

**BEETLES SAVE NEEDLES:
Successful Biocontrol of *Adelges
tsugae*
in Northwestern North Carolina
using *Laricobius nigrinus*.**

**Richard McDonald
Symbiont Biological Pest Management**



HEMLOCK
THE HEART OF APPALACHIA



WWW.HEMLOCKFEST.ORG



In Order to **Solve** Hemlock Adelgid Pest Problem :
You must be properly trained!!

- Proper ID of the pest (comes in later...).
- Specifically trained field folks (10,000 hours).
- B.S., M.S., Ph.D. in Biological Control/IPM
- Need real world experience!!
- Can't put a greenhorn (students) out there and expect to save an ecosystem!
- If you are serious about saving an ecosystem, then call out the AVENGERS! Top people!!
- 2/3 hemlock forest ON PRIVATE LAND. No resources for that.
- Researchers need to listen to field folks... :)

Threshold for Hemlock Regrowth

- Hemlocks get most of their sun in the WINTER
- Once a hemlock has less than 1/3 of its needles infested, it grows better than normal.
- Hemlocks in balance with HWA/predators grow better than hemlocks without HWA.
- Sturdier trees – why are western hemlocks 1/3 bigger than easterns? Insects and some other factors.

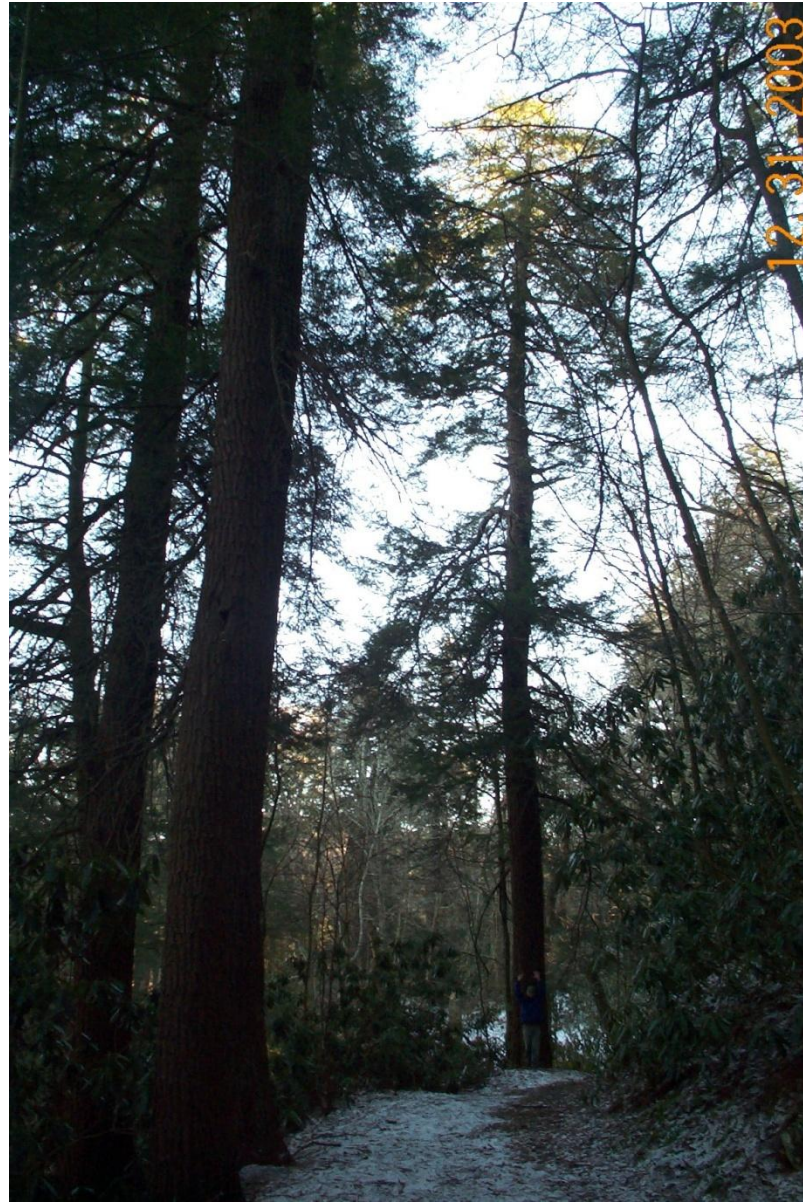
Keys to Success in Controlling Pests

- Proper identification of the pest is # 1!
- Although HWA is native to Asia....
- It is also **NATIVE** to the Pacific Northwest!
- Used Farmscaping techniques in Forest – they worked! More conifers are better...
- Forestscaping? Replant hemlocks/other conifers/other trees. Native Biodiversity.

Operational vs. Research

- Real time response-ninja!
- Goal – save as many trees as quickly as possible
- Whatever worked initially
- Incorporate the latest development to help steer us in the right direction ASAP
- South dying FAST! Train folks.
- Publishing in Scientific Papers comes after we save trees.
- Statistics- 4 out of 5 times worked, then $p=0.2$; Journals reject this.
- No rush to save trees
- No input from field people back into system
- Good Science takes time...didn't have. DNA!
- Journals want statistics to show something works 19/20 times; $p=0.05$ – don't get in a natural system.
- Both Operational and Research were competing for the same pot of money...adversarial design; any suggestions for improvement were seen as threats.

Success of HWA in E. North America is partly due to errors in identification!



Prior to 2006:

- 1) HWA native to Asia;
- 2) No effective natural enemies;
- 3) ***Hemlock forest doomed.***



Photo: M. McClure

HEMLOCK WOOLLY ADELGID

An entomologist discusses new discoveries about the life cycle of this important pest and offers tips for control and management

By Dr. Mark S. McClure

A tiny, aphidlike insect that was accidentally introduced from Asia during this century has become a destructive pest of native hemlocks in North America. The insect is the hemlock woolly adelgid (*Adelges tsugae*), so named because it is covered with a secreted woolly substance for most of its life (photo, opposite).

A serious threat to nursery and forest trees, hemlock woolly adelgid is probably native to Japan. During 1984, I found it in several areas of that country on two native hemlocks, *Tsuga diversifolia* and *T. sieboldii*. However, its densities there were always low and harmless, which is often typical for a native insect.

The adelgid has become established in both western and eastern North America (map, opposite). It reached the West first, where it was collected from *T. heterophylla* in Vancouver, British Columbia, in 1922 and in Oregon in 1924. The adelgid has since been collected from *T. mertensiana* as well, and it now occurs from northern California to southeastern Alaska.

In the West, this pest has been generally innocuous. The only reported injury has been to ornamental hemlocks growing in poor conditions. The situation is very different in the East, where woolly adelgid was first discovered in Virginia 40 years ago. Thousands of *T. canadensis* and *T. caroliniana* have been killed in forests and landscapes from North Carolina to southern New England.

Adelges tsugae occurs primarily on the young branches of these eastern hemlocks, where it sucks sap and probably also injects toxic saliva while feeding. This causes rapid desiccation and foliage discoloration; trees usually die within four years (photo, opposite).

There is little doubt that hemlock woolly adelgid is here to stay in North America, and that it will continue to spread into contiguous hemlock-growing areas of the northern US and southern Canada. This pest is extremely cold-hardy and is readily spread by wind, birds, forest-dwelling mammals and by humans during logging, nursery and recreation activities (3).

During the past seven years, I have been studying the life cycle and habits of hemlock woolly adelgid in an attempt to devise effective management methods. This article summarizes what I have discovered so far — and how much remains to be learned.

I began studying hemlock woolly adelgid in 1985, when this insect first invaded Connecticut. At that time, *A. tsugae* was thought to have a rather simple life cycle composed of wingless

1992 American Nurseryman

No effective natural enemies of HWA found in 42 sites visited in Seattle.

April to September studies...

