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*
Worldwide distribution of HWA and Tsuga species.
Havill 2008
Life Cycle

**HEMLOCK**

**PROGREIDIENS**

- Lifestages:
  - Spruce
  - Adult
  - Nymphs 2, 3, 4
  - Crawler
  - Eggs
  - Adult
  - Nymphs 2, 3, 4
  - Crawler
  - Eggs

- Stages:
  - Aestivating Nymph
  - Oct
  - Nov
  - Dec
  - Jan
  - Feb
  - Mar
  - Apr
  - May
  - Jun
  - Jul
  - Aug

- Images:
  - Spruce tree with insects
  - Hemlock tree with insects
  - Close-up of insects
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
    • $1 \times 100 \times 50 = 5,000$ 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
Confirmed Hemlock Woolly Adelgid
In New York State By Town

Hemlock Woolly Adelgid Detection
- 1987 - 1997
- 1998 - 2008
- 2009 - 2015
- 2016
- 2017
- No Detection

New York State Department of Environmental Conservation
Bureau of Invasive Species and Ecosystem Health

Updated 8/17/2017

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
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

<table>
<thead>
<tr>
<th>Winter</th>
<th>13/14</th>
<th>14/15</th>
<th>15/16</th>
<th>16/17</th>
<th>17/18</th>
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<tbody>
<tr>
<td>Mean number of HWA counted at each sample date:</td>
<td></td>
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<tr>
<td>Mine Kill SP</td>
<td>1,214</td>
<td>735</td>
<td>823</td>
<td>1,008</td>
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<td>Taugannock SP</td>
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<td>976</td>
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<td>Total number of HWA counted each winter by site:</td>
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<tr>
<td>Mine Kill SP</td>
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<td>8,084</td>
<td>8,233</td>
<td>12,096</td>
<td>12,336</td>
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<tr>
<td>Taugannock SP</td>
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<td>9,756</td>
<td>7,884</td>
<td>17,084</td>
<td>10,683</td>
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<td>TOTAL</td>
<td>3,788</td>
<td>17,840</td>
<td>16,117</td>
<td>29,180</td>
<td>23,019</td>
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</table>
Four winters of HWA mortality

Four Winters of HWA Mortality at Mine Kill & Taughannock State Parks

- 2014/15
- 2015/16
- 2016/17
- 2017/18

Mine Kill
Taughannock
2015/16 Taughannock SP - mortality

2015/16 Winter Temperatures and HWA Mortality at Taughannock State Park

Ambient temperature (°C)

Proportion mortality

Graph shows ambient temperature and proportion mortality over the winter months from December 2015 to April 2016 at Taughannock State Park.
2015/16 Winter Temperatures and HWA Mortality at Mine Kill State Park
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*)

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

*Laricobius* (*Coleoptera: Derodontidae*)
The key to HWA biocontrol will be to have effective predation for both generations.
Classical Biocontrol

• 1992 *Sasajiscymnus tsugae* (Col: Coccinellidae) from Japan
• 1995-7 *Scymnus spp.* (Col: Coccinellidae) 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
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

- 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.
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!
Foot Surveys:
27 September 2014
12 October 2014

Zoar Valley MUA
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
199 trees

395 trees

Forty Parking Lot

Zoar Valley MUA

199 trees

Two Acre Treatment Area

TNC Deer Lick Preserve
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
• Adults: 1 inch long, ½ inch wide at rest, 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 eggs are laid in the fall. Preferred host is the Tree of Heaven, *Ailanthus altissima*, but any smooth bark tree will do.

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.
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, etc.
- 1 inch long, brownish-gray, waxy and mud-like when new
- Old egg masses are brown and scaly
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
- Red: Positive
- Green: Negative

Pennsylvania Department of Agriculture
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 plan as appropriate.
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