

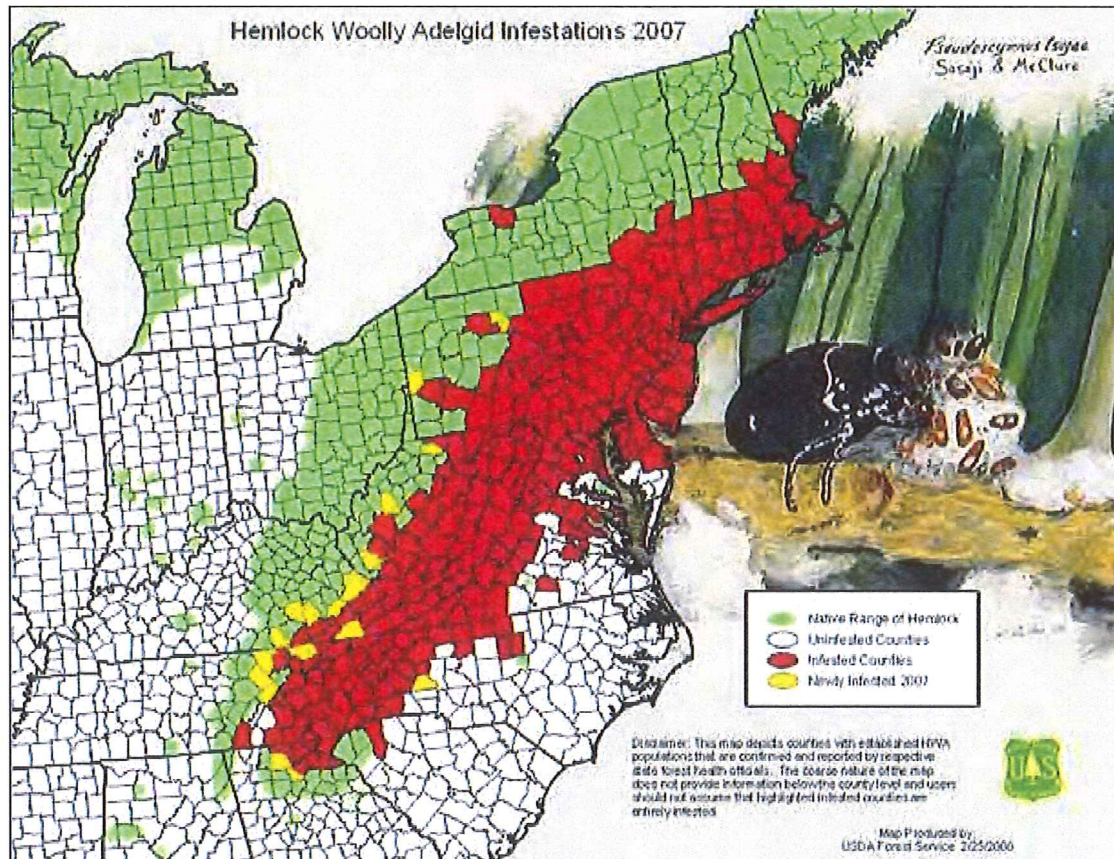
# Forest Health Technology Enterprise Team

TECHNOLOGY  
TRANSFER

*Hemlock Woolly  
Adelgid*

## FOURTH SYMPOSIUM ON HEMLOCK WOOLLY ADELGID IN THE EASTERN UNITED STATES

HARTFORD, CONNECTICUT  
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## THE CASE FOR *SASAJISCYMNUS TSUGAE*: BIOLOGICAL CONTROL HAS HELPED SAVE CONNECTICUT'S HEMLOCKS

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Connecticut's eastern hemlocks, *Tsuga canadensis*, have been under siege since the first detection of *Adelges tsugae*, hemlock woolly adelgid (HWA), in southern Connecticut in 1985. From 1986-2000, the adelgid spread to infest every one of the 169 towns in Connecticut. In response to the attack, The Connecticut Agricultural Experiment Station discovered, reared, and released >80% of the total *Sasajiscymnus tsugae* released to date between 1995-2001, but only after >90% of the towns in Connecticut had reported HWA infestations. There has been no large-scale chemical intervention in the state's forests and state parks to combat HWA in Connecticut. *S. tsugae* (> 176,000) has been released in 26 sites statewide in Connecticut to date.

