Hemlock Woolly Adelgid – *Adelges tsugae*
Update on Distribution and Control
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Distribution

At time of the report of the Global Invasive Species Initiative on Hemlock woolly adelgid (HWA), the pest was active in 12 states from Massachusetts to North Carolina (Martin 2003). Approximately 325,000 ha (25% of 1.3 million ha) of eastern and Carolina hemlocks were infested. Currently, that number has been updated to 16 infested states from southern Maine, south to northern Georgia, and west to eastern Tennessee (1). HWA now infests an estimated 50% of hemlock trees (1). The USFS, Forest Health Protection group has a listing (url listed below) of infested counties as of March 2004.

Monitoring Hemlock Forest Health

Plots established in the Delaware Water Gap National Recreation Area monitoring the relationship between forest health and HWA population densities determined a strong relationship between the percent of twigs infested with HWA and new vegetative growth. Trees with 45% or greater HWA infested twigs exhibited 4% or less of new growth as measured on 81 permanent plots, each with 10 marked trees (Evans 2004).

A study comparing uninfested, moderately infested, and heavily infested trees, assessed canopy impacts and ecosystem changes at these 3 different sites in New England. The authors determined that infested trees had lower needle densities and decreased biomass. Infested trees were observed to shed more needles. Moderately infested trees had fewer current-year shoots compared to uninfested trees. Meanwhile, heavily infested trees had no new foliage or growth. Bacteria, yeasts, and fungi on needles were significantly increased on moderately and heavily infested trees compared to uninfested hemlocks. Throughfall collection was greater in infested trees (80% bulk precipitation collected vs. 66% under uninfested trees). Differences in spatial gradients beneath trees were also observed. The authors suggest that increased nitrogen availability and nitrification was also due to higher inputs (more dropped needles and increased number of microorganisms) in addition to previous suggestions of higher soil temperatures and decomposition rates. Soil changes in declining hemlock stands may explain the greater abundance of black birch (*Betula lenta*), which is highly competitive and grows well in high nitrogen environments (Stadler *et al*. 2005).

Control Information

Tree resistance:
Research on the topic of tree resistance to HWA is currently ongoing (Montgomery, pers. comm., 2005).

Biological control:
Laricobius nigrinus
This beetle has been observed in association with HWA in the Pacific Northwest (Washington, Oregon, Idaho and British Columbia). Unlike the classical biological control agents imported from Asia, *L. nigrinus* is active during the winter rather than spring and may provide additional complementary control of HWA (Lamb *et al.* 2005). Its lifecycle is well synchronized with that of HWA. Although it will eat other related adelgids and Homoptera, it prefers and needs to feed on HWA in order to complete its development (4). Field studies using sleeve cages indicated successful overwintering of adults from November to the following April in Virginia. Numbers of HWA were significantly reduced on caged branches with *L. nigrinus* beetles compared to those without beetles (Lamb *et al*. 2005). Progeny of released beetles (over 12,000 eggs laid by 144 adults) in sleeve cages reduced HWA numbers by 50%. Challenges with mass production of *L nigrinus* include the need for cold temperatures, soil during the pupal and diapausing adult stage, and maintaining the synchrony of lifecycles with that of field HWA (Cheah *et al*. 2004). However, despite these difficulties, enough numbers were reared such that in 2003-2004, this beetle was released in Pennsylvania, North Carolina, West Virginia, Virginia, Maryland, and Tennessee (1). Establishment and control are currently being assessed and preliminary observations during the fall of 2005 were promising (Lamb, pers. comm., 2005).
The bottom line: Research results with this beetle are very exciting because it is active during the winter. Feeding by *L. nigrinus* could be complementary with imported biological control agents that feed later in the spring, possibly having an additive control affect.

Other *Laricobius* sp.
In 2002 two other *Laricobius* spp. were discovered in China and have been imported for rearing and testing as a possible biological control agent in the U.S. (Cheah *et al*. 2004). One species is currently in the host-specificity testing phase and the other species is being imported and reared so that numbers are available for further testing. Another *Laricobius* sp. identified in Japan is slated for potential testing (Lamb, pers. comm., 2005).
The bottom line: Classical biological control for other *Laricobius* beetles is underway.

Scymnus* beetles – *S. camptodromus, S. ningshanensis,* and *S. sinuanodulus
Scymnus beetles are native to China and this genus is not present naturally in North America. Although *Scymnus* beetles will eat aphids, the beetles prefer to feed on HWA and the 1st instars require feeding on HWA eggs in order to survive. *Scymnus ningshanensis* fed on woolly alder aphids, alder leaf aphids, basswood aphids, and greenhouse aphids, however, *S. ningshanensi* did not feed on the hemlock psocid (1). All three have one generation per year (Cheah *et al*. 2004).