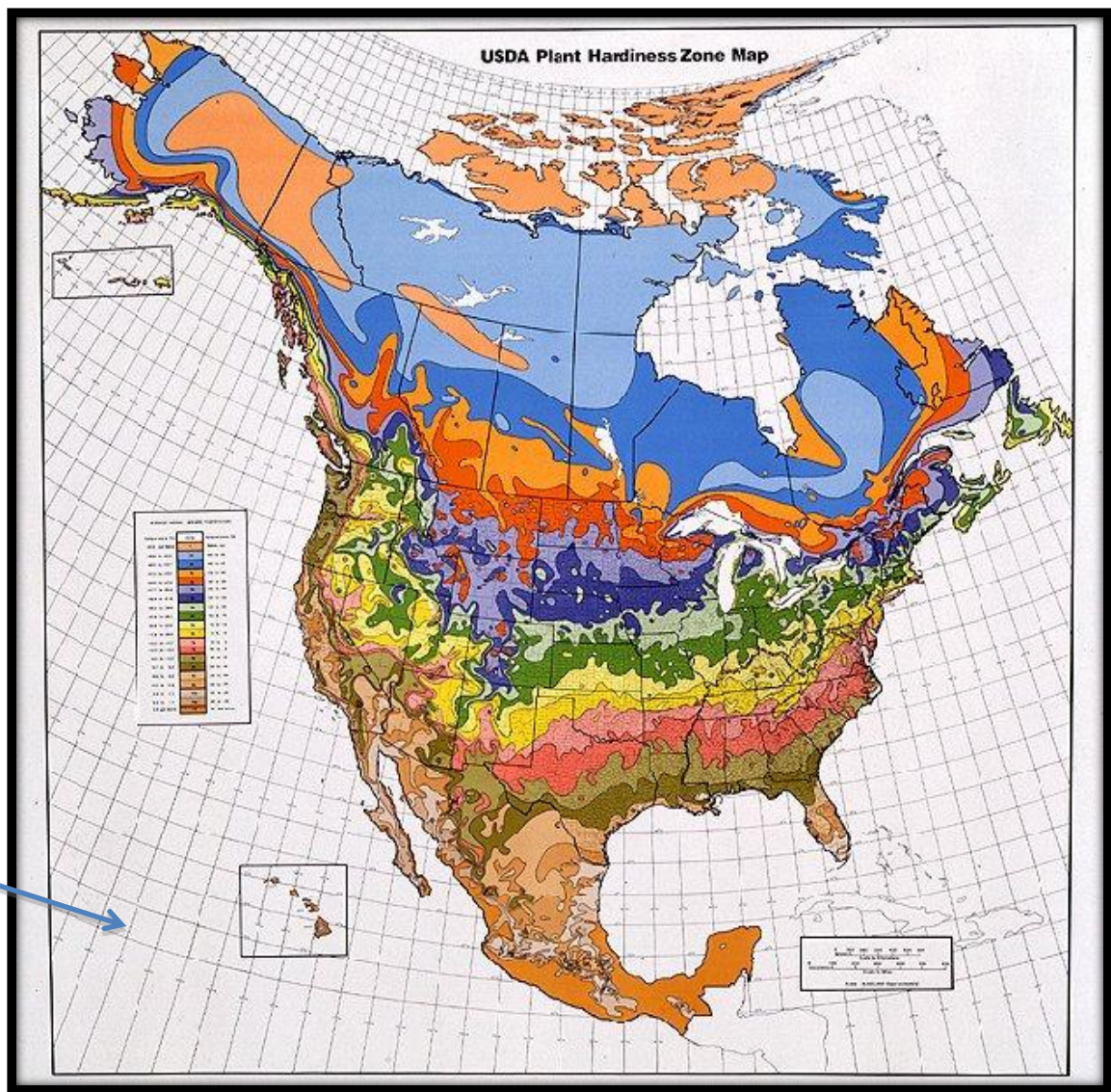
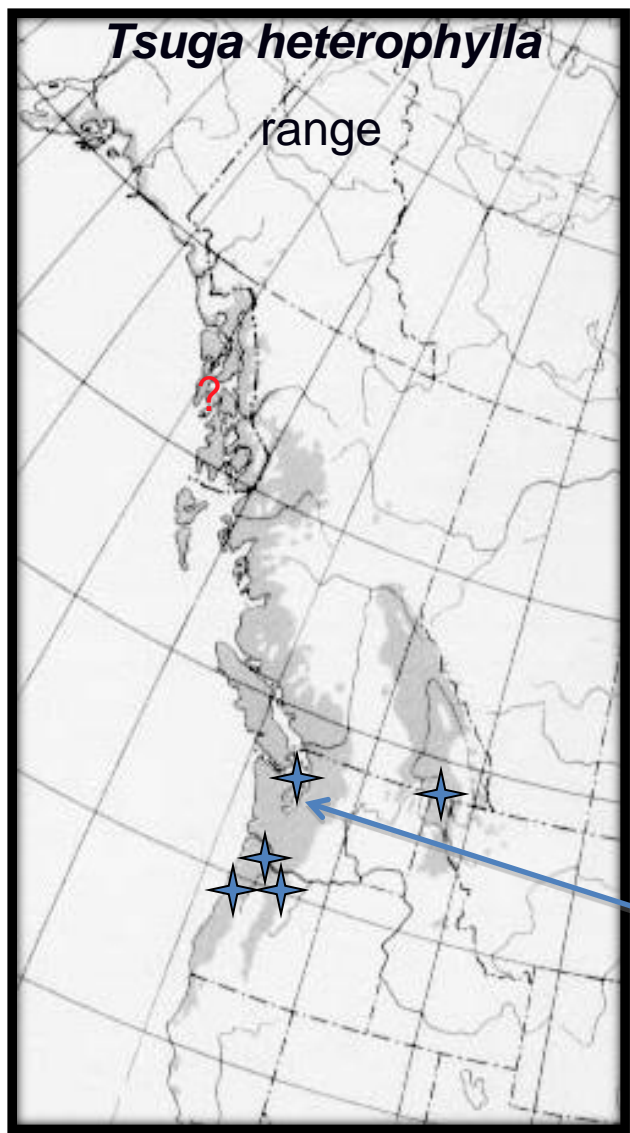
Lari active mid-October and DONE by April

Totally missed most important winter predator — Lari.

This threw folks off track for 10 years or more.

“It ain't what you don't know that gets you into trouble. It's what you know for sure that just ain't so.” Mark Twain

2006 - Hemlock Woolly Adelgid is native to PNW!
This was the game changer for us....



Success of HWA in E. North America??

By 2006 we knew:

- 1) HWA DNA native to Pacific Northwest!! Havill of FS.
- 2) Effective natural enemies;
- 3) **100s of naturally growing eastern and dozens of Carolina hemlocks in Seattle!!! WTH?**

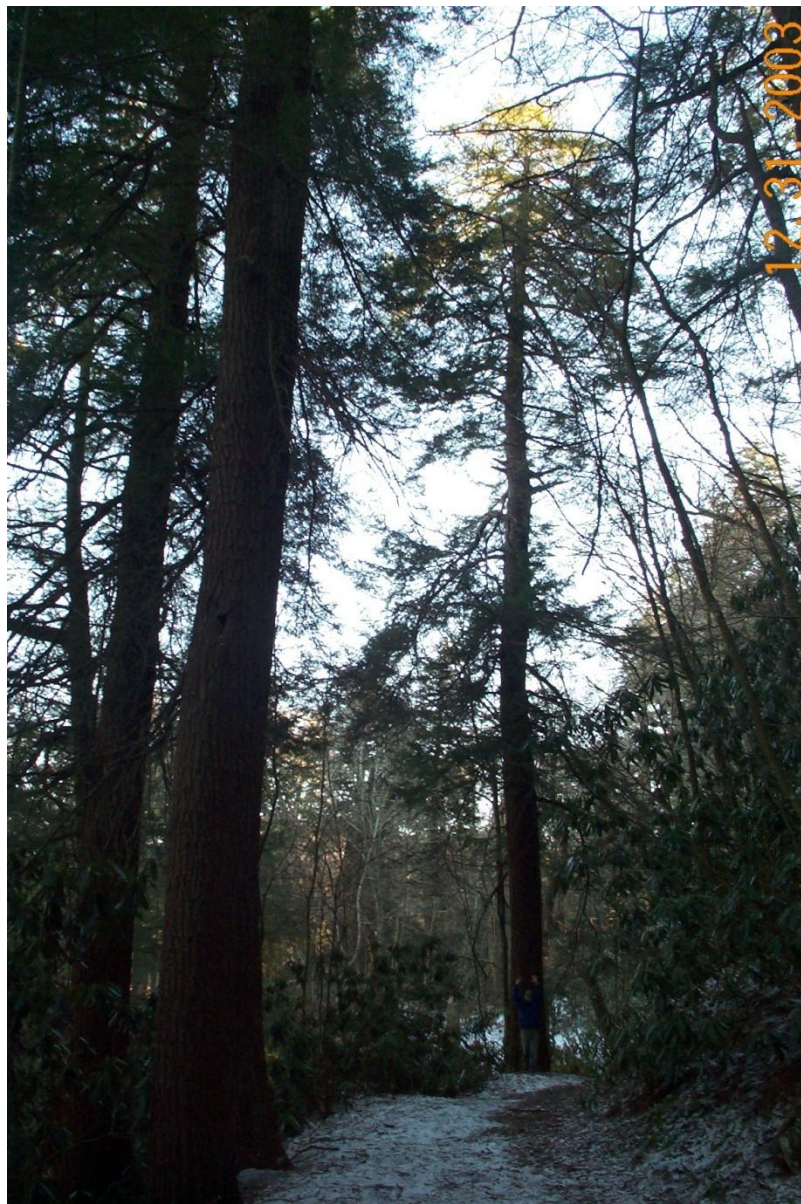


Photo: M. McClure

Mechanism of HWA feeding

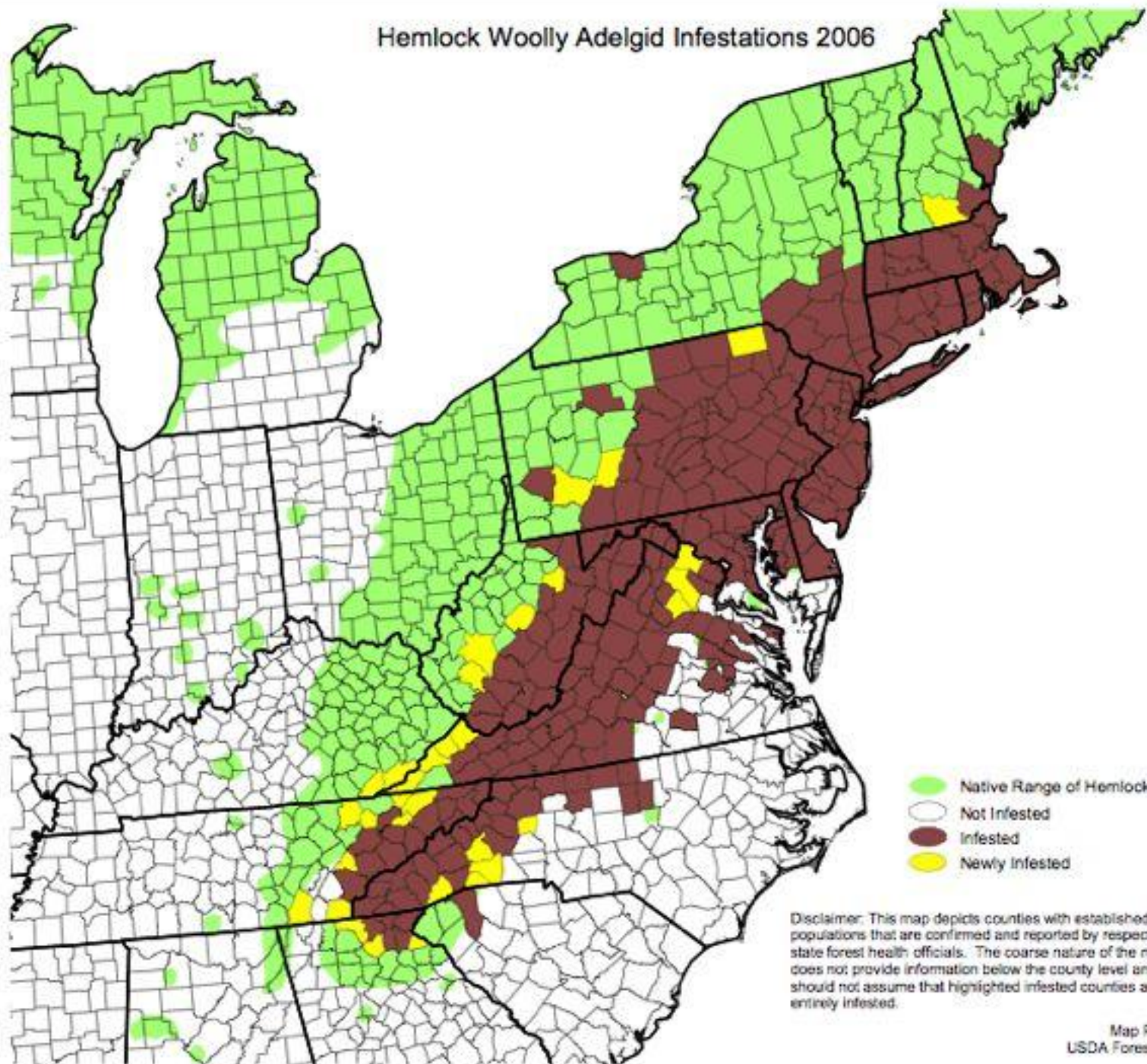
Google Image Result for <http://www.arboretum.harvard.edu/research/images/adelgid.jpg>

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An adelgid nymph feeding on a hemlock needle (left); crawlers in their protective cottony nests (above).

