Biological Control of the Hemlock Woolly Adelgid, *Adelges tsugae*, in the eastern United States

Where we've been and directions for the future

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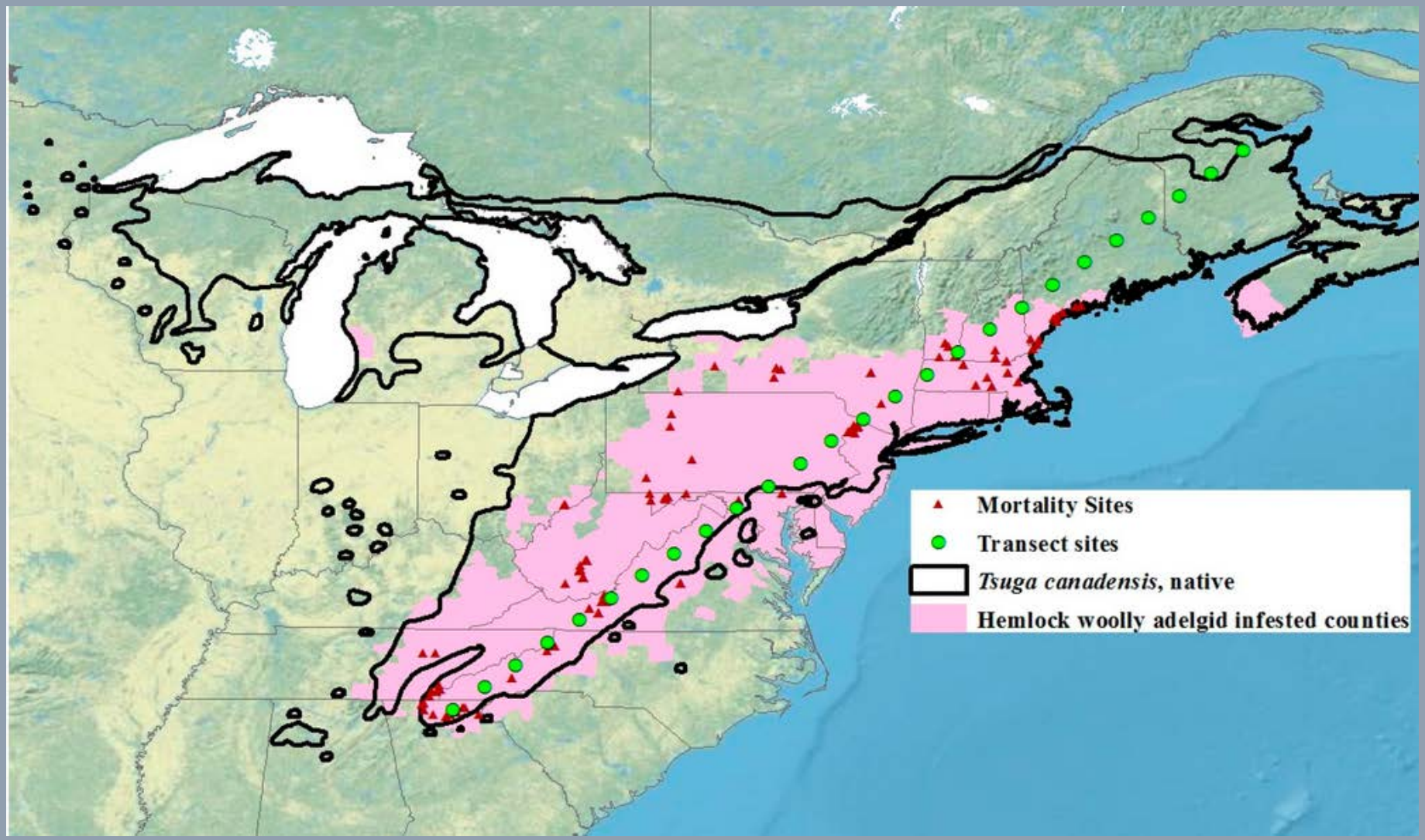
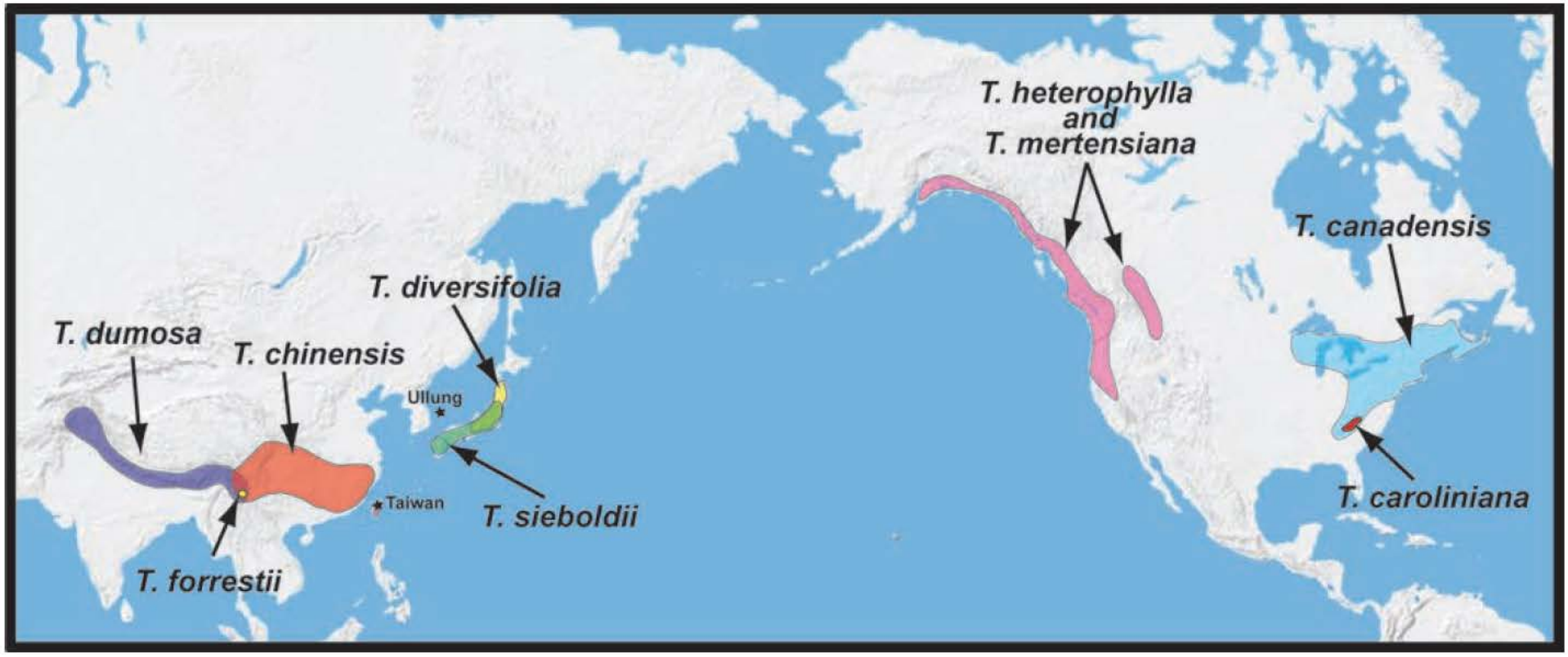
Introduction and Spread in the eastern US

- Early 1900's first introduced in Richmond, VA area likely on nursery stock from southern Japan
- 1951 first sample placed in national museum from Richmond, VA area. This was then noticed when trees were found impacted in 1970's
- Has since spread to include almost all of the southern distribution of *Tsuga canadensis* and all that of *T. caroliniana*

HWA Distribution 2017



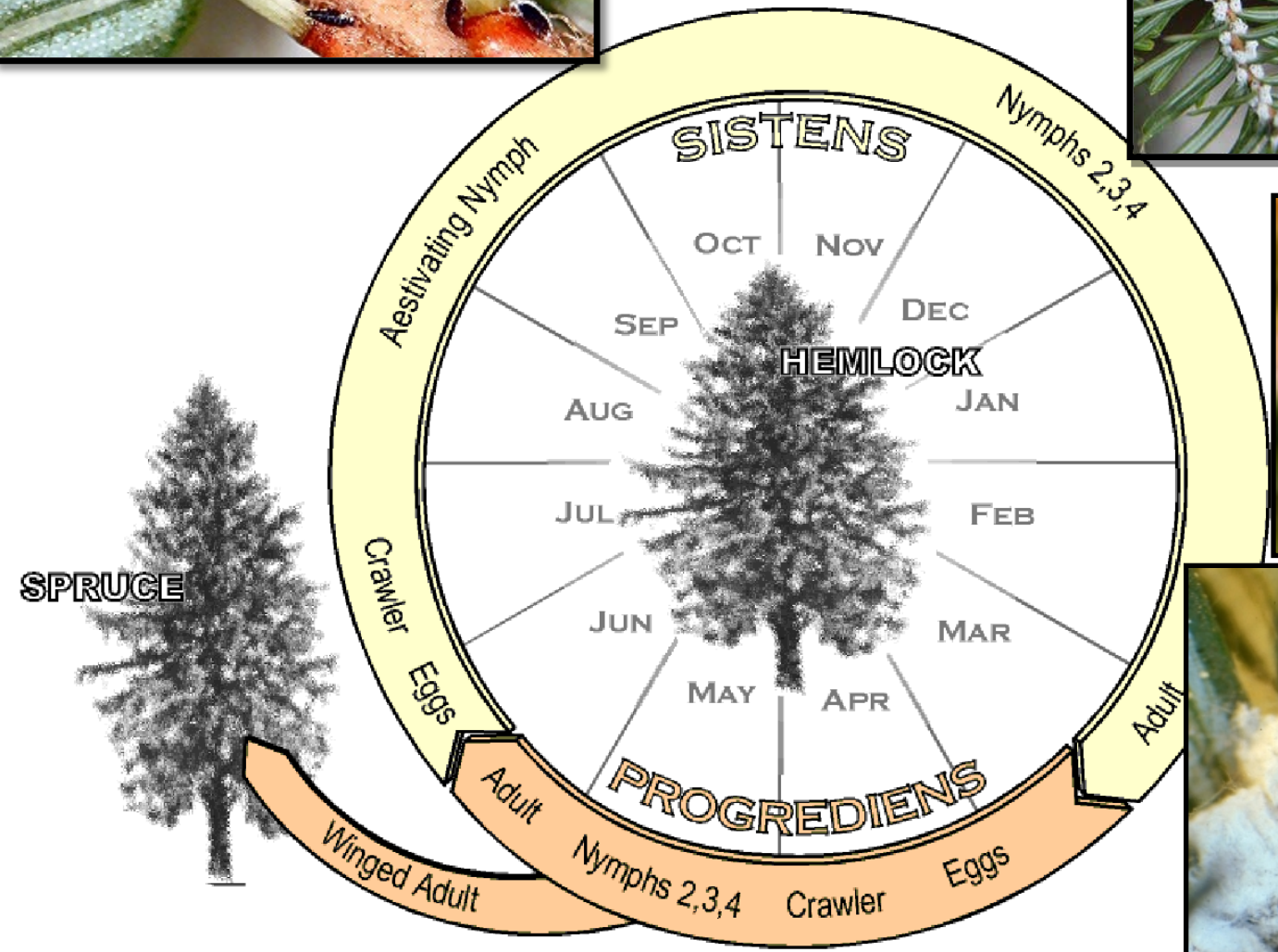
McAvoy et al. 2017



Worldwide distribution of HWA and Tsuga species.