In 2005, dramatic recovery of adelgid-impacted, declining hemlocks was recorded in many of the older established release sites. Annual foliage transparency trends in release sites showed that even declining hemlocks can recover in one year when precipitation is ample and drought stress is minimal (the last major severe drought event occurred in 2002). This prompted a comparative survey of 14 non-release sites, which were located to match release sites climatically, topographically, and in HWA infestation history. Hemlock health assessments were made in these sites and also in eight baseline hemlock sites that had no infestations of either adelgid or elongate hemlock scale, *Fiorinia externa*. Crown health of hemlocks was rated (n = 15 trees/site) using standard U.S. Forest Service Forest Inventory and Analysis (FIA) crown health assessment procedures, which has also been the method used to assess the conditions of hemlocks in release sites. Although HWA winter mortality can significantly reduce adelgid populations in Connecticut during severe winters (2003 and 2004), recent winters in 2006 and 2007 have been relatively mild. HWA winter mortality in Connecticut has only averaged 61% and 40%, respectively, in 2006 and 2007. In 2005, hemlock foliage transparency (a measure of the fullness of the crown) was significantly lower in the 14 annually monitored *S. tsugae* sites, as compared to that in paired non-release matches ( $p < 0.0001$ ). Mean foliage transparency in 6- to 11-year release sites was also similar to that in the baseline sites, located at high elevation in the colder northwest corner of the state, indicating that recovery of hemlocks had approached that in non-infested sites. Hemlock health ratings in 2006 and 2007 showed that this recovery has persisted, and in 2007, foliage transparencies in release sites ( $21.6 \pm 8.1$ ) remained similar to that in the baseline uninfested sites ( $23 \pm 5.0$ ). This recovery has continued even in the southernmost sites, which have not had significant recent winter mortality of HWA. Hemlock recovery in monitored release sites has been recorded in all types of soil types and sites, from rocky ridge tops to riparian, ravine to level habitats. There has been negligible hemlock mortality in release sites since 2001. In addition, HWA crown levels in 2006 and 2007, measured in classes of <10%, 11-50%, 51-75%, and

>75%, showed that in the majority of release sites, average adelgid levels have been reduced from the initial pre-release levels.

In order to address recent reports that *S. tsugae* minimally oviposits in sleeve cages, a field study was also conducted in Connecticut in 2006. Single pairs of 3-month-old, reproductive laboratory-reared *S. tsugae* from the Valley Laboratory were placed in sleeve cages on infested branches on a range of HWA densities (late sistens-developing progrediens) from 5/23/06-7/14/06, a period of 7 weeks, when ambient temperatures were optimal, with weekly average temperatures within sleeve cages ranging from 16-23.5 °C. Sleeve cages (n=15) were harvested and counts made of all live and dead adults, larvae, and pupae to generate the net reproductive response of a female. Results showed that 100% oviposition was recorded with a mean  $27 \pm 14$  eggs per female. Females also showed a density-dependent oviposition response ( $p < 0.05$ ) with a maximum of 56 eggs/female.

### ACKNOWLEDGEMENTS

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# The Case for *Sasajiscymnus tsugae*: Biological Control has Helped Save Connecticut's Hemlocks

CAROLE CHEAH

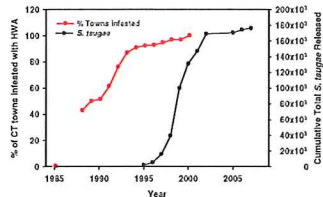
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## The Facts:

•Connecticut's hemlocks have been under adelgid attack since the first discovery of HWA in 1985. From 1985-2000, HWA spread to infest every town in CT (Fig.1); statewide decline of hemlocks was noted in 1994

•There has been no chemical intervention on a forest wide scale to combat HWA in CT. Widespread large releases of *S. tsugae* in the most heavily infested forests over most of the state has been the main strategy to combat HWA with >80% of the total released to date occurring from 1996-2001. Over 176,000 *S. tsugae* have been released in 26 sites statewide from 1995-2007, but releases only began after >90% of the state was infested (Fig. 1)

Fig. 1 Chronology of HWA and *S. tsugae* in Connecticut



## The Evidence:

•Substantial crown recovery in many release sites was first recorded in 2005 and has continued annually (Fig. 2) in spite of much warmer winters in 2006 and 2007 (Fig. 3). Declining hemlocks can significantly recover in one year when precipitation is ample and drought stress is minimal (Fig. 4)