Hemlock Woolly Adelgid Infestations 2006



- Native Range of Hemlock
- Not Infested
- Infested
- Newly Infested

Disclaimer: This map depicts counties with established HWA populations that are confirmed and reported by respective state forest health officials. The coarse nature of the map does not provide information below the county level and users should not assume that highlighted infested counties are entirely infested.



Progress with HWA Biocontrol

1. Native winter predator *Laricobius nigrinus* established 80 miles in every direction from 2003 Banner Elk/GGCC NC release sites. (F11 generation) (Hemlock regrowth over 15,000 to 20,000+ square miles.)
2. *Scymnus coniferarum* – summer HWA predator discovered (2006).
3. Ultraviolet-A light reveals predation activity and HWA status.

Laricobius nigrinus

2-3 mm in length

Shining black

Fine erect ashy hairs

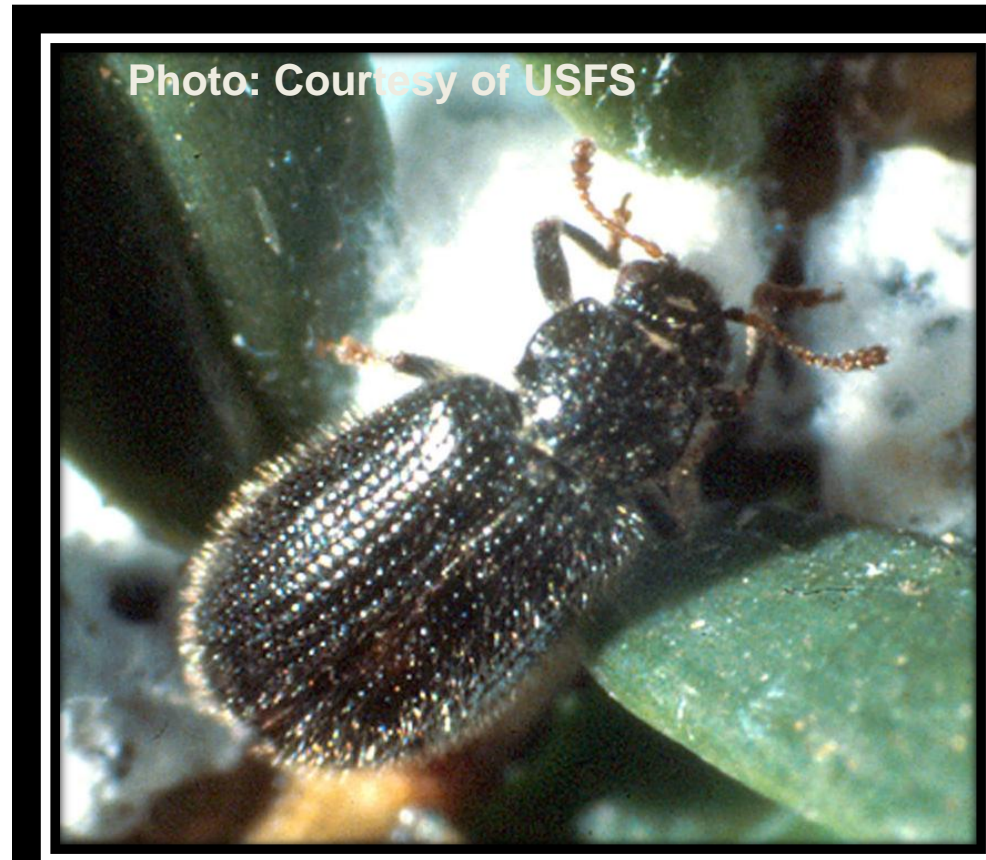
Striate elytra (10 rows-oval)

11 segmented antennae (club 3)

5-5-5 tarsal segmentation

Imported from Victoria B.C. to US in 1997 for study, approved for release by APHIS in 2000.

- **Winter active** predator!
- Host-specific to adelgids
- Synchronized with HWA
- High fecundity
- Long oviposition period
- Selective oviposition
- Consumes all HWA stages
- Long-lived (Oct.-May.)
- Females 3 June or later



Laricobius nigrinus studies in PNW

- Pan Pacific Entomologist 81(1/2): 97-98 (2005); 2001: **47% HWA ovisacs 'disturbed'**; **2002: 22% HWA ovisacs 'disturbed' @ WPA**
- **March 2005:** David Mausel & I go to Seattle to study this beetle.
- 600/1200 ovisacs have a Lari egg or larva in them (50%).
- 94% (564) of the remaining 600 ovisacs were eaten by predators (Lari); (47%).
- **50% + 47% =97% predation rate.**
- HWA populations crashed.
- Mausel & Prof. Gara got the nearly the same rates in 2001.



Photo: Courtesy of USFS



Laricobius nigrinus egg (yellow) above a cluster of HWA eggs.
(Photo: Mausel).



Laricobius nigrinus larva inside HWA ovisac; a single larva consumes 220-250 eggs to complete development.

(Photo: Mausel)

Release Site #1 - Hemlock Hill

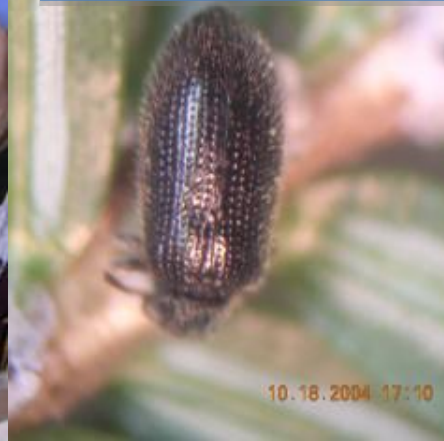
- **Site #1 - Hemlock Hill, Lees McRae College, Banner Elk, NC**
- **Unique Old Growth Stand (30 acres)**
- 300 Beetles released **31 Dec 2003**; 30 beetles per tree/10 trees. Five trees along river; five above on ridge. (-1 degree C)
- HWA moderate (29% tips infested)



Initial release of *Laricobius nigrinus* in NW NC.



Dr. Gina Luker – recovers 2 F1 Ln 16 Oct 2004 along with Prof. Stewart Skeate.



- Dr. David Mausel, Virginia Tech, released 300 Lamb-lab-reared *L. nigrinus* adults on 31 Dec 2003 @ Hemlock Hill, Banner Elk & 150 adults Oct 2004 at Holloway Mountain. These were two of Dr. Mausel's 22 release sites on the east coast. Dr. Luker was the NC state forestry liason for the NC releases.

L. nigrinus Sampling: Beat Sheets

- Sampling started in 2004, the following fall post-release
- Mid September - November
- Twice per month ($\Sigma = 12$)
- 4 - 8 branches/release tree
- Recorded the number of *Ln* found, tree #, weather, sampling time, date, etc.

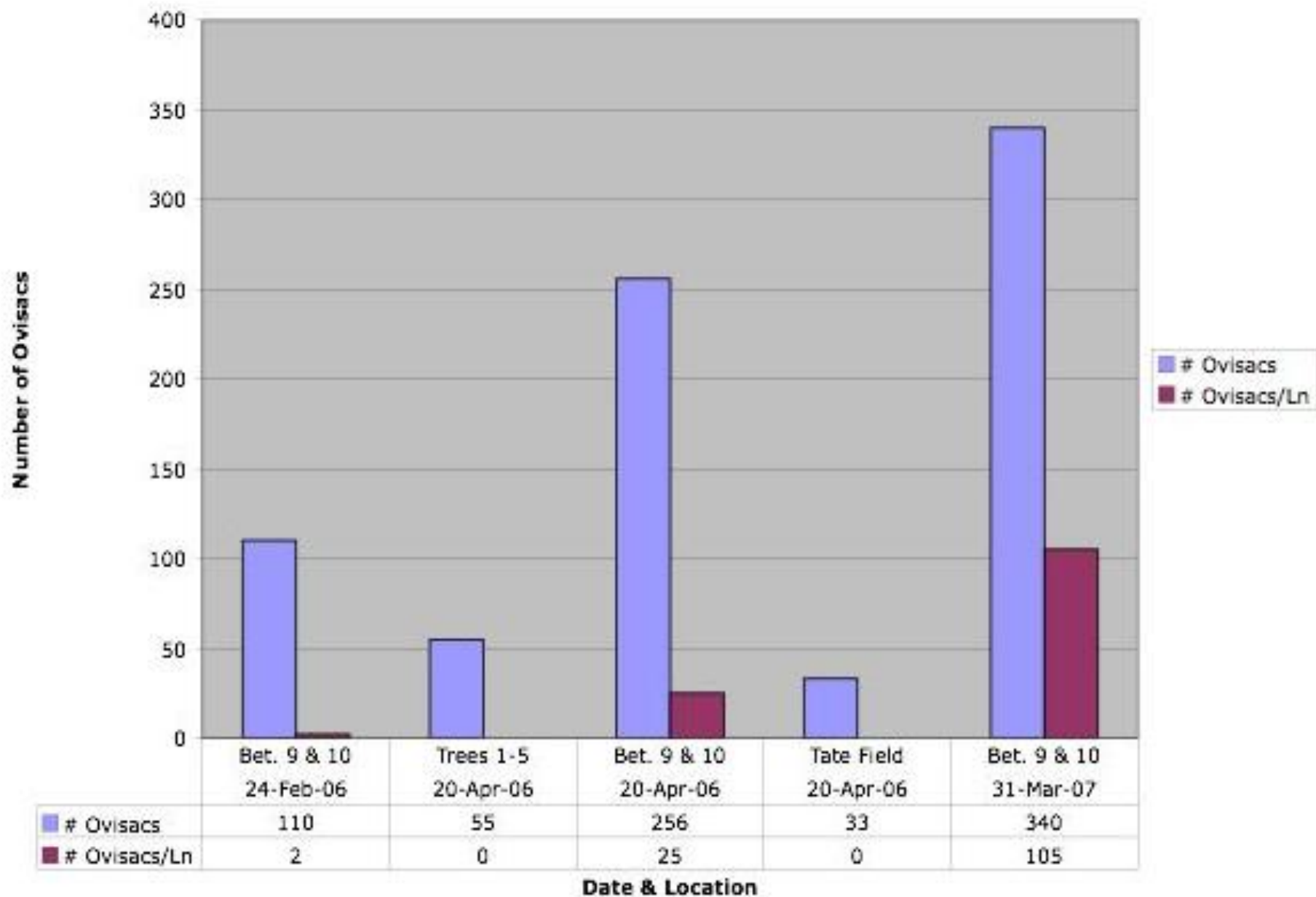




L. nigrinus Additional Sampling: Ovisac Dissections

- HWA collected in late March (2 branches/tree, mid-upper canopy)
- Branches brought back to Laboratory, dissect ovisacs to determine presence of Ln egg/larva.