Havill 2008

Life Cycle


SISTENS
PROGREDIENS
HEMLOCK
SPRUCE
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
Aestivating Nymph
Nymphs 2,3,4
Adult
Eggs
Crawler
Winged Adult
Adult
Nymphs 2,3,4
Crawler
Eggs


crawler
UGA5018073

Hemlock Woolly Adelgid
The Problem

- Asexual reproduction (all females)
  - One individual can start a new population
  - High Reproductive Potential
    - 2 generations per year & up to 200 eggs/female, but generally less
    - 1 x 100 x 50 = 5,000 potential progeny from 1 female/yr.
- Native natural enemies are lacking in the Eastern North America
- No documented resistance by Eastern or Carolina hemlock

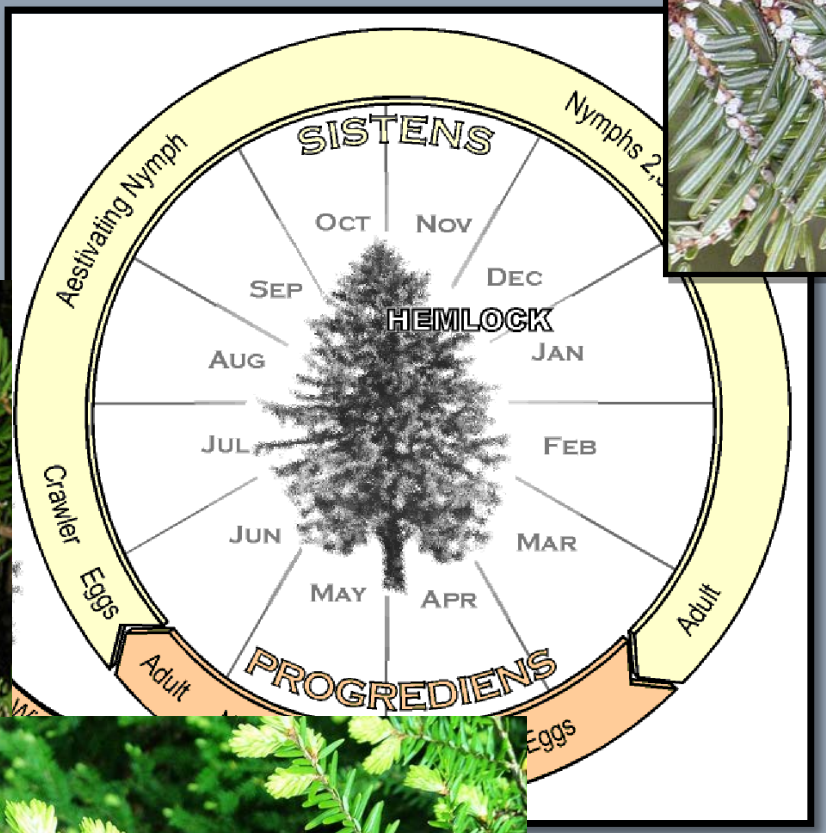
Impact on trees

- Inserts stylets into twigs near base of needles, feeds on xylem ray parenchyma cells
- Feeding kills buds first then the needles
- Usually kills trees within 4 to 10 years, it takes longer in mesic sites, up to 20 years.

Yearly tissue infestation cycle

Winter Sistens

Early summer Sistens settle on current years shoot growth

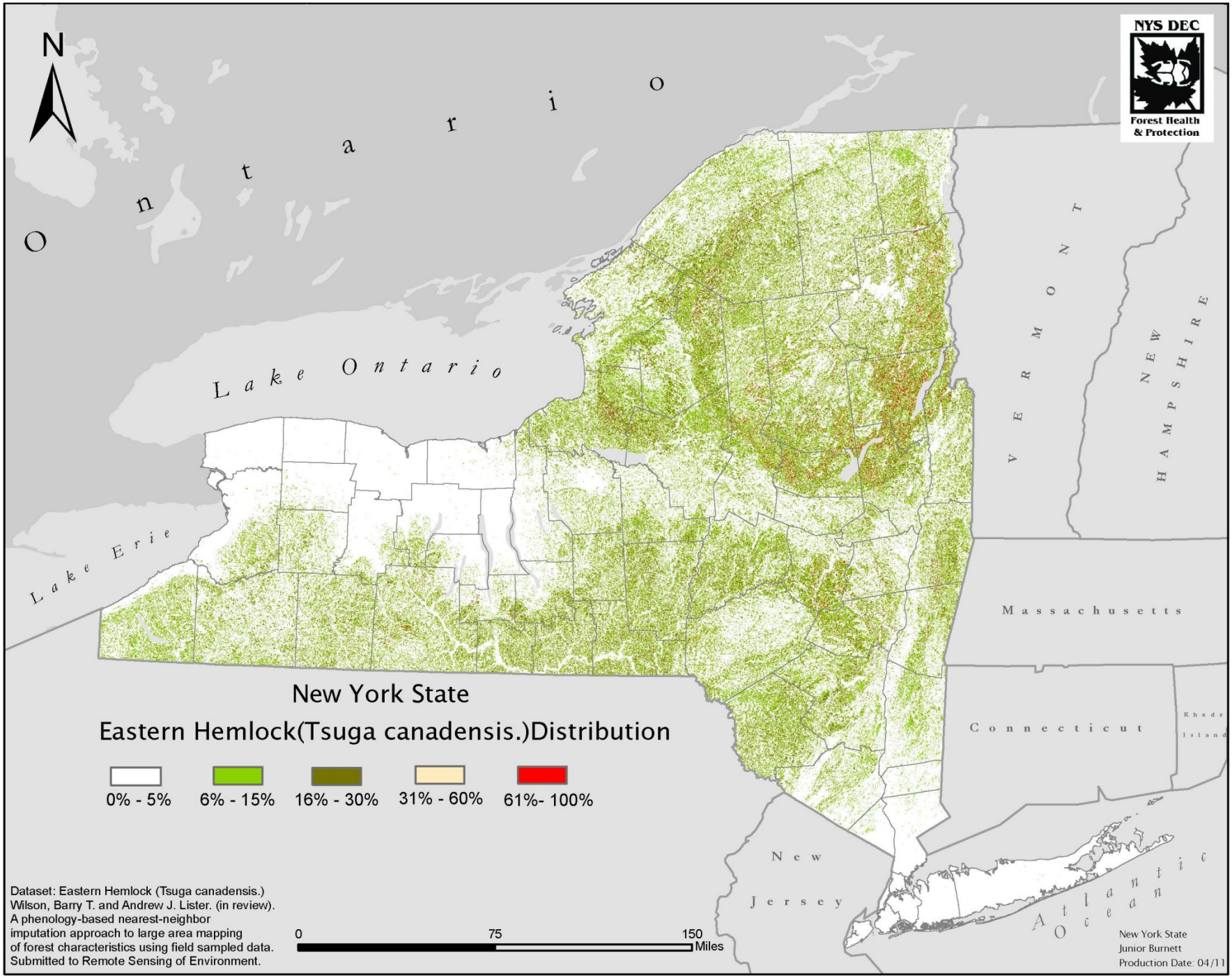


Spring Progrediens on shoots from previous spring, with their mothers

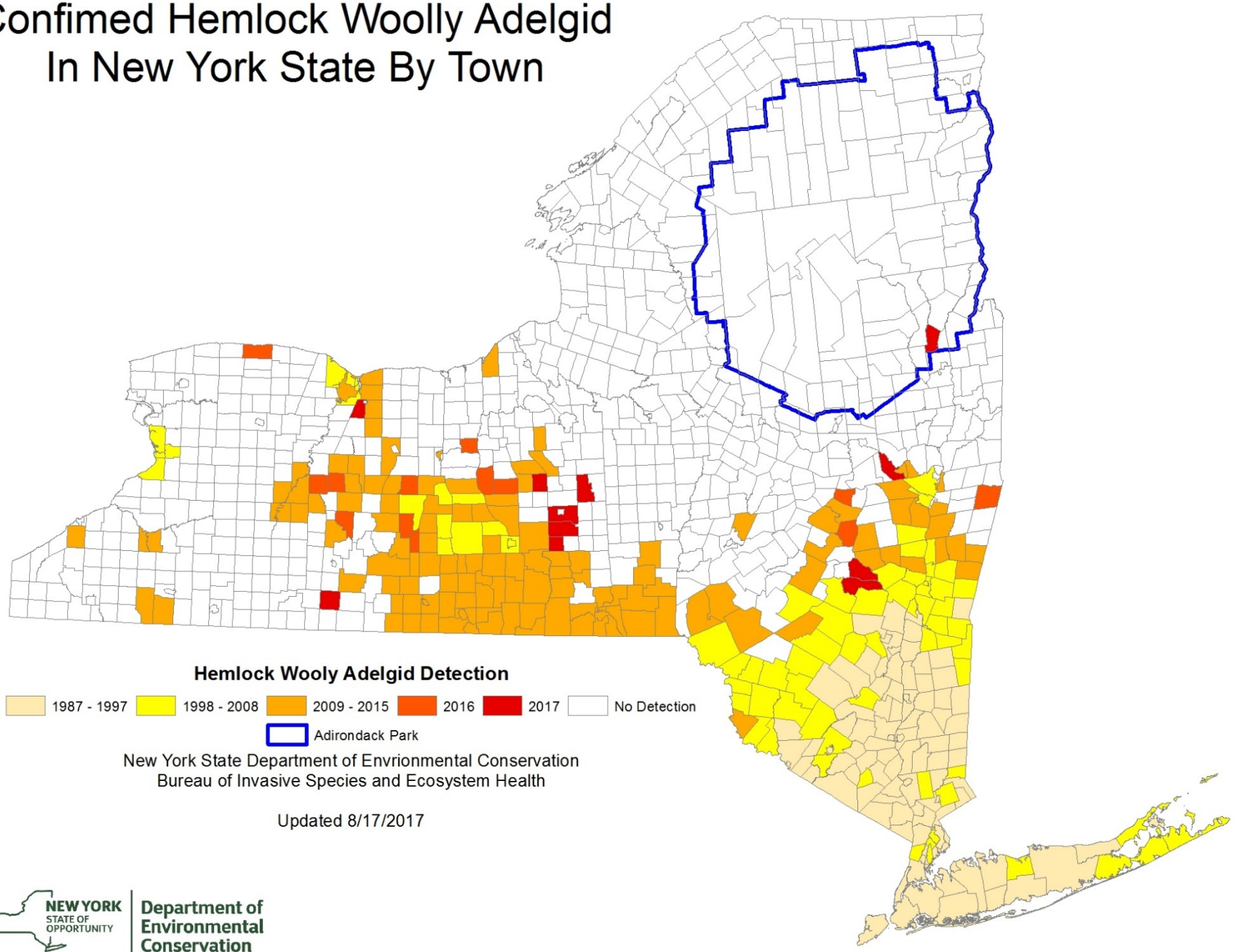
Middle of infestation

Spring/ early summer settlement

Sistens Progrediens Sistens


N
NYS DEC
Forest Health & Protection
Ontario
Lake Ontario
Lake Erie
VERMONT
NEW HAMPSHIRE
Massachusetts
Connecticut
Rhode Island
New Jersey
Atlantic Ocean
New York State
Eastern Hemlock(Tsuga canadensis.)Distribution
0% - 5%
6% - 15%
16% - 30%
31% - 60%
61%- 100%
Dataset: Eastern Hemlock (Tsuga canadensis.)
Wilson, Barry T. and Andrew J. Lister. (in review).
A phenology-based nearest-neighbor
imputation approach to large area mapping
of forest characteristics using field sampled data.
Submitted to Remote Sensing of Environment.
0
75
150
Miles
New York State
Junior Burnett
Production Date: 04/11

