't be a Vector. Be cautious about transporting Firewood
  - Use local firewood or purchase it
- Pay attention to trees on your own property

How to find us

UNG Environmental Leadership Center

- https://www.facebook.com/ungbeetlelab/
- Check our UNG website

The ELC is working to train the next generation of environmental leaders in North Georgia through 4 programs:

- **Ecological Protection Lab** – Biocontrol for Hemlocks
- **Water Lab** – 30 yrs of water quality monitoring – Upper Chattahoochee
- **Chestatee Restoration** – Restoring degraded uplands with organic mulch
- **Campus Sustainability** - UNG as regional leader in sustainability models

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Environmental Leadership Center
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References

1 – Success in Biological Control – Cornell University

https://biocontrol.entomology.cornell.edu/success.php

2 – ***Sasajiscymnus* (formerly *Pseudoscymnus*) *tsugae***

(Coleoptera: Coccinellidae)

https://biocontrol.entomology.cornell.edu/predators/sasajiscymnus.php

X1 (Slide #- UGA study offers hope for hemlock attack. http://news.uga.edu/releases/article/uga-study-offers-hope-for-hemlock-attack/