Predation Rate of HWA Ovisacs at Hemlock Hill



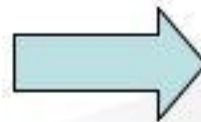
Seattle, Washington
Same Trees w/Ln;
2005 vs.2006

- Increasing *L. nigrinus* populations
- Significant impact on HWA populations
- Improved or maintained hemlock health

Tsuga heterophylla

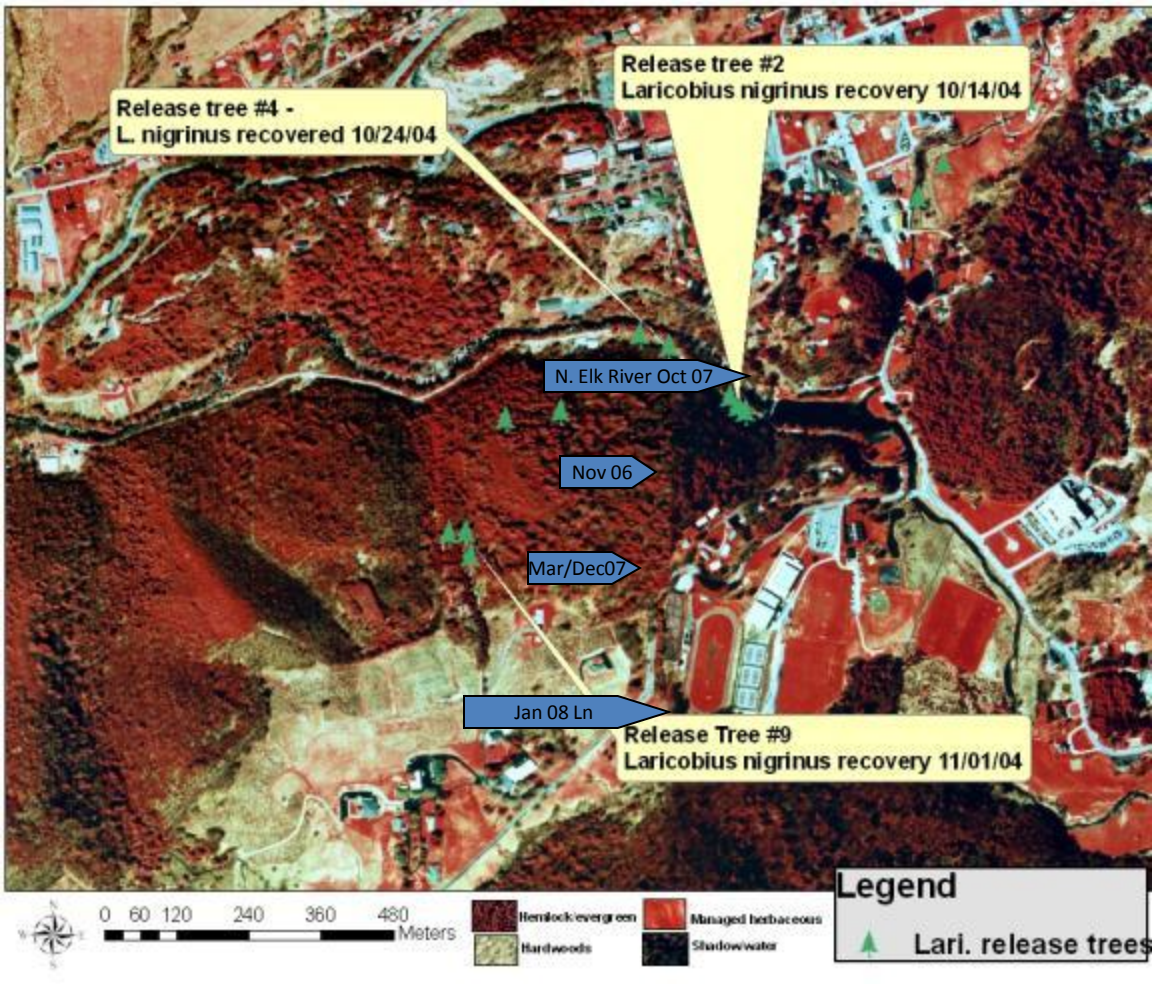
2006 -Same branches
Low HWA

Tsuga heterophylla
2005 - High HWA; High
Predation rate by Ln



L. nigrinus Dispersal

Laricobius release site Hemlock Hill, NC



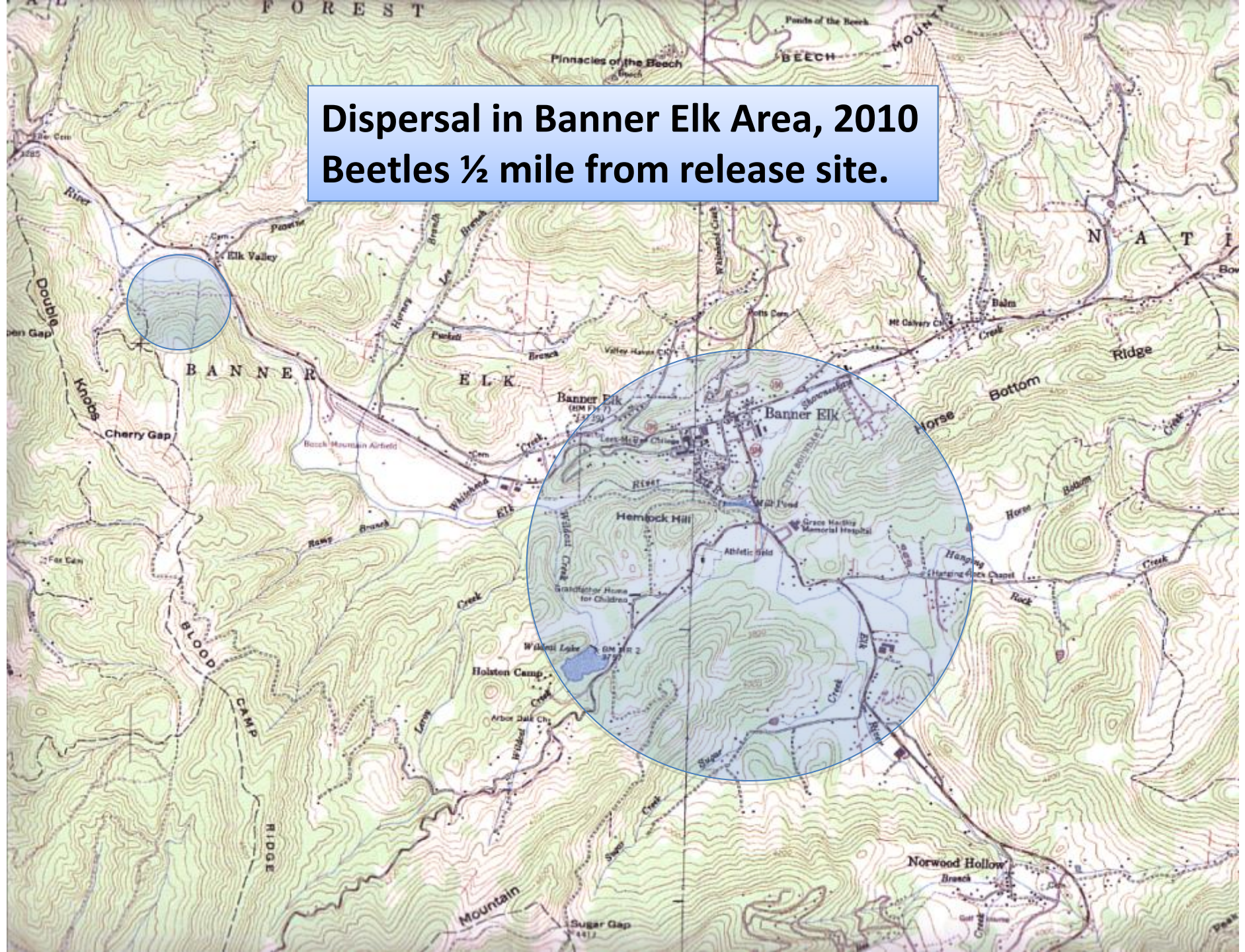
Mid-November 2006 – 1 adult,
main ridge of Hemlock Hill,
300+ meters from the nearest
release tree.

March 2007 - 1 adult,
600 meters from nearest
release tree.

December 2007 - 2 adults ,
same area as above

January 2008 – 1 adult,
800 meters from nearest
release tree and on opposite
site of open athletic field.