Confimed Hemlock Woolly Adelgid In New York State By Town



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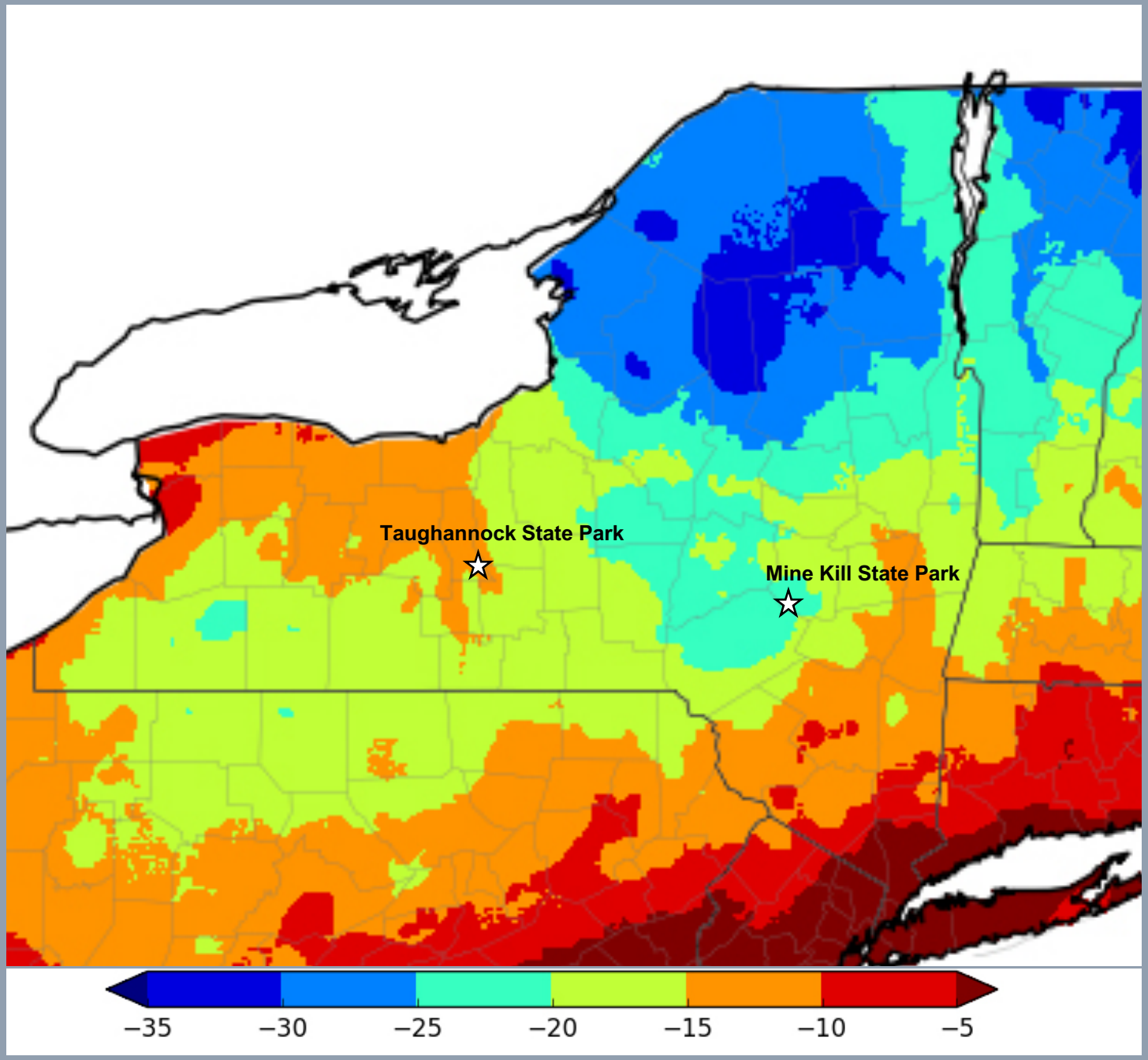
Scott McDonnell, NYSDEC. July 2016.

Natural Control of Insect Populations

- Host Tree Resistance
  - Many factors involved, most poorly understood
  - Evaluation of progeny from Northern NJ stand
- Abiotic Factors
  - Temperature
- Biological Control
  - Predators, Parasitoids, and Pathogens
- Additive effect of all agents involved



Northeast Regional Climate Center, Cornell University, 2014

HWA and Cold Weather

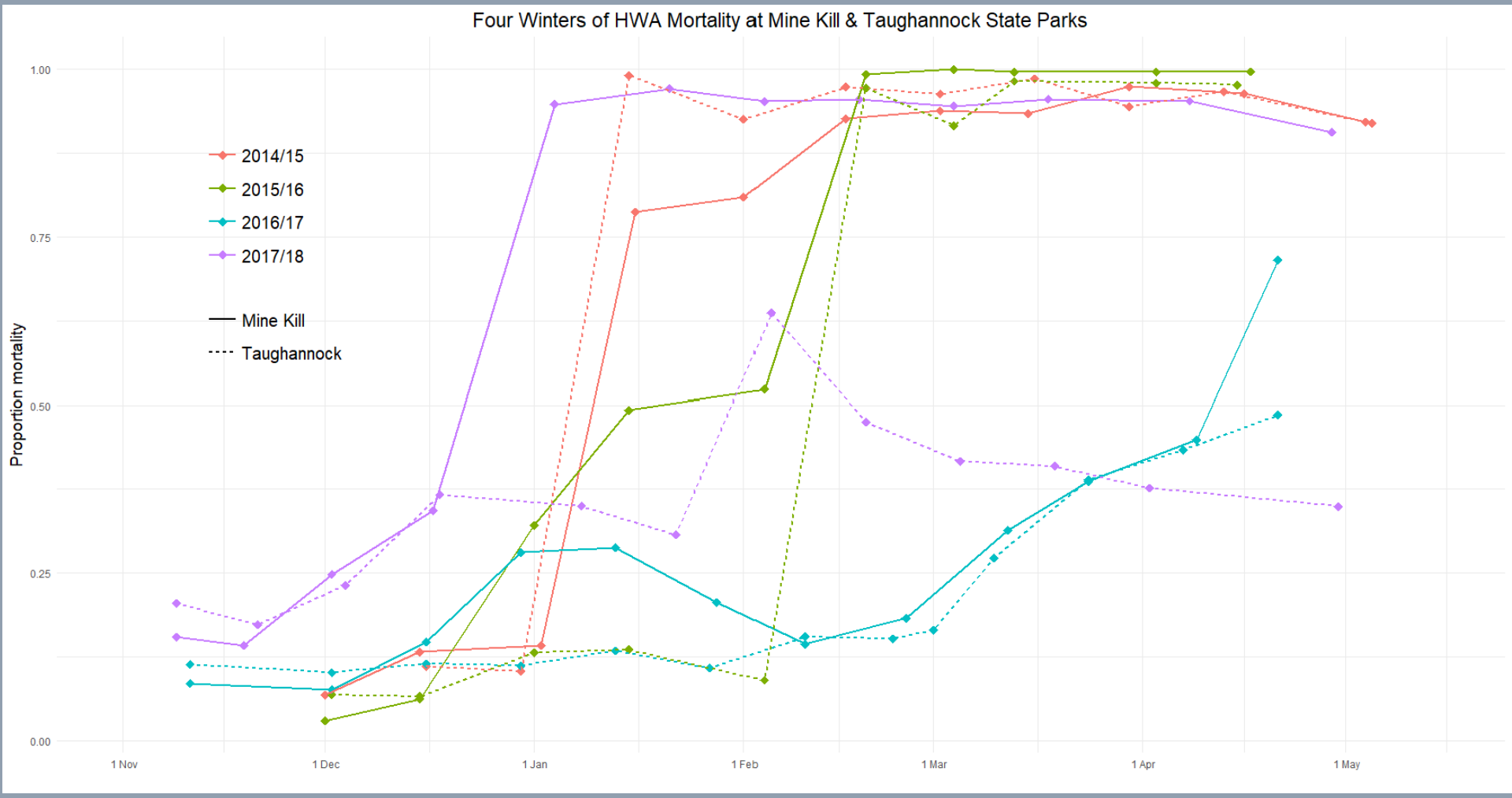
- Taughannock State Park
  - Lowest temperature -22C (-8F) on 4 Jan 2014
  - 91% mortality, n=3253
- Mine Kill State Park
  - Lowest temperature -30C (-18F) on 23 Jan 2014
  - 82% mortality, n=2936
- The colder location has less mortality!
- Are HWA populations adapting to the cold?

Response to cold

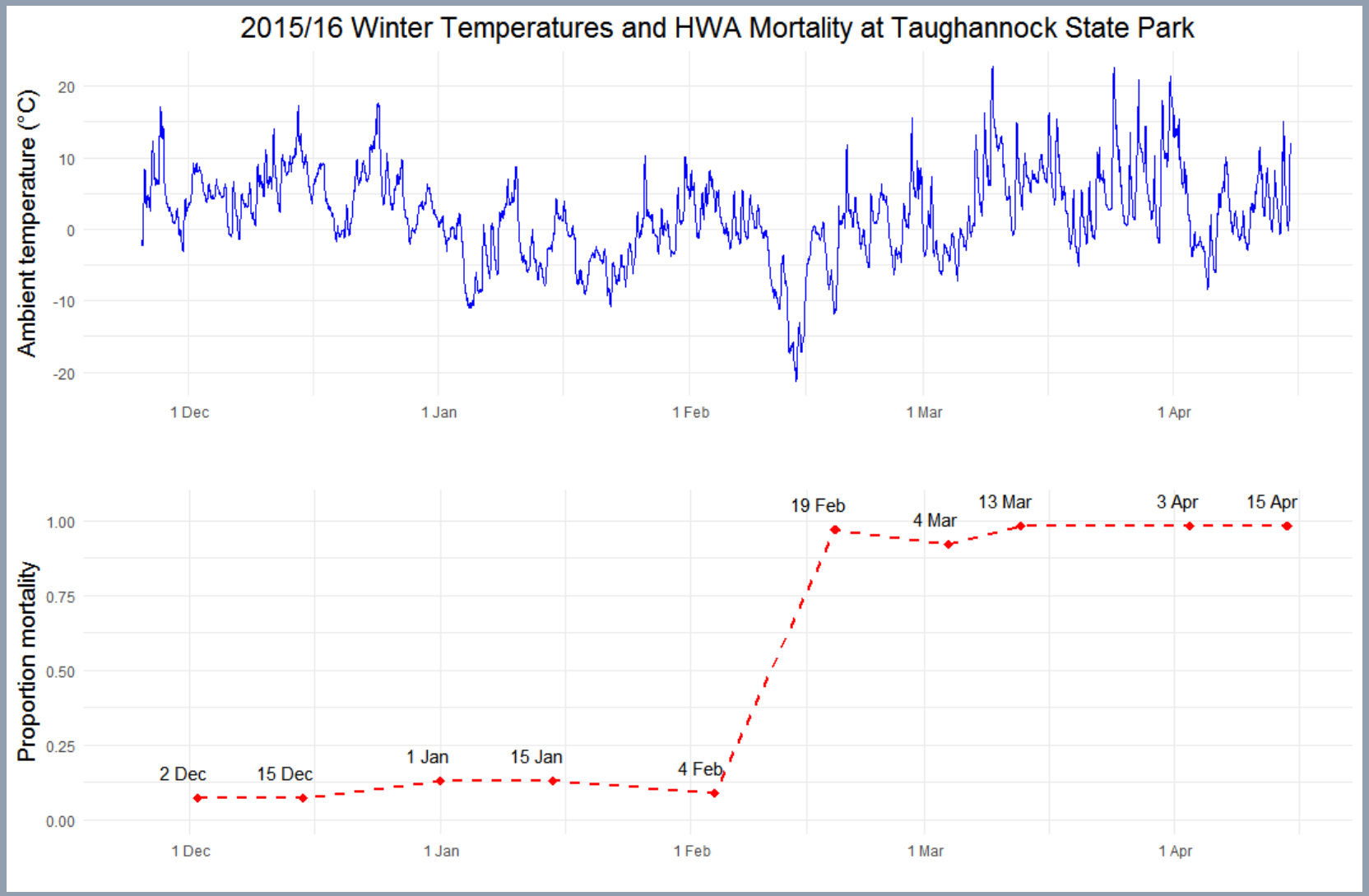
- Direct counting of dead HWA
  - Biweekly sampling at two study sites (warm and coldest)
  - Started in winter of 13/14… 5 winters so far

Winter	13/14	14/15	15/16	16/17	17/18
Mean number of HWA counted at each sample date:					
Mine Kill SP	1,214	735	823	1,008	2,467
Taugannock SP	681	976	788	1,314	2,137
Total number of HWA counted each winter by site:					
Mine Kill SP	2,427	8,084	8,233	12,096	12,336
Taugannock SP	1,361	9,756	7,884	17,084	10,683
TOTAL	3,788	17,840	16,117	29,180	23,019