Scymnus ningshanensis and *S. sinuanodulus* have two periods of oviposition (egg laying). Shortly after overwintering, eggs are laid (1-2 eggs per day for 1.5 months) and after a period of about 4 weeks, if prey is available oviposition occurred for up to 7 months. Eggs of both species take approximately 10 days to hatch (Cheah *et al*. 2004). At 20˚C, developmental time (egg to adult eclosion) of *S. ninshanensis* was 6 days faster than *S. sinuanodulus*. Compared to *Sasajiscymnus tsugae* (formally *Pseudoscymnus tsugae*), which laid the same number of eggs regardless of HWA density, *S. ningshanensis* lays more eggs as the density of HWA increases (1).

Field studies demonstrated a reduction in HWA numbers in sleeve cages containing *Scymnus* beetles. The pretreatment population of HWA, however, was the greatest determinant of beetle control. Beetles did best at keeping low populations of HWA from increasing to detrimental levels to hemlock trees (Cheah *et al*. 2004). Currently, large numbers of *S. ningshanensis* are being reared for potential release and *S. sinuanodulus* has been released in several states last fall and early spring 2005 (Montgomery, pers. comm., 2005).

Scymnus camptodromus eggs diapause over winter and hatch the next spring, making colony rearing more difficult (Cheah *et al*. 2004), however, research towards rearing this beetle in large numbers continues (Montgomery, pers. comm., 2005).
The bottom line: *Scymnus* beetles lay more eggs if HWA density is high and field trials suggest good control of HWA populations. *Scymnus sinuanodulus* has been released in several states, *S. ningshanensis* are being reared in large numbers for future releases (anticipated to be soon), and successful rearing methods are still being researched for *S. camptodromus*.

Sasajiscymnus tsugae **(formerly *Pseudoscymnus tsugae*)**
Currently, beetles have been released in Connecticut, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, North Carolina, Pennsylvania, Rhode Island, South Carolina, Tennessee, Virginia, and West Virginia as of 2003 (1). Millions of beetles released since 1995 have been mass reared by the New Jersey Department of Agriculture and a partnership (LLC) formed by the North Carolina Department of Agriculture and Clemson University (Cheah *et al*. 1994).

Beetles have successfully established in some release areas and were overwintering and reproducing (Cheah *et al*. 2004). Beetles have been collected in Pennsylvania and Connecticut indicating establishment (Flowers *et al*. 2005). Beetles released in Connecticut and Virginia in 1997 reduced HWA densities by 47-83% (Cheah *et al*. 2004). *S. tsugae* actively feeds during the late spring (Lamb *et al*. 2005).

In Connecticut, the ability of *S. tsugae* to prevent further hemlock decline depended on site characteristics and tree health. Where hemlocks were growing in rocky or shallow soils, under drought stress, or stressed by other insects (e.g. elongate hemlock scale or hemlock borer), *S. tsugae* were not able to rapidly establish in order to prevent further hemlock decline. However, it was observed in years with more rain and cooler springs

and summers than usual, that hemlock trees recovered, producing new shoot growth. In areas where HWA numbers are low, releases of beetles have enabled recovery of trees within 4-7 years. Winter environmental conditions unfavorable to HWA during 2000 and 2003 have also impacted HWA numbers in these areas (Cheah 2004).
The bottom line: Beetles are being released in more states. Areas with healthy hemlock trees and lower densities of HWA stand the best chance for recovery after *S. tsugae* release and establishment.

Verticillium lecanii
This entomopathogenic fungus was tested against HWA in Massachusetts and also to determine effects on the beetle biological control agent, *S. tsugae*. In two years of field testing, *V. lecanii* (isolate ARSEF 6010) significantly reduced HWA populations after applications during the fall. Both lab and field results suggest no significant effect on the survival of *S. tsugae* exposed to *V. lecanii*. Late summer or fall ultra low volume (ULV) applications were suggested due to application opportunities and because the wax layer covering the adelgids was not present at this time (Cheah *et al*. 2004). The potential impact of ULV applications of *V. lecanii* on non-target organisms should be studied.
The bottom line: *V. lecanii* (ARSEF 6010) applications could reduce populations of HWA potentially in combination with releases of *S. tsugae,* however, non-target affects should be studied.

References

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1) http://na.fs.fed.us/fhp/hwa/ (accessed December 2005)