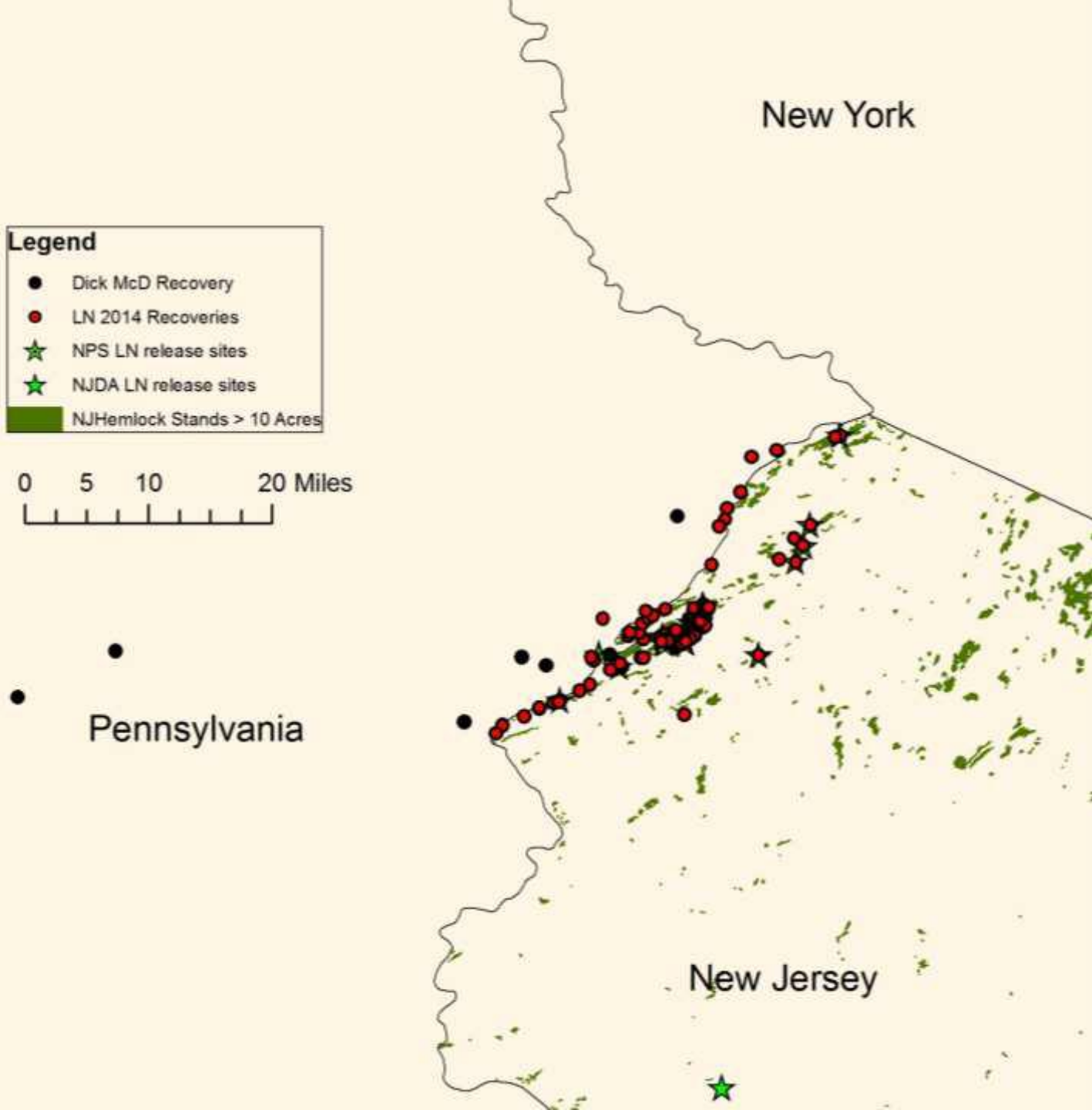

**Dispersal in Banner Elk Area, 2010
Beetles ½ mile from release site.**



Legend

- Dick McD Recovery
- LN 2014 Recoveries
- ★ NPS LN release sites
- ★ NJDA LN release sites
- NJHemlock Stands > 10 Acres

0 5 10 20 Miles





From February 2008-2012, Grandfather Golf and Country Club released 13,000+ wild caught *L. nigrinus* from Seattle, Washington.



Grandfather Mountain (GGCC) – 1,980 M tall
Dispersed *L. nigrinus* beetles like a volcano.