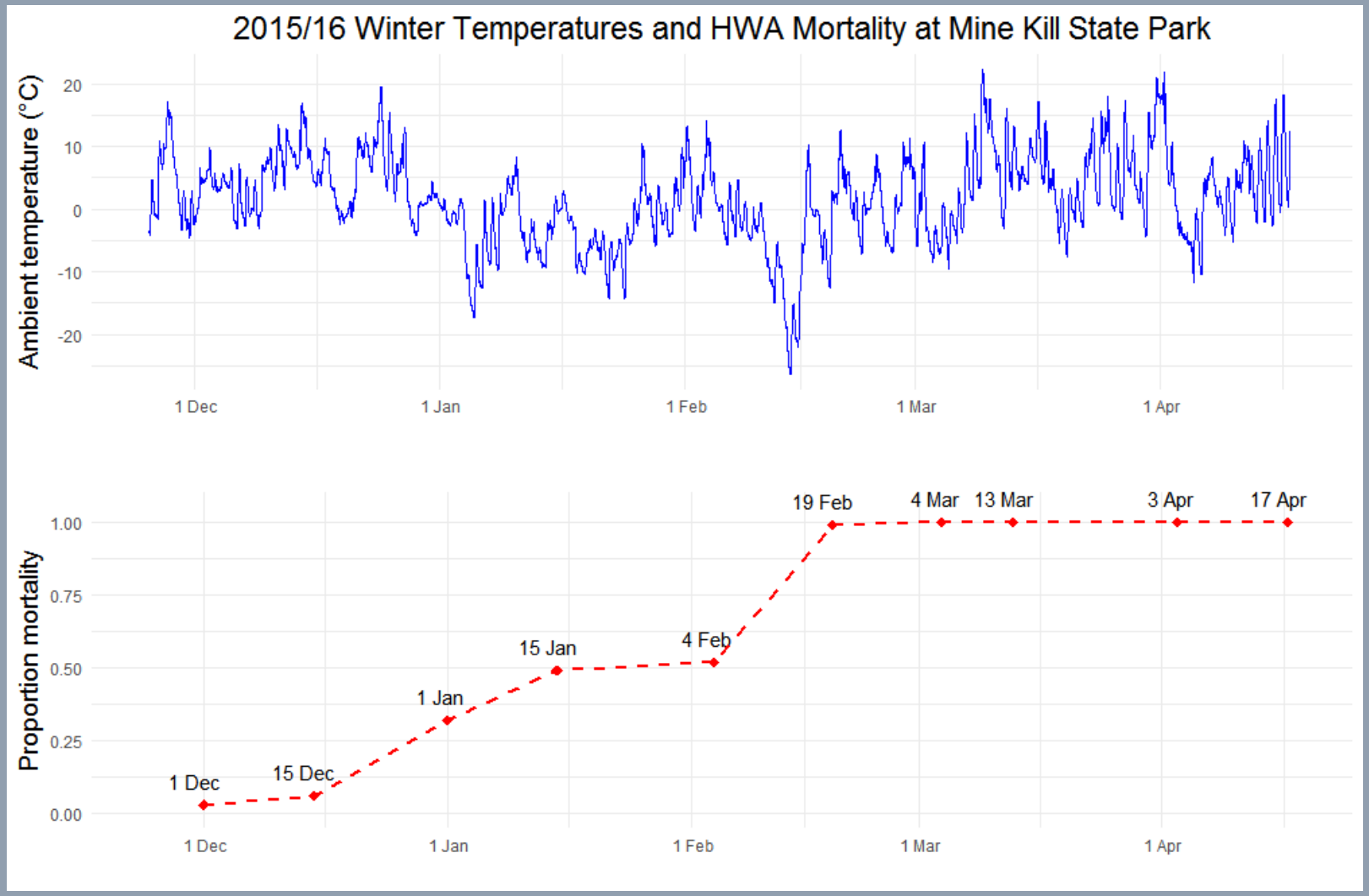
Four winters of HWA mortality



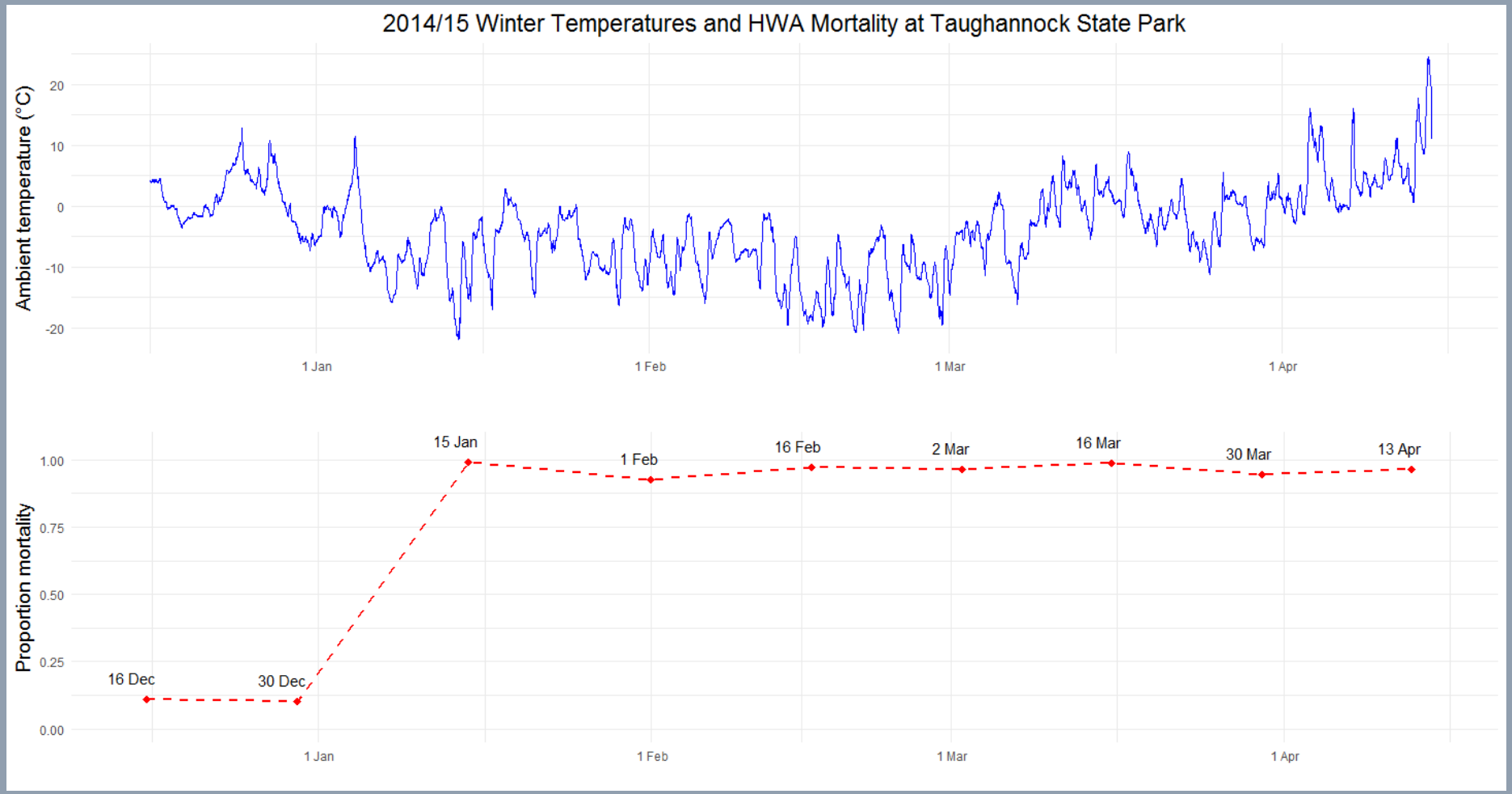
2015/16 Taughannock SP - mortality



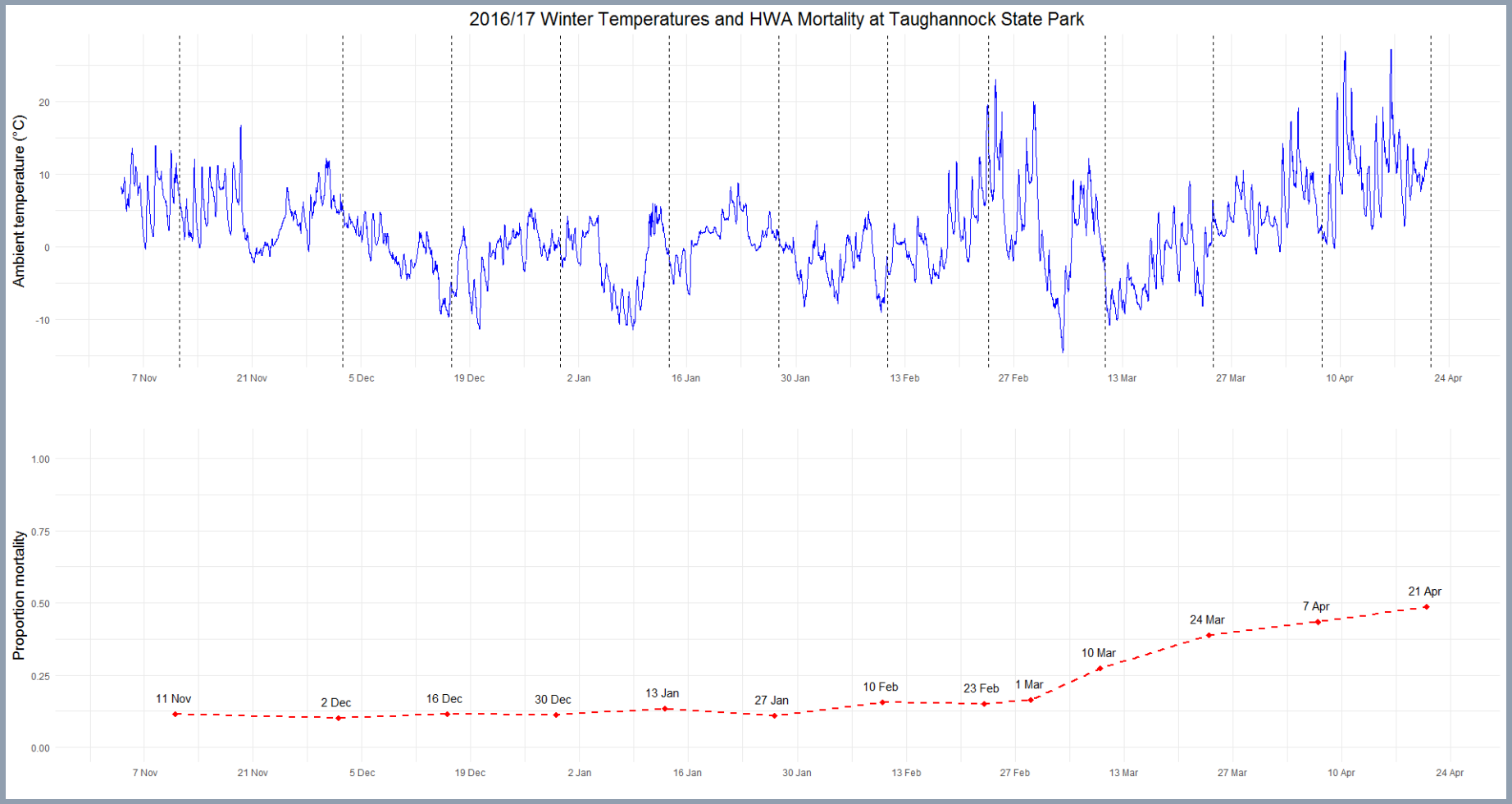
2015/16 Mine Kill SP - mortality



2014/15 Taughannock SP - mortality



2016/17 Taughannock SP – mortality



HWA Predators can be divided into two basic groups:

Spring/Summer feeders: prey on progrediens eggs and nymphs as well as sistens eggs.

Leucopis (Diptera: Chamaemyiidae)
Scymnus (Coleoptera: Coccinellidae)

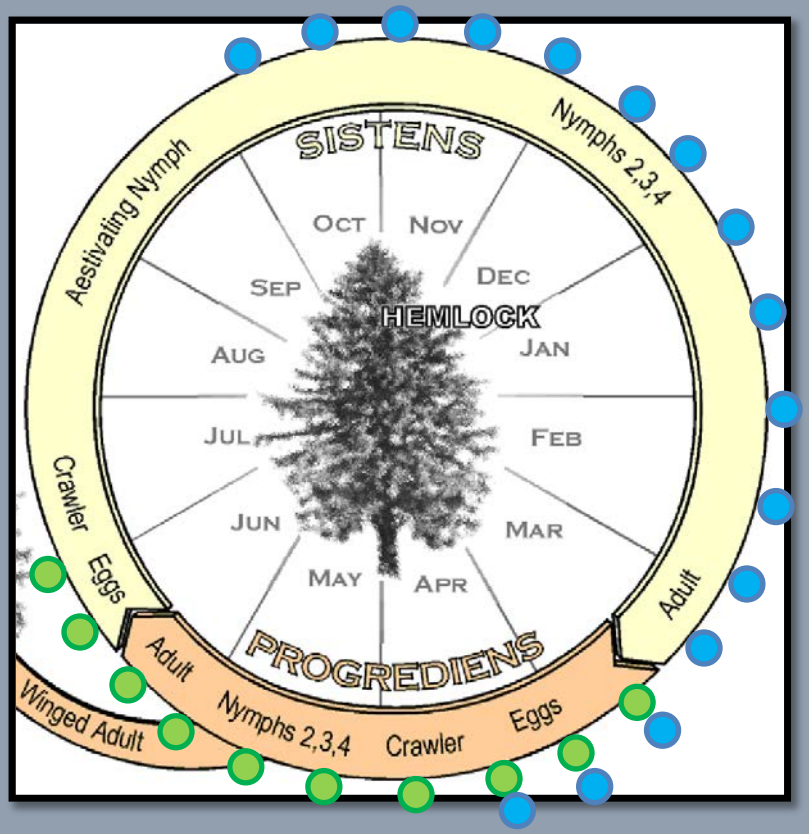
Photo Melody Keena, USFS

Winter/Spring feeders: prey on sistens nymphs through winter and progrediens eggs in spring