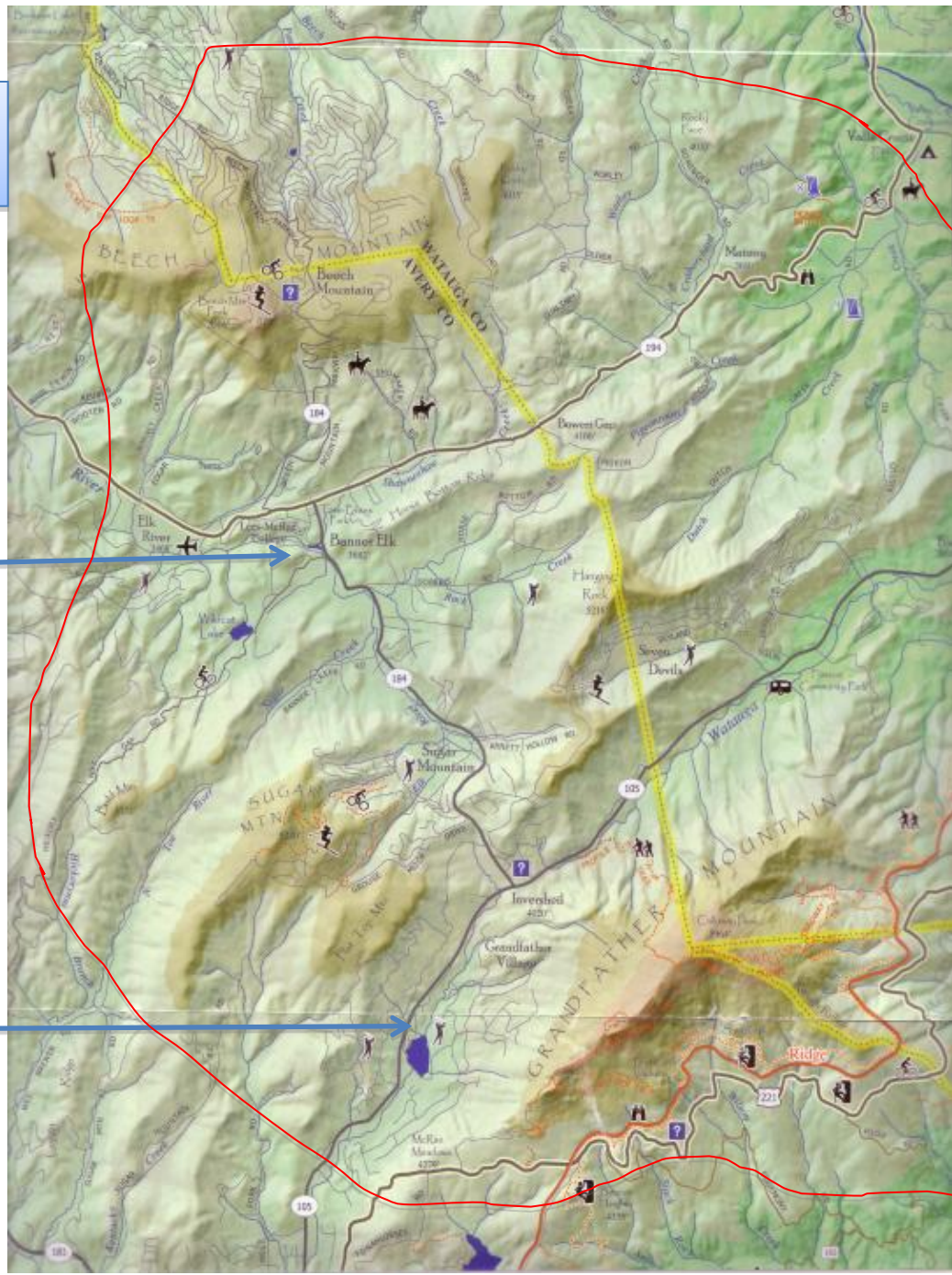
Release Sites
& Recovery Areas

Approximate area
of recoveries in 2012

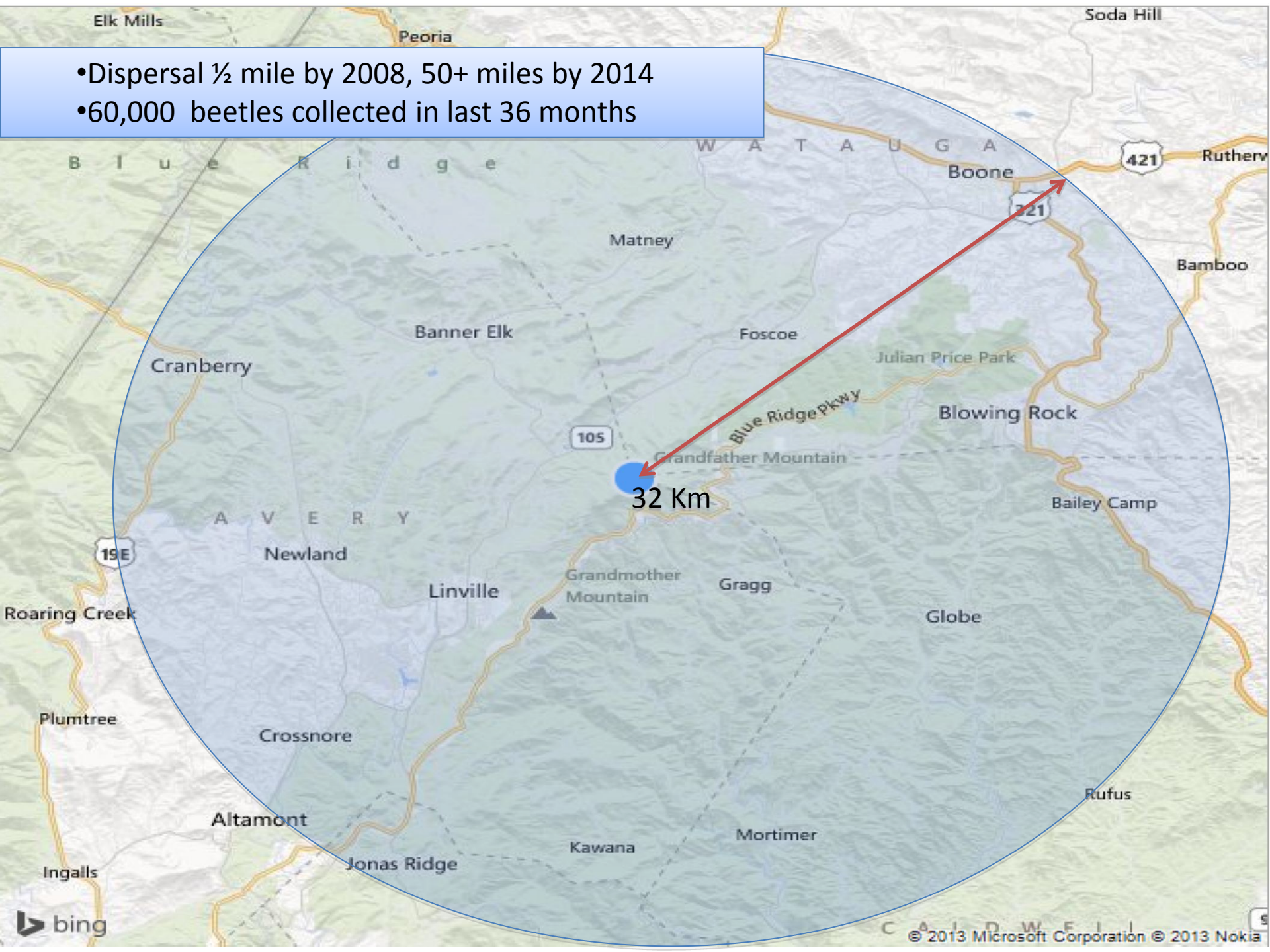
Banner Elk

Grandfather

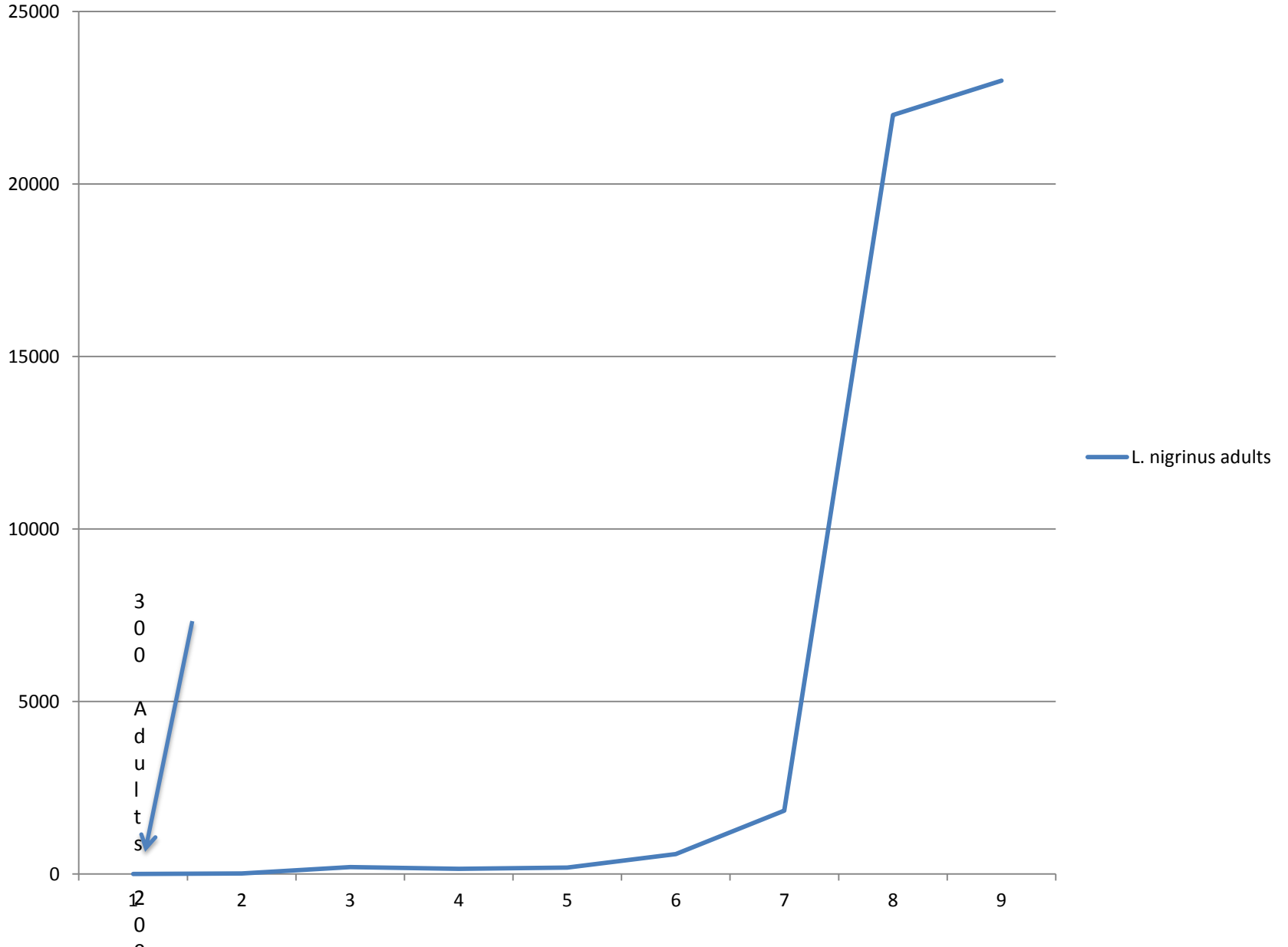
Holloway



- Dispersal ½ mile by 2008, 50+ miles by 2014
- 60,000 beetles collected in last 36 months



L. nigrinus adults



Plot Lat/Long Points on Map by Coordinates

1526 335 519
Share Tweet Google +

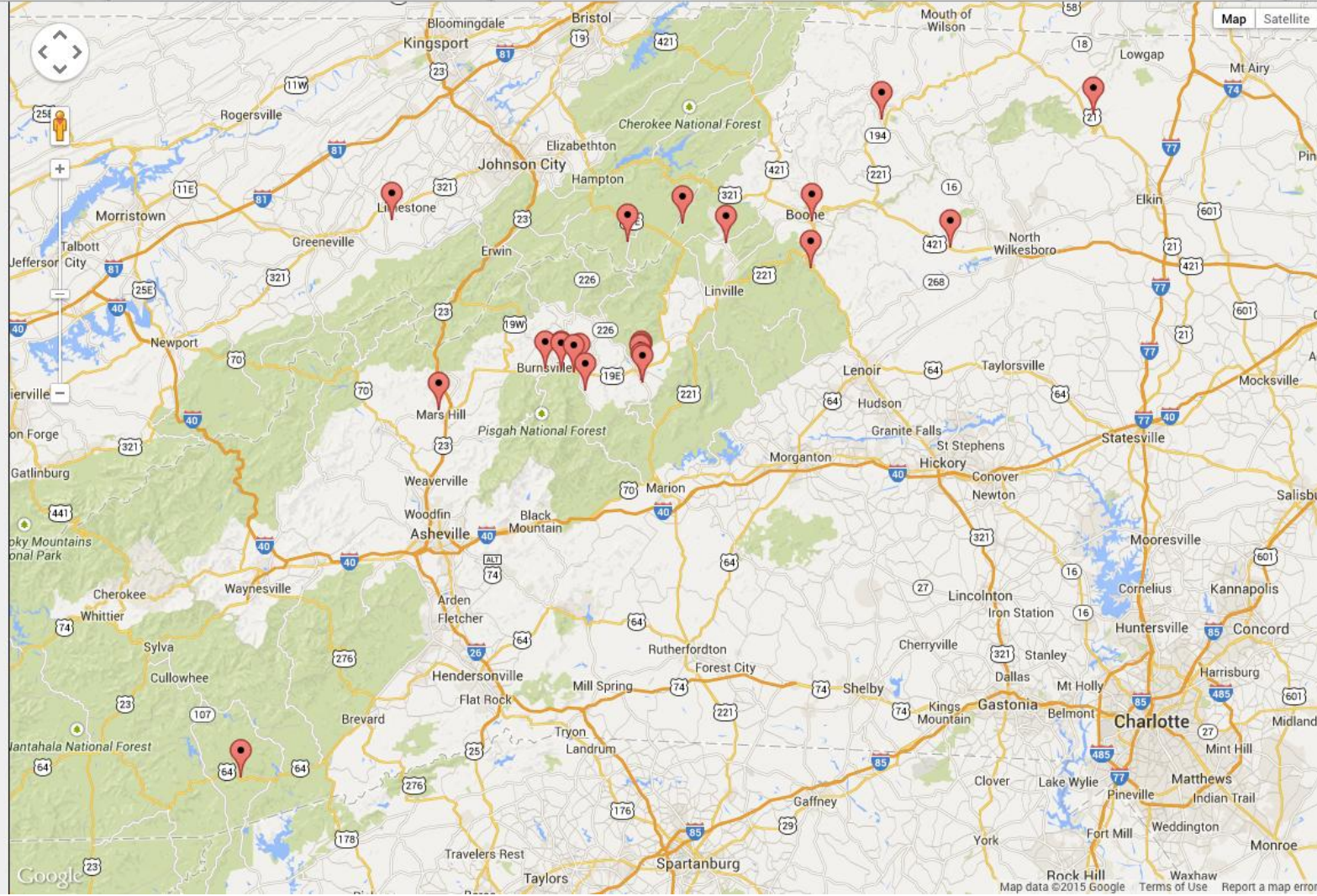
INSTRUCTIONS:
Enter Lat/Long Coordinates (one per line in format: lat,long [no spaces] - [see example](#))
Note: more than 2,000 points will be slow.

Coordinates (Format: lat,long in decimal form):

- 35.88806, -82.0661
- 35.8933, -82.06861
- 35.9096, -82.0719
- 35.9116, -82.0688
- 35.9100, -82.2305
- 35.9138, -82.2597
- 35.9155, -82.2602
- 35.9161, -82.2986
- 35.9113, -82.2150
- 36.2036, -82.6655
- 36.2016, -81.6577
- 36.1594, -81.8658
- 36.4083, -80.9830
- 36.1508, -81.3250
- 36.1988, -81.9691

Plot Map Points

More updates coming soon!
Please send questions, comments and feature requests to:
Darrin@DarrinWard.com
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Release trees one through five along the Elk River. Pronounced regrowth occurred, starting in July 08 and lasting until mid-August.