Laricobius (Coleoptera: Derodontidae)

Photo Ashley Lamb, VT

The key to HWA biocontrol will be to have effective predation for both generations

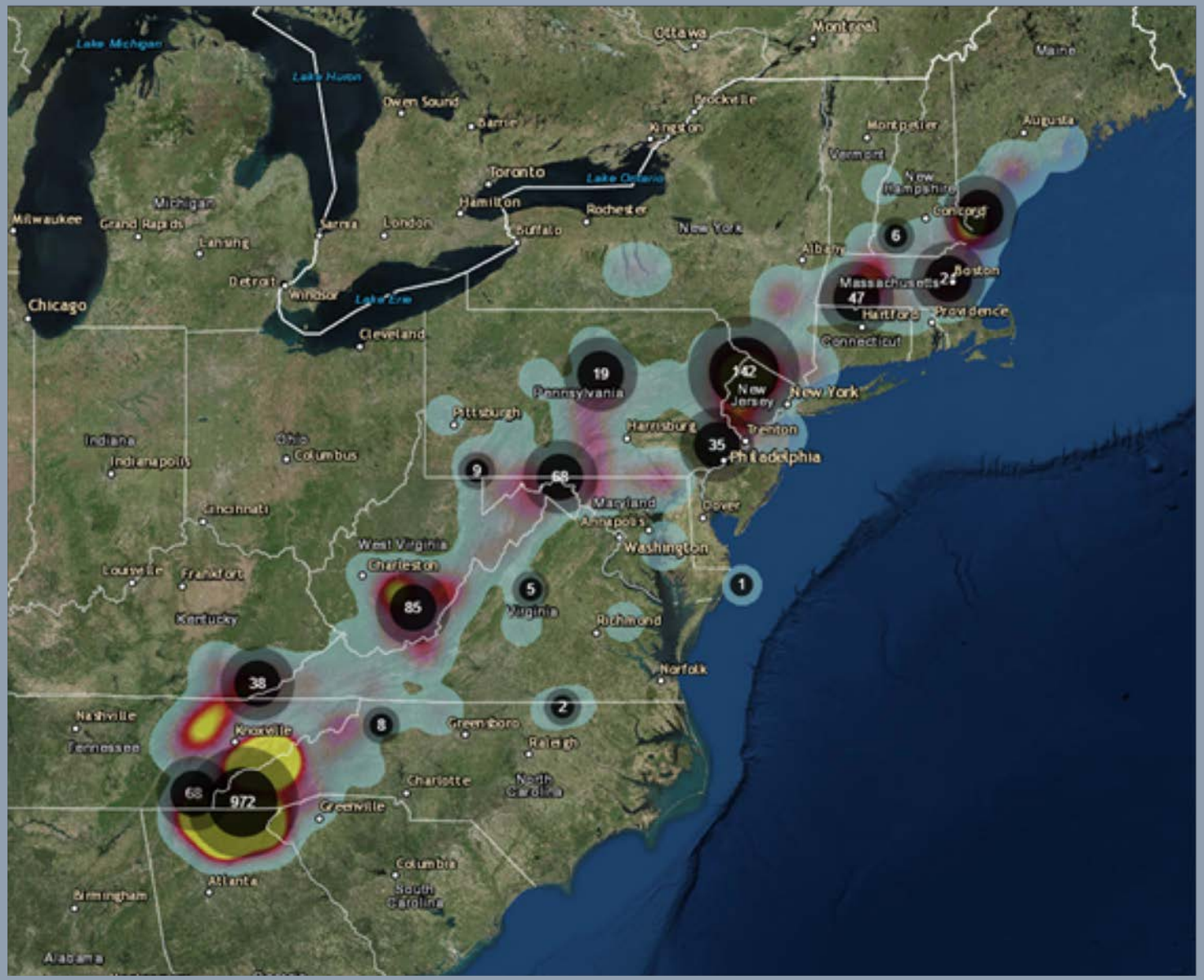


- Spring/Summer
- Winter/Spring

Classical Biocontrol

- 1992 *Sasajiscymnus tsugae* (Col: Coccinelliedae) from Japan
- 1995-7 *Scymnus spp*. (Col: Coccinelliedae) from China
- 1997 *Laricobius nigrinus* (Col: Derodontidae) from Pacific Northwest
- 2005 *Laricobius osakensis* from Japan
- 2008 *Leucopis spp*. (Diptera: Chamaemyiidae) from Pacific Northwest

Predator releases to date



Laricobius nigrinus
Coleoptera: Derodontidae

- Winter/Spring feeder
  - Emerges as adult in fall and begins feeding on sistens
- 1997 S. Salom and L. Humble brought collections from Victoria, BC to VT for evaluation.
- First releases in 2003
- Mass rearing has been successful at labs in VA, TN, GA, and now hopefully in NY

Laricobius nigrinus

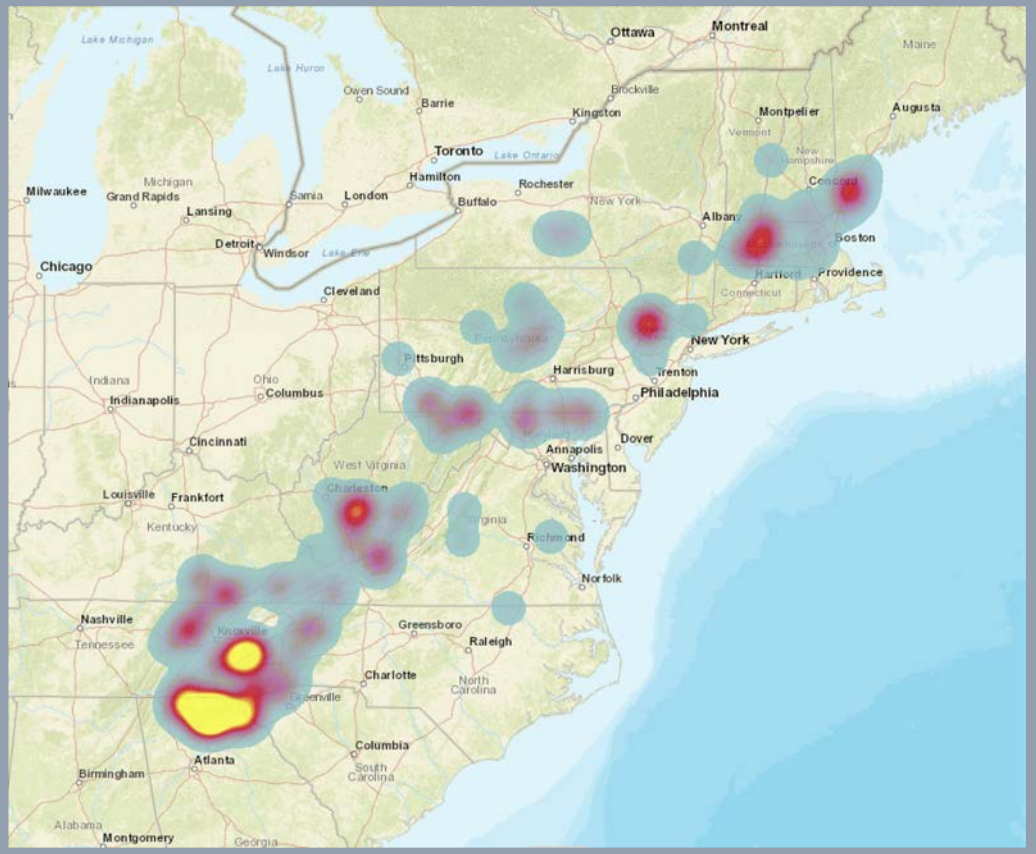
- To date over 330,000 released throughout eastern states from Labs and wild collections in Pacific Northwest and NC.
- Establishment widespread on east coast
  - Better in warmer areas

Gabriella Zilahi-Balogh, Agriculture and Agri-Food Canada, Bugwood.org

Nick Dietschler, Cornell Univ.

Winter feeding of adult L. nigrinus in new lab at Cornell Univ.

Laricobius nigrinus releases

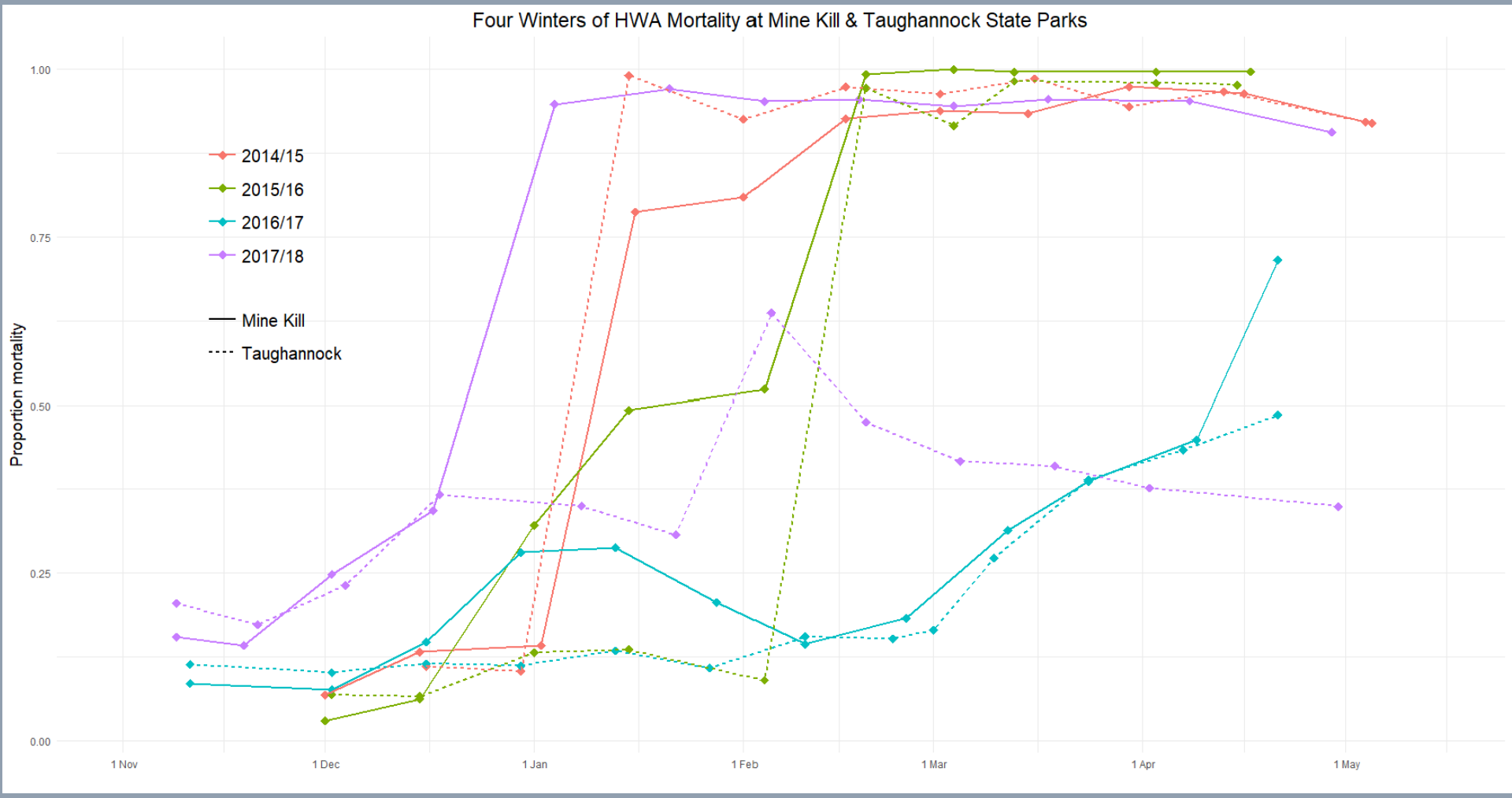


553 releases since 2003
Wild caught and laboratory cultures

Laricobius nigrinus

- Recoveries in early NC release areas have been impressive after 10 years
  - Over 12,000 in 2013
- Recovery of populations after the winters of 13/14 and 14/15 (polar vortex) and then the Feb freeze of 2016 were slow
  - Yet fall 2017 collections in NC were recovering
- Recoveries at the 19 release sites in NY have been limited to 3 of the earliest… why?