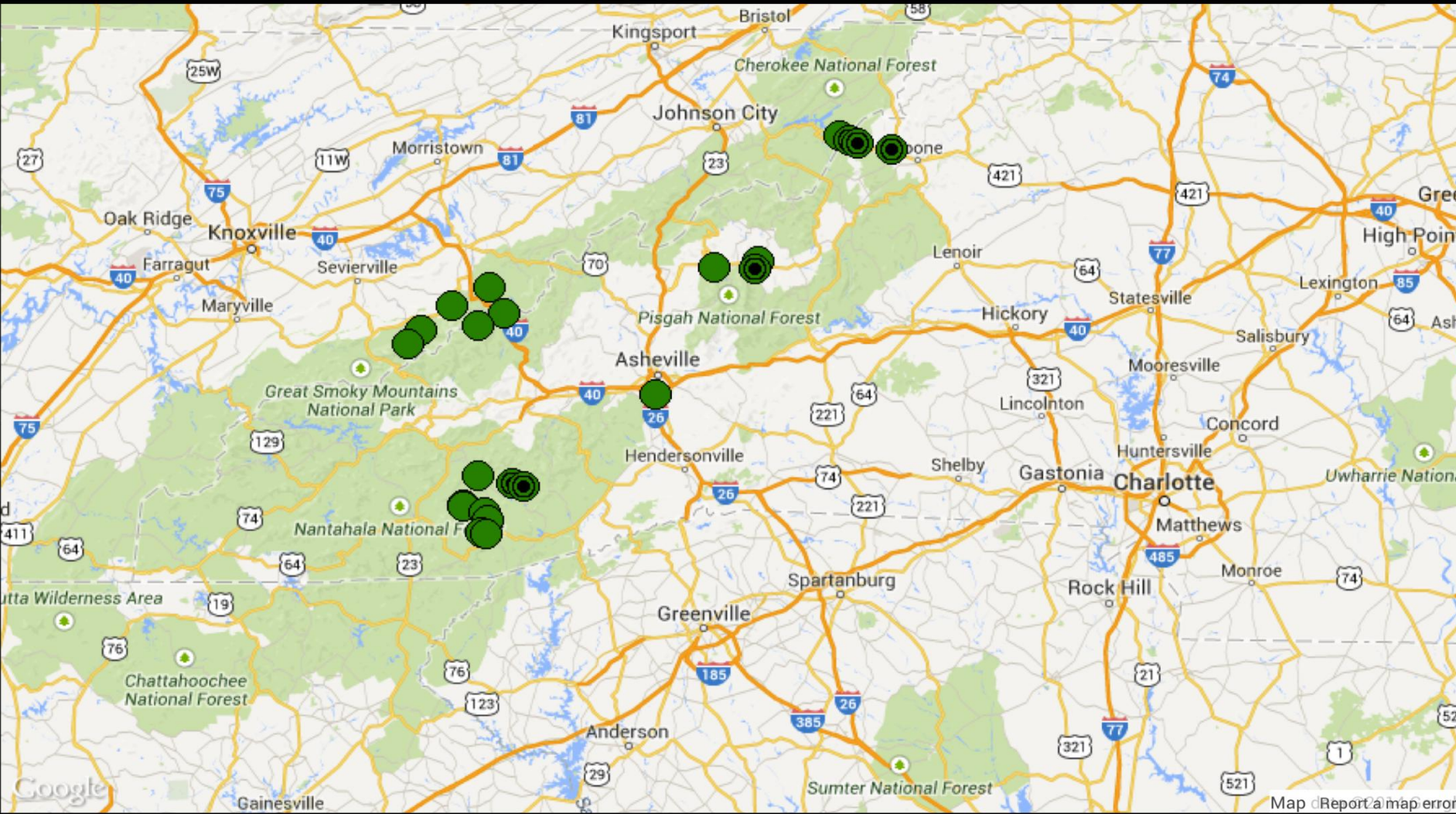
Looking North to Beech, Flat Top, Sugar, and 7 Devils Mtns - Peaks and valleys where *Laricobius nigrinus* has dispersed and is generally established – 5000 square miles.



A panoramic view of a mountain range. The foreground is dominated by dark green evergreen trees. The middle ground shows rolling hills covered in a mix of evergreens and deciduous trees with brownish foliage. A winding road is visible in the valley. The background consists of numerous layers of mountain ranges, creating a sense of depth and distance. The sky is overcast with soft, grey clouds.

Looking southwest towards
Hawksbill/Table Rock Mtns.
Ln found at base of Hawksbill
On Carolina Hemlocks. Black
Mountains in distance have
L. nigrinus in Celo Valley.

	Release	Post-release survey
<i>Sasajiscymnus tsugae</i>		
<i>Scymnus sinuanodulus</i>		
<i>Laricobius nigrinus</i>		



Success of *Laricobius nigrinus* in the mountains of northwestern North Carolina

- **Successful control of HWA with one predator.**
- **Once hemlocks have less than 30% of needles infested, they grow like normal – predators drop level below 30%.**
- **Beetles consume 97% of dense HWA populations.**
- **Predation causes patch dynamics of HWA.**
- **Massive hemlock regrowth over 5000 square mile area.**
- **Operational levels of beetles because of urban community interface – we collect 1000s in city setting.**

Overview

1. Native HWA winter predator *Laricobius nigrinus* established (F11) 80+ miles in every direction from Banner Elk NC release sites.
(Hemlock regrowth over 20,000 square miles.)
2. *Scymnus coniferarum* – summer predator.
3. Ultraviolet light reveals predation activity and HWA status.

Scymnus coniferarum Crotch (Scw) – Western hemlock (*Tsuga heterophylla*) was new record host tree and HWA was a new host. Predator is active during the 2nd (summer- progrediens) generation of HWA. Photo: Nathan Havill USFS.



2 Ecological Zones:

1) Mesic cove – wet

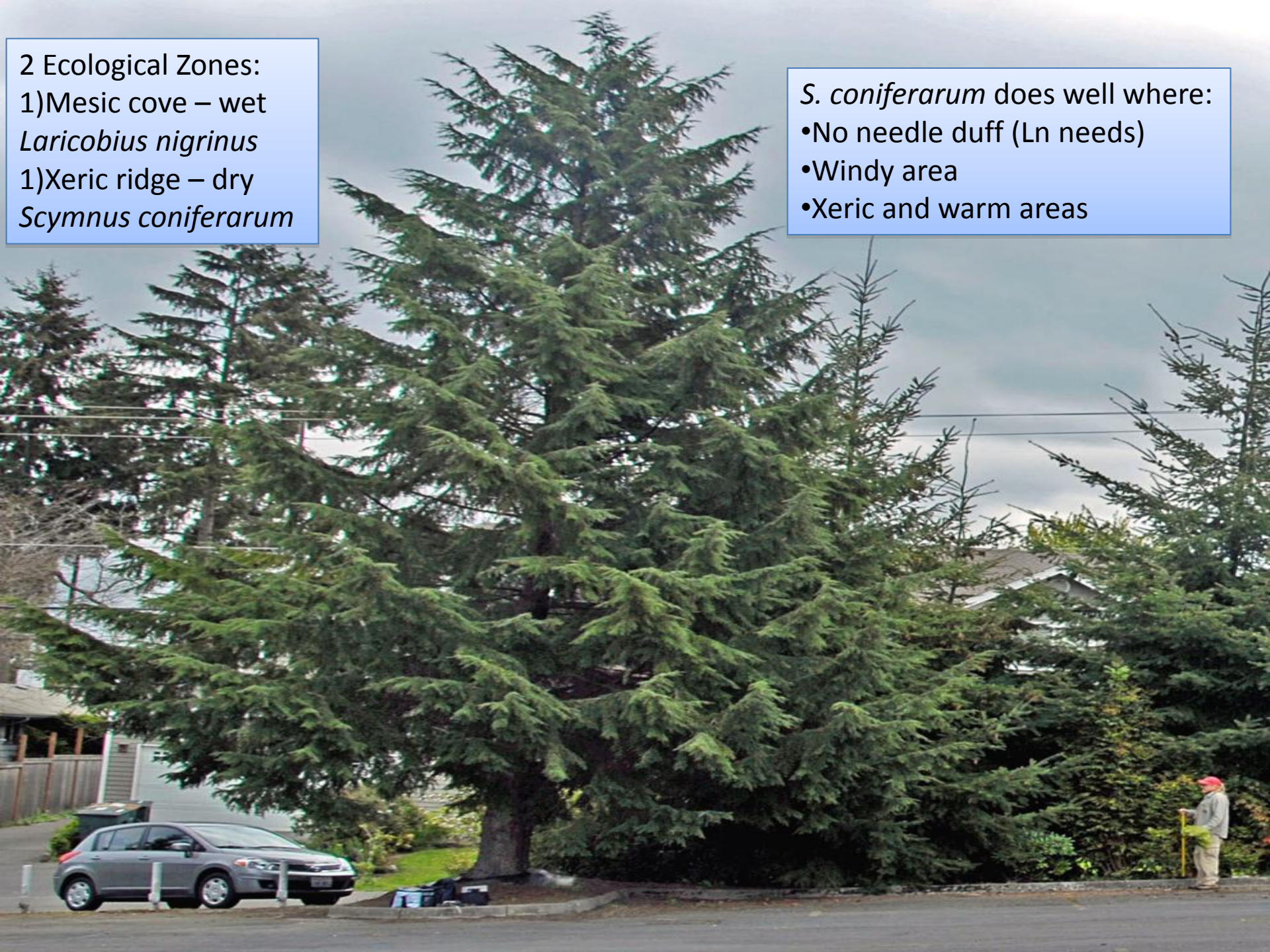
Laricobius nigrinus

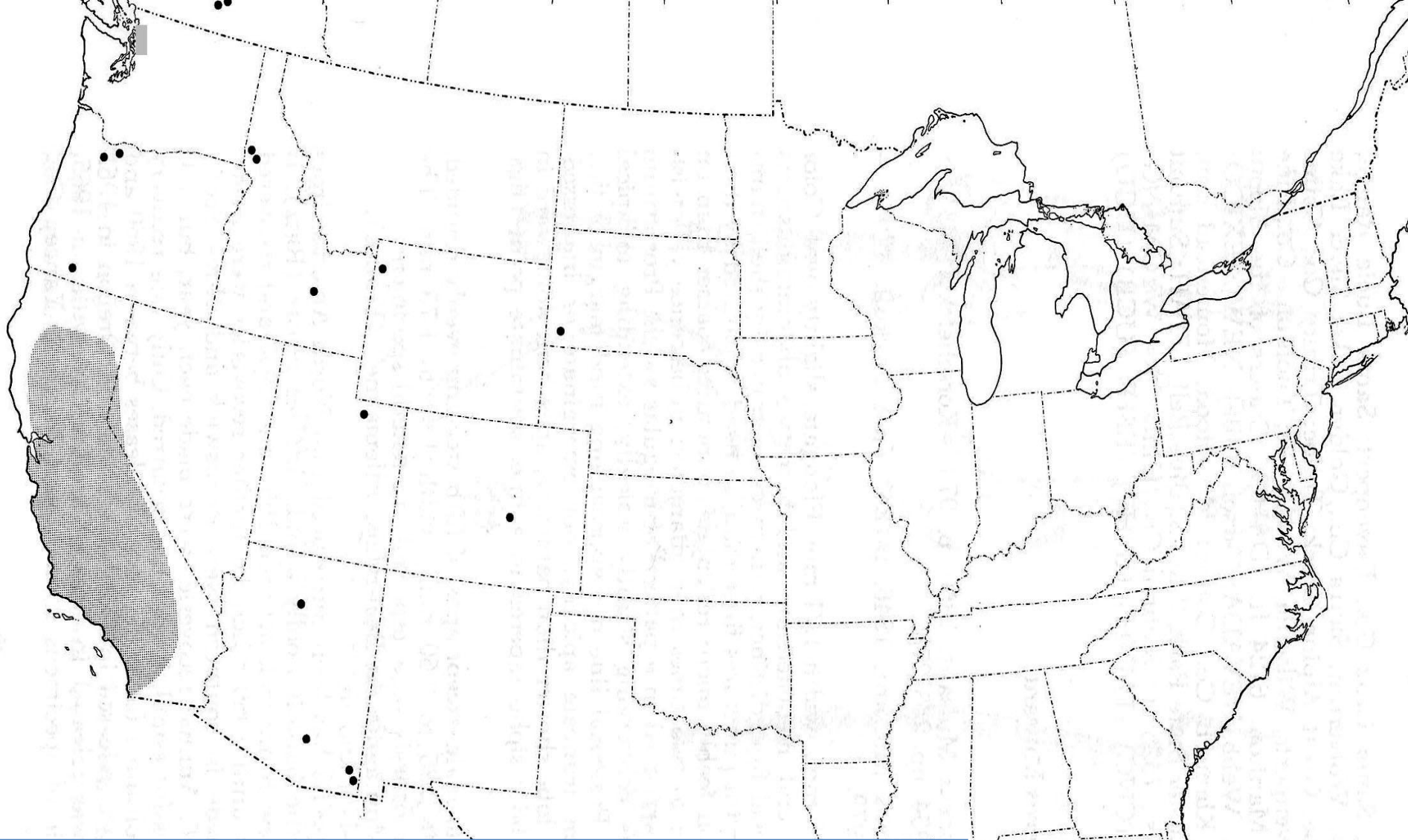
1) Xeric ridge – dry

Scymnus coniferarum

S. coniferarum does well where:

- No needle duff (Ln needs)
- Windy area
- Xeric and warm areas





Collection records of *Scymnus (P.) coniferarum* based on museum specimens; shaded = general area of many collections with dots showing peripheral localities (from Gordon 1985); grey rectangle is area of recent collections in the Seattle area.