Four winters of HWA mortality



Is Progrediens survival and reproduction enhanced by Sistens winter mortality by cold weather or winter predators?

When is the tissue actually damaged beyond the point of nutritional value/ usefulness to HWA?

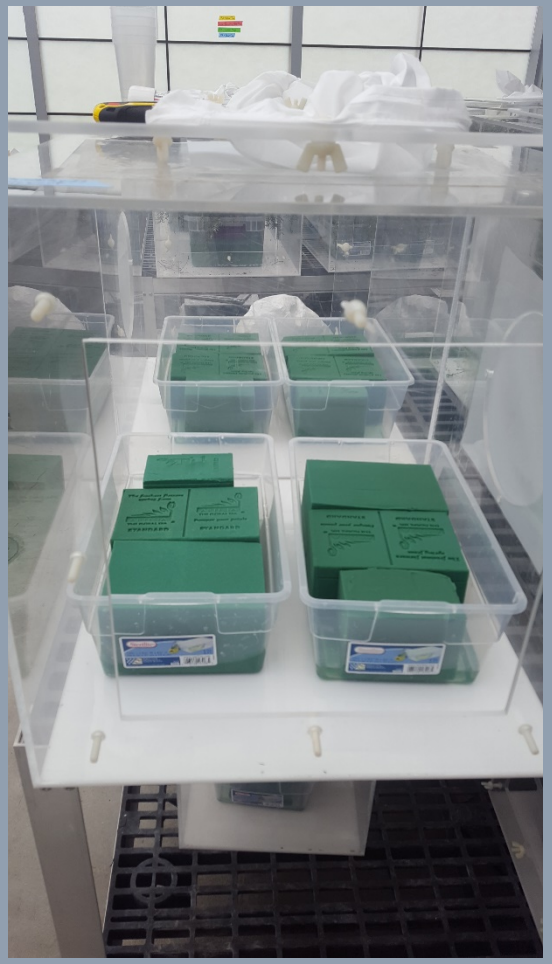
Leucopis argenticollis & piniperda Diptera: Chamaemyiidae

- Spring/Summer feeders
  - Feed as larvae on eggs and early instars of both sistens and progrediens
- Multivoltine (more than one generation per year) predators native to Pacific NW
- D. Ross, K. Walin, and G. Kohler recognized these as important predators in 2007

Leucopis argenticollis & piniperda

- First work evaluating establishment potential in eastern US completed in 2015
- Field releases and F1 recovery in 2017 at 9 sites in NY
- Recent evaluation indicates survival for one or more growing seasons in NY

Setting up western foliage in quarantine



Releasing Leucopis spp. in mesh bags which are removed after one month

Scymnus spp. Coleoptera: Coccinellidae

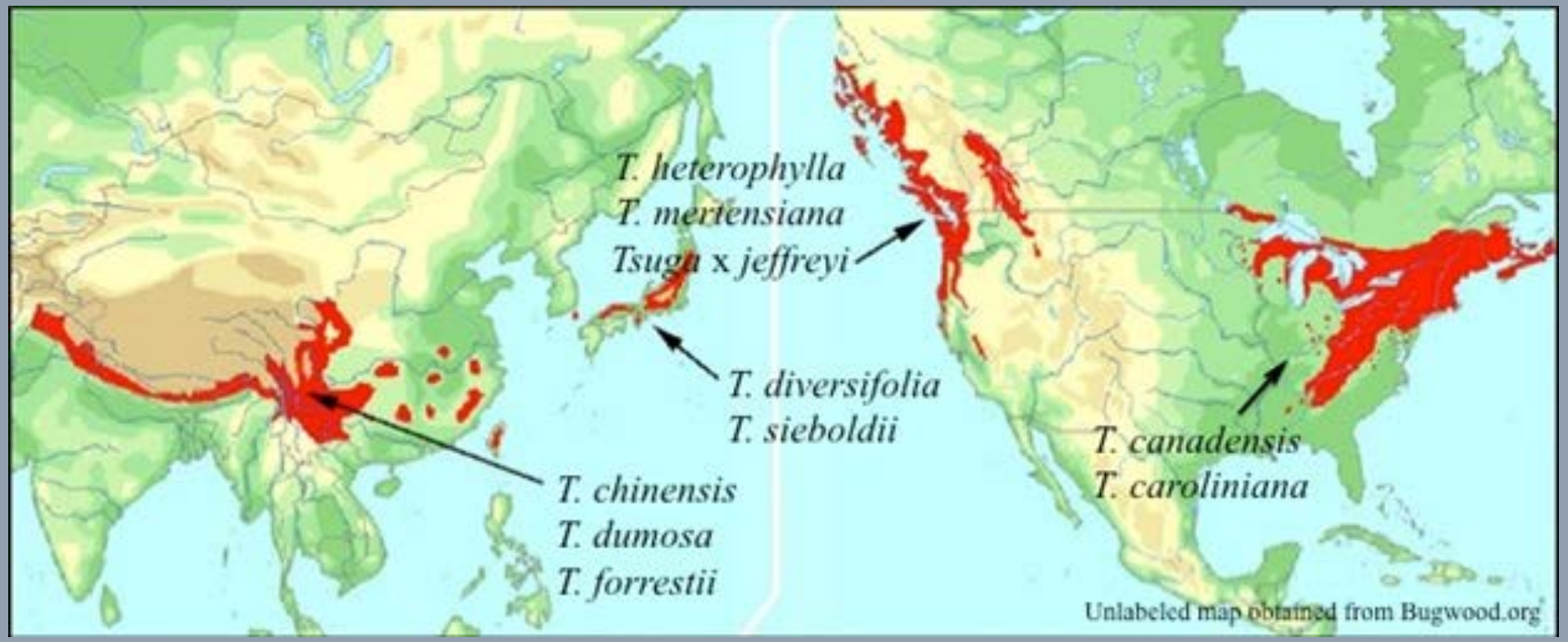
Melody Keena, USFS

- Spring/Summer feeders
- 1995 M. Montgomery found three unknown species in China and brought back to US for evaluation.
- All are abundant predators in native areas
- *S. ningshanensis* and *S. sinuanodulus* were finally released in 2004 but in very limited numbers. No subsequent recoveries have been made.

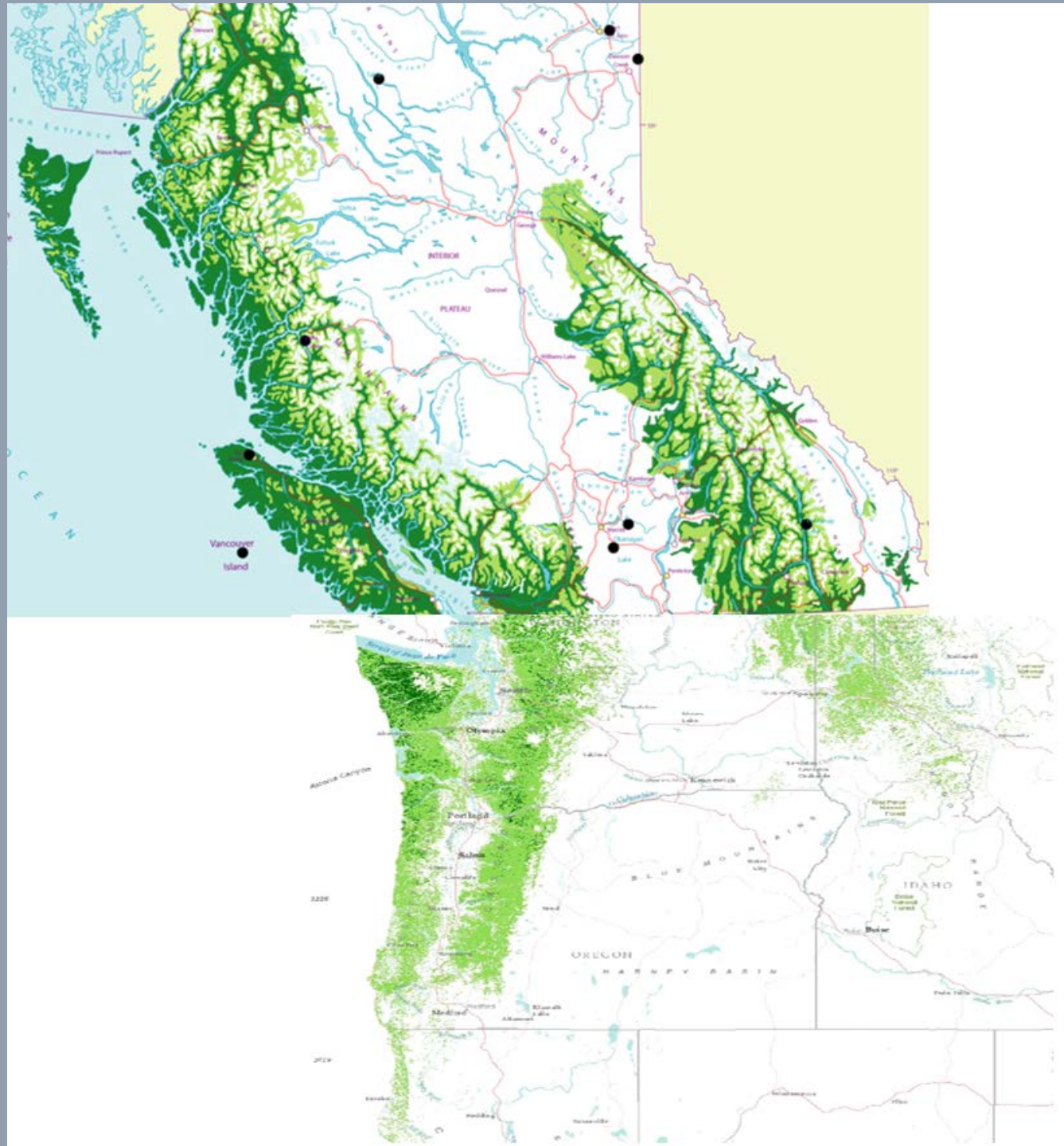
Scymnus camptodromus

- Feeds on all life stages of HWA and long lived
- Very difficult to rear in lab
- Almost ready for release when NAPPO review required another test which could not be completed before the colony was lost.

Worldwide distribution of Hemlock, *Tsuga* spp.