Progress with *Scymnus* *coniferarum*

- Permit approval Sept. 2012 (recent)
- Reproduces within tree – Ln must leave tree to pupate.
- *Xeric Habitat*: hemlocks that don't have needle duff (wind).
- Parking lots, parks, temples, cemeteries, etc.
- Nature? bluffs, rocky outcroppings, mountain ridges, along rocky creeks/rivers, windy areas.
- **Alternate adelgid hosts – Pines, firs, spruces.**
- ***BRACKETING-** Predator for every life stage of HWA.*

Pine adelgids & Pollen are important;
able to collect 1000s in PNW (Lari).



Overview

1. Native HWA winter predator *Laricobius nigrinus* established (F11) 80+ miles in every direction from Banner Elk NC release site.
(Hemlock regrowth over 20K square miles.)
2. *Scymnus coniferarum* – summer predator.
3. Ultraviolet light reveals predation activity and HWA status.

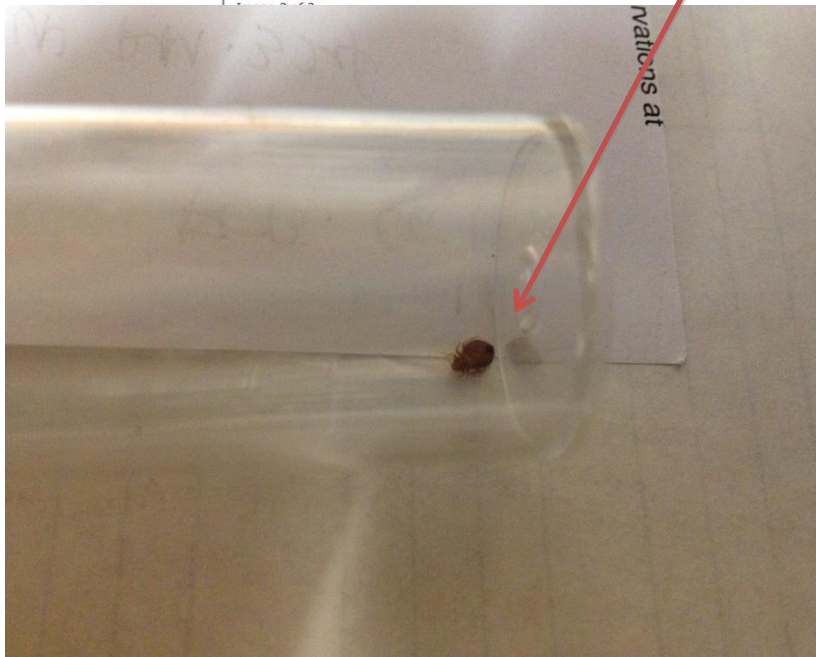
U/V SPY PEN



Click to Enlarge



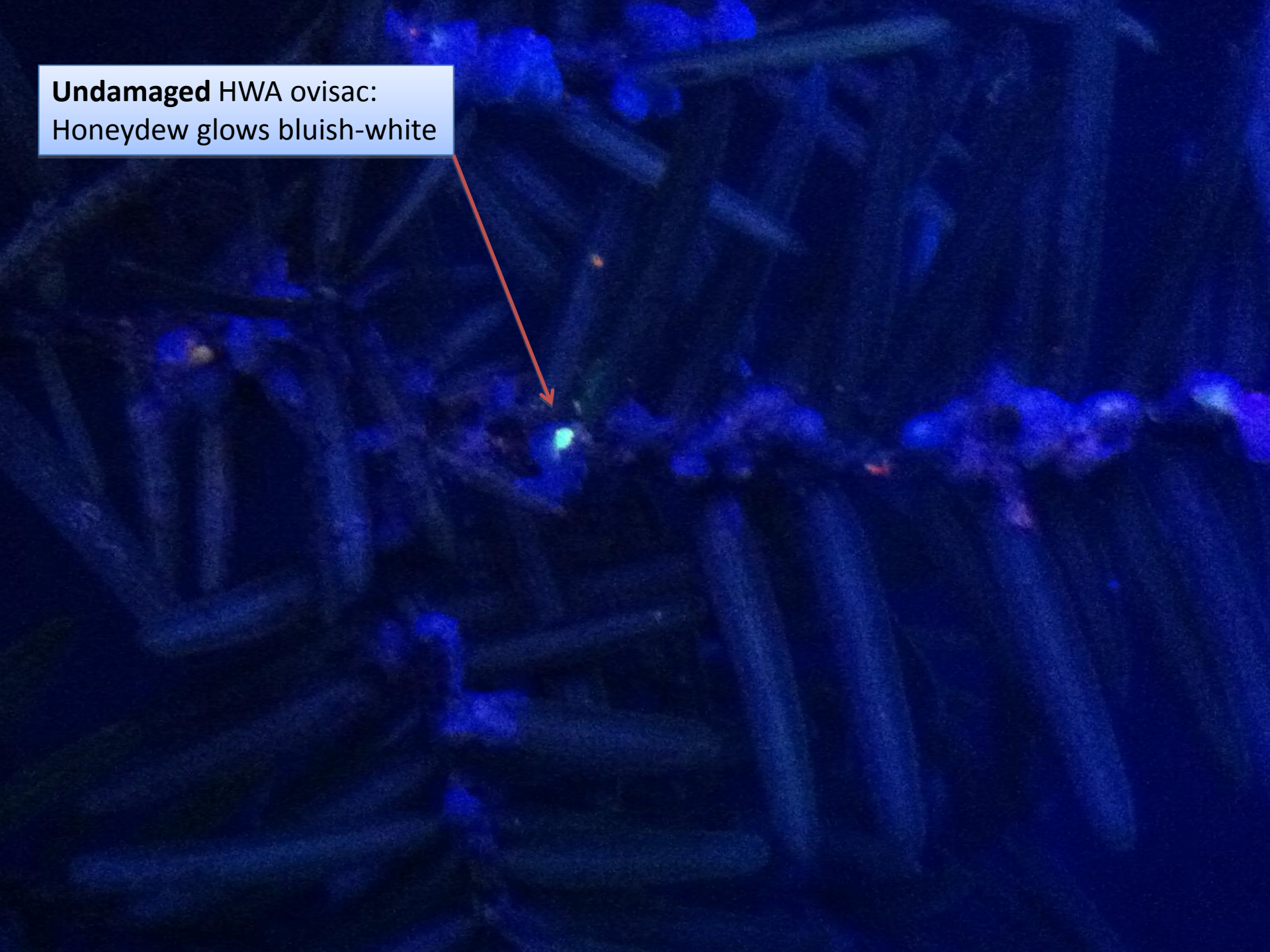
U/V Spy Pen



Ultraviolet Light reveals:
Predator frass is orange



Undamaged HWA ovisac:
Honeydew glows bluish-white



Damaged HWA adults hemolymph:
Glowes chartreuse (yellow-green)





Damaged HWA eggs glow:
Bright yellow

**A Simple Method of Detecting Hemlock Woolly Adelgid (Hemiptera: Adelgidae)
Predator Activity Using Ultraviolet-A Light**

R.C. McDonald and L.T. Kok - Journal of Entomological Science (In Press). March 2014

Table 1. Colors of the fluorescence of the series of Aphins-*fb* in acid, neutral, and alkaline media under UV-A light.*

Medium	Protoaphin	Xanthoaphin	Chrysoaphin	Erythroaphin
Acid	Dull green	Blue-green	Intense chartreuse	Orange-red
Neutral	Dull green	Blue-green	Intense chartreuse	Orange-red
Alkaline	Dull violet	Brilliant chartreuse	Brilliant chartreuse	Dark ruby-orange

*After Duewell et al. (1948) in: Rockstein et al. *Biochemistry of Insects* (1978) p.248.

Summary – HWA progress

1. *Laricobius nigrinus* established (F11) 80+ miles in every direction from Banner Elk NC release site. Hemlock regrowth 20,000 square miles.
2. *Scymnus coniferarum* – summer predator.
3. Ultraviolet light reveals predation activity and HWA status. Need lots of help here!
4. Replant areas, resurrect nurseries, TRAIN
5. Baseline data – then Airplane plant analogy



Funding for Program

Funding for this project was provided in part through an Urban and Community Forestry Grant from the North Carolina Division of Forest Resources, Department of Environment and Natural Resources, in cooperation with the USDA Forest Service, Southern Region.



Grandfather Golf & Country Club

Collection & Redistribution of *Laricobius nigrinus*



Collecting *Laricobius nigrinus* in the Pacific Northwest

- Working with the Virginia Tech team, we found that *L. nigrinus* occurs in high numbers at selected locations in the PNW
- **Able to collect 1000's of beetles from the field for redistribution back East**
- Field collected beetles are *twice as fertile* as laboratory reared beetles











ClampOn





A clear plastic container with a black cap is attached to the lock assembly. The container is empty and has some faint markings on its side.

0106

A set of keys is attached to the lock assembly. The keys include a black keychain with three buttons labeled "HATCH GLASS", "UNLOCK", and "LOCK". There is also a white tag with a barcode and the text "HITCHES ADVANTAGE".



Shipping & Redistribution of *L. nigrinus* to HWA infestations in the Eastern US



- *L. nigrinus* adults are field collected and packed carefully to be kept cool during shipment.
- Containers are shipped overnight to selected locations for immediate (next day) release of beetle adults.