Distribution of Western hemlock, *Tsuga heterophylla*, in the Pacific Northwest

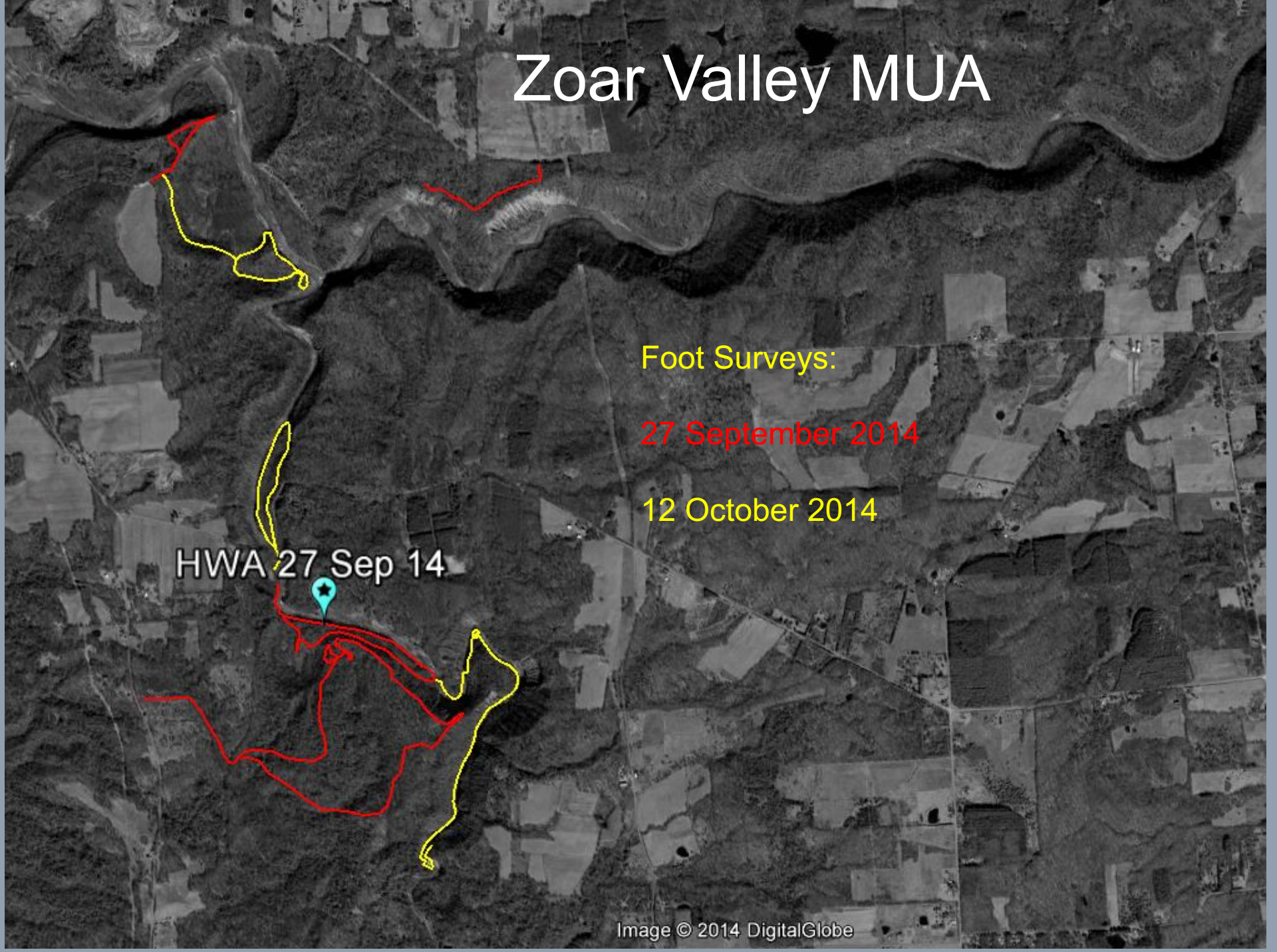


Systemic Insecticides

- Imidacloprid
  - Various formulations and application techniques
    - Injections – restricted use only
    - Time release tablets - restricted use
    - Soil drench available to homeowners
  - Effective for 7 years or more
  - Slow to move through tree
- Dinotefuran (Safari)
  - Restricted and Basal bark spray only in NY
  - Effective for only 1 or maybe 2 years
  - Fast movement in tree

Evaluate Efficacy

- Identify areas of NEW growth
  - Always best in Spring with bright green shoots
  - Be sure to look at the tops!
  - Insecticides are slow to move through tree, give it a year but pay attention!!!
  - Mistakes happen
- Dinotefuran is expensive but worth it!
  - Fast movement in tree will take down HWA reproduction and allow the tree to recover
  - Essential component of Rapid Response!

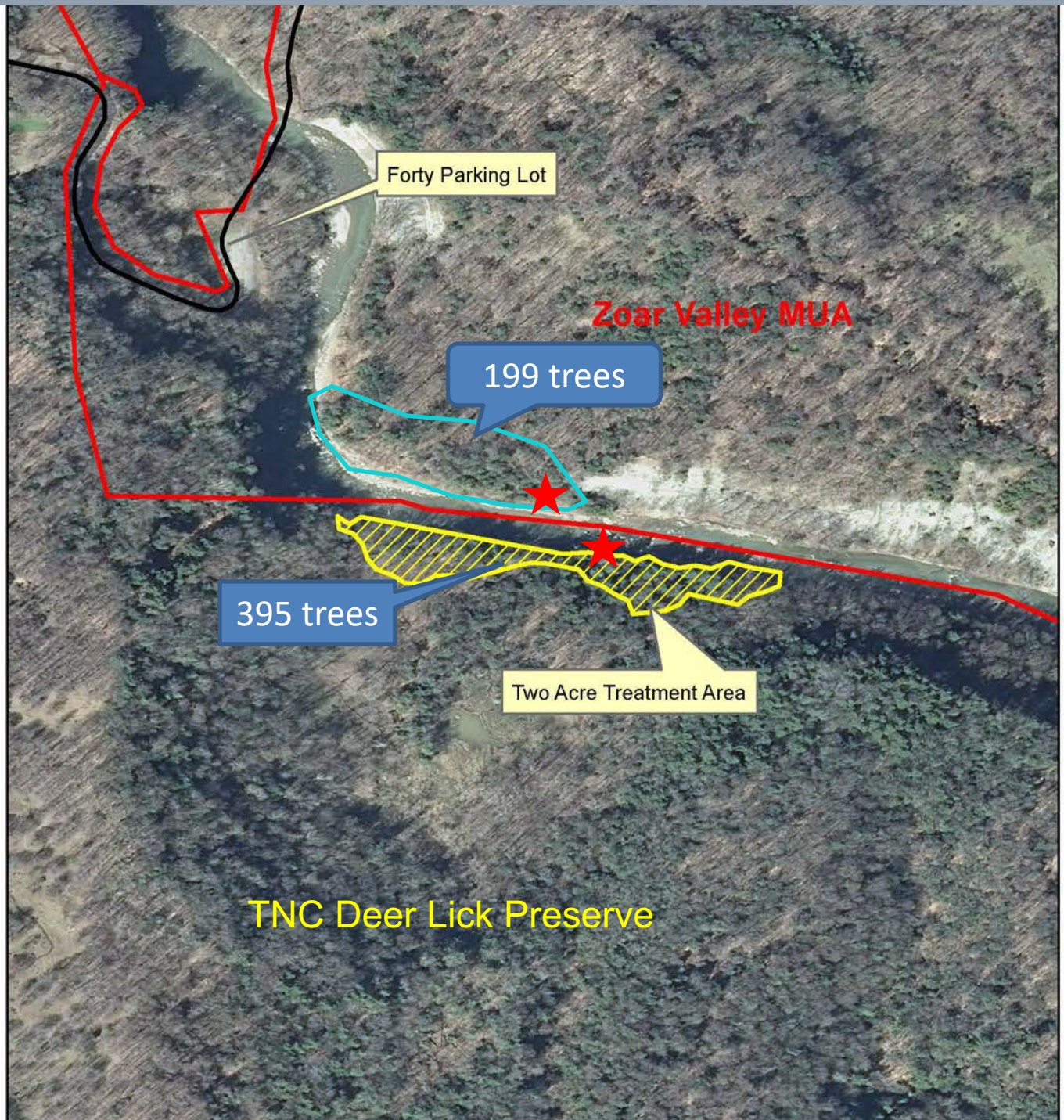

Zoar Valley MUA
Foot Surveys:
27 September 2014
12 October 2014
HWA 27 Sep 14
Image © 2014 DigitalGlobe

Single infested tree discovered 27 September 2014

HWA located on branches hanging over the creek bed.

This is commonly the first place HWA is discovered.

Birds visiting the water likely to carry HWA crawlers on their feet that will then disembark when the bird alights on a branch


Forty Parking Lot
Zoar Valley MUA
199 trees
395 trees
Two Acre Treatment Area
TNC Deer Lick Preserve

NEW YORK STATE OF OPPORTUNITY. Department of Environmental Conservation | Agriculture and Markets

Willow Eyres, Response & Management Coordinator, NYSDEC

Spotted Lanternfly

Lycorma delicatula (SLF)

- Plant hopper native to China and Southeastern Asia
- Discovered in Pennsylvania in 2014
- Use their sucking mouthparts to feed on the sap of more than 70 plant species
  - Prefer Tree of Heaven (*Ailanthus altissima*)
  - Grapes, apples, hops, maples

Identification

- Nymphs: black with white spots, turn red before transitioning into adults

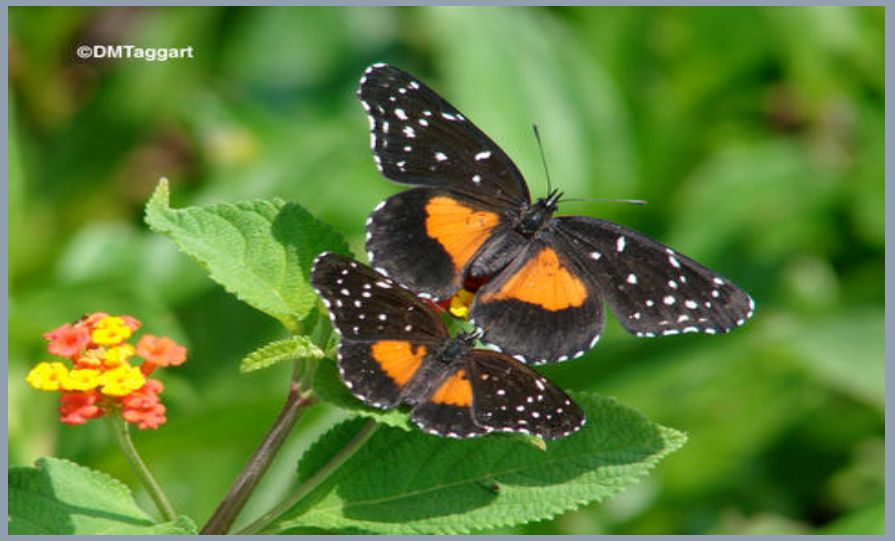
- ıch long, ½ inch
  st, beautiful wings

Lookalikes

Apantesis behrii

Grapevine epimenis

Western conifer seed bug



Crimson patch

Life Cycle

Adult forms can be seen as early as July.

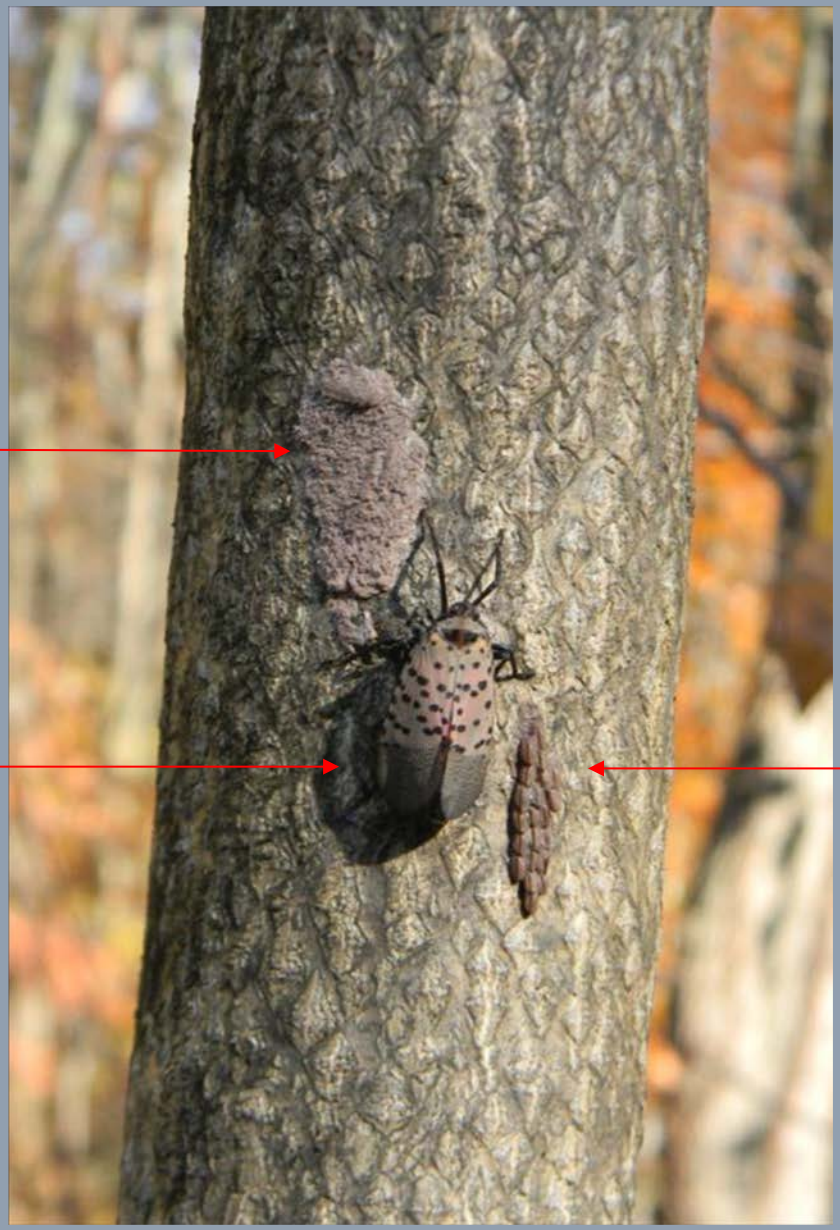
The nymphs have 4 instars and develop red spots in addition to the white spots exhibited in earlier instars.

Nymphs begin to hatch in late April to early May.

The eggs are laid in the fall. Preferred host is the Tree of Heaven, *Ailanthus altissima,* but any smooth bark tree will do.

SLF egg masses

- Egg masses contain between 30-50 eggs, are laid on many different objects, and are often well hidden
- Easily transported on vehicles, stone,


Covered egg mass
Adult SLF
Uncovered egg mass

Lookalikes

Gypsy moth eggs

Mud dauber nests

SLF Impacts

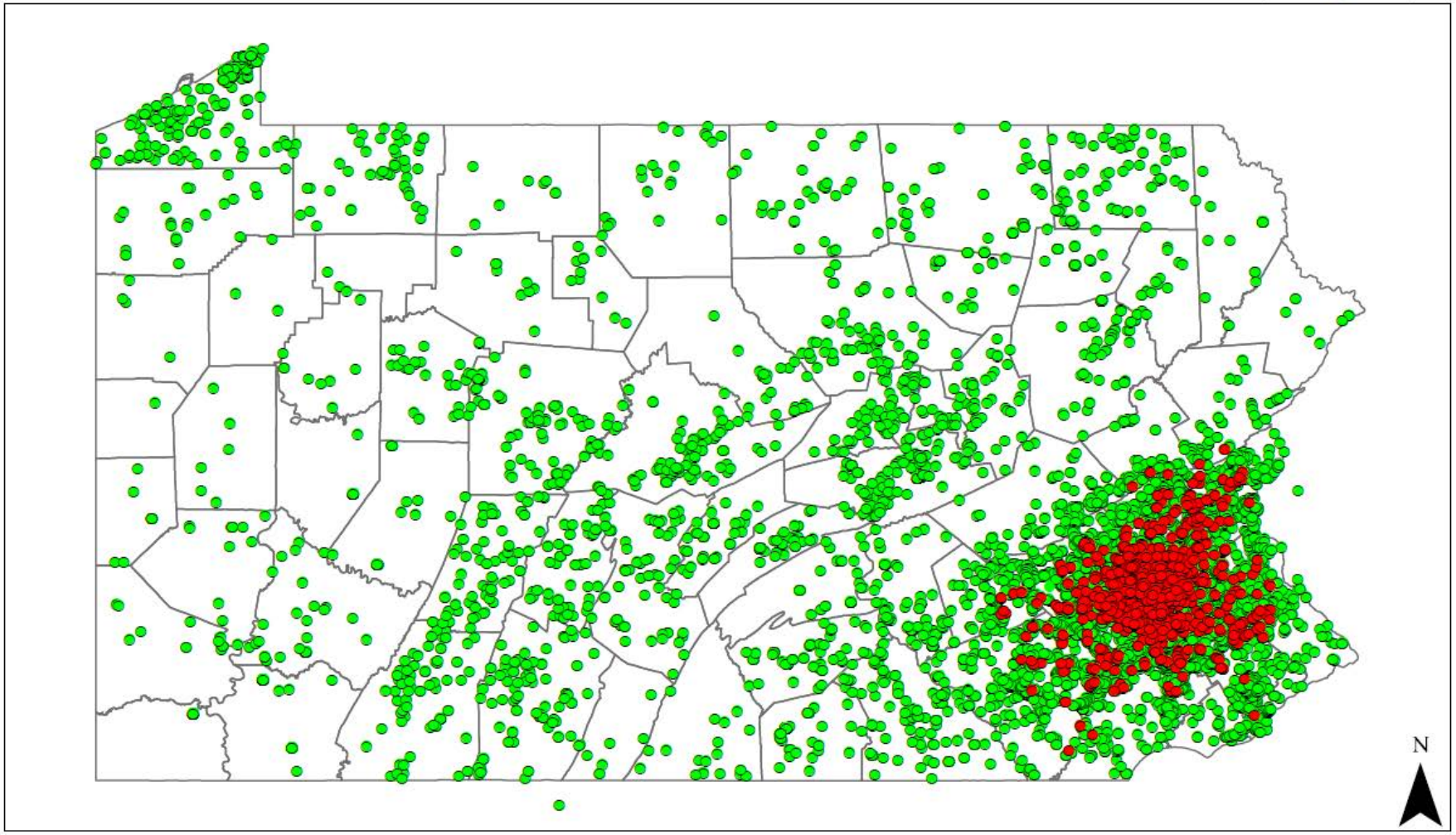
- Feeding stresses plants, making them vulnerable to disease and attacks from other insects.
- Excrete large amounts of sticky honeydew
  - Attracts sooty molds that interfere with plant photosynthesis, negatively affecting the growth and fruit yield of plants.
- Significantly hinder outdoor activities

Signs of infestation

- Sap oozing or weeping from tiny open wounds on tree trunks, which appears wet and may give off fermented odors.
- Massive honeydew build-up under plants, sometimes with black sooty mold.

2014 -- 2017 Lycorma Detection Survey

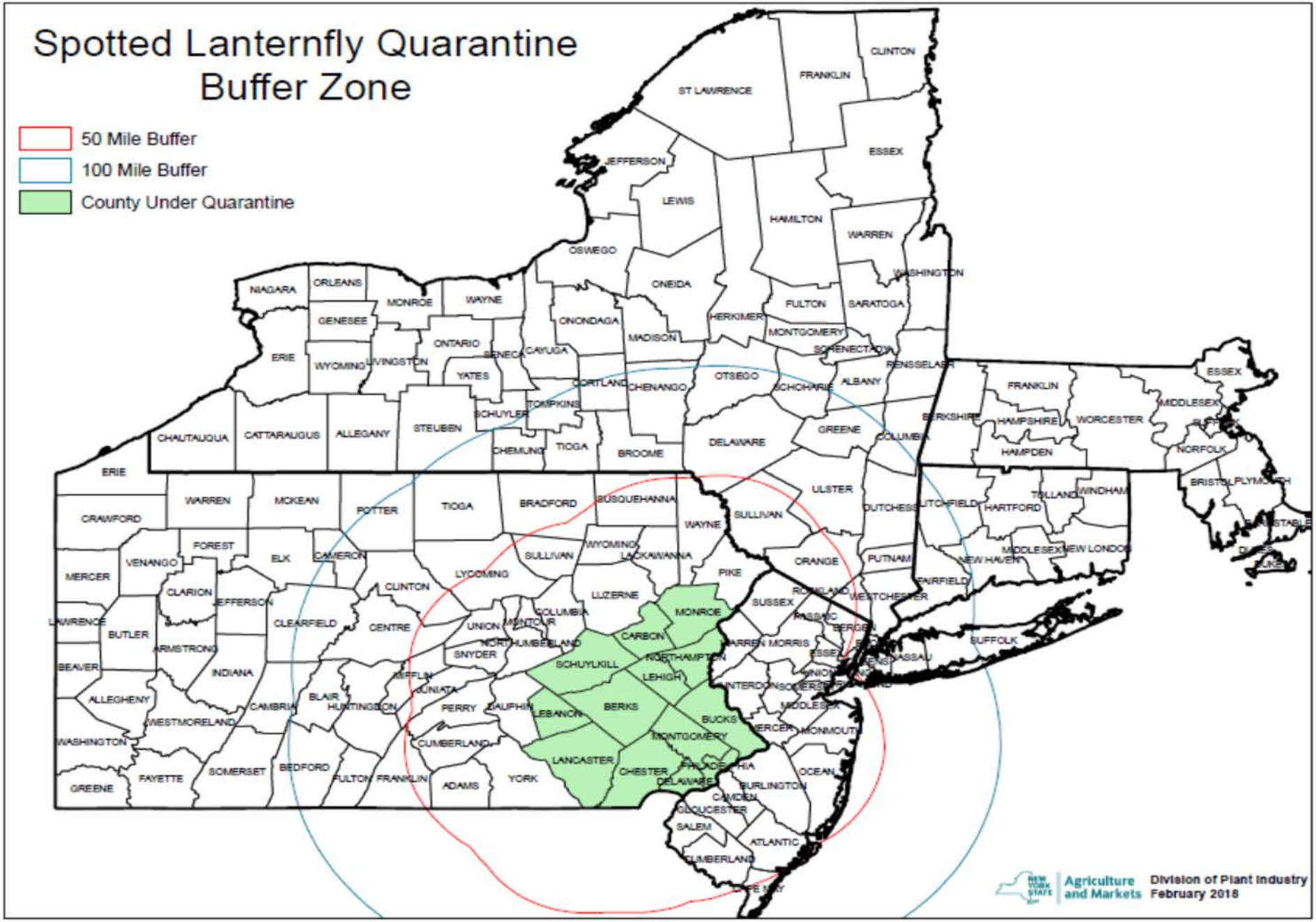
Results through 12 October 2017



Spotted Lanternfly Presence

- Positive
- Negative

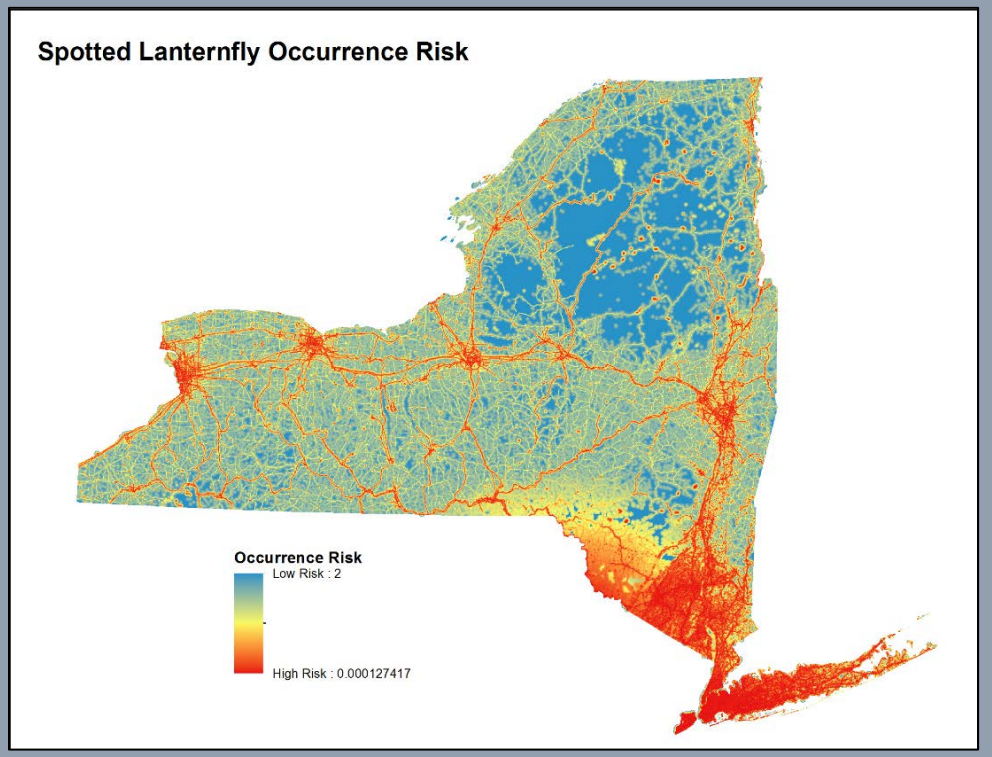
pennsylvania
DEPARTMENT OF AGRICULTURE


Spotted Lanternfly Quarantine Buffer Zone
50 Mile Buffer
100 Mile Buffer
County Under Quarantine
Agriculture and Markets
Division of Plant Industry
February 2018

Survey Objectives

- 1. Prioritize areas for SLF based on known occurrence, risk of introduction and potential hazard, using the best available information (right)

- 2. Establish baseline distributions and densities of *Ailanthus altissima* particularly in areas at high-risk of SLF introduction.



Survey Objectives

- 3. Conduct area-based visual detection surveys for hosts, adults, nymphs and egg masses to verify the presence/absence of Ailanthus and SLF at high-risk locations.
-
- 4. Conduct delimitation surveys as needed around any confirmed SLF detections.

Survey Objectives

- 5. Deploy sticky band traps in highly visible, high-risk Ailanthus stands to intercept resident or introduced populations of SLF and to educate the public about SLF detection efforts.

- 6. Evaluate the efficacy of various survey methods in New York, and revise this

Regulatory Plan

- NYSDOT Check Points
- Nursery Grower and Dealer Inspection
- Stone Yards, Wood Products
- Campgrounds and Rail Yards
- Christmas Tree Vendors and Tree Lots
- Warehouses, Distributions Centers, and Parcel Facilities

- DEC Commissioner Order for Protective Zone establishment under 9-1303

Response

- When SLF is found in NY, the primary goals will be to:
  - Delimit the infestation using grid system
  - Develop a site management plan
  - Eradicate the infestation

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FOREST SERVICE U S DEPARTMENT OF AGRICULTURE
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