•Hemlock recovery has occurred statewide in all types of sites and soils for 14 monitored release sites in riparian to ridge top, ravine to level hemlock habitats

•Hemlock recovery has also occurred in southern sites where winter mortality of HWA has not recently been a significant factor in depressing adelgid populations

Fig. 3 HWA Winter Mortality in Connecticut 2000 - 2007

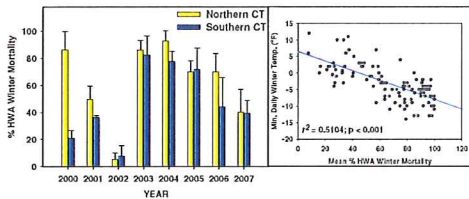
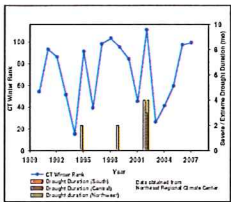
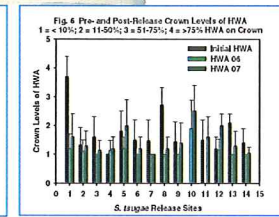
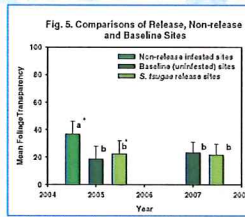
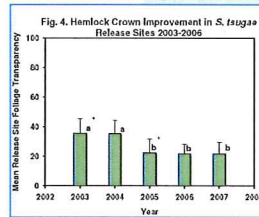
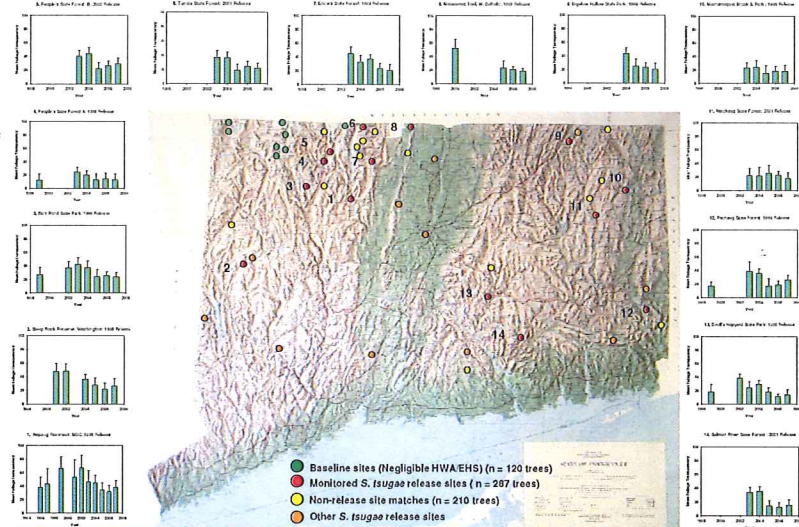


Fig. 7 Winter patterns and drought events in CT



**Additional Evidence:** A sleeve cage experiment was also conducted in CT to investigate recent reports that *S. tsugae* minimally oviposits in field bag studies. Reproductive 3 month old laboratory reared *S. tsugae* were caged in single pairs on hemlock branches with a range of late HWA sisters egg mass densities - developing progrediens from 5/23/06-7/14/06, when ambient temperatures were optimal. Sleeve cages (n = 15) were then harvested and counts of all live and dead adults, larvae and pupae were tallied for each female's reproductive response. Results showed that 100% oviposition occurred (mean 27 ± 14 eggs/female) and females showed a **density-dependent oviposition response** with a maximum of 56 eggs/female (Fig. 8).

Fig. 2 Hemlock Crown Recovery in Monitored 6-11 year *S. tsugae* Release Sites



•In 2005, non-release sites were matched climatically, topographically and 15 trees/site rated, as were baseline uninfested sites for comparison (all ratings used standard FIA crown health assessments)

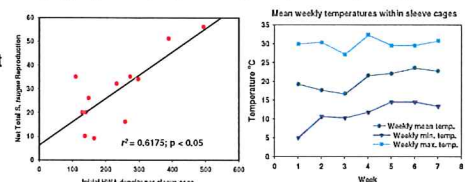
•Results showed that hemlocks in non-release sites had significantly thinner crowns than in release sites (p < 0.001). Crown health in release sites had recovered to similar levels in uninfested sites (p > 0.05; Fig. 5) by 2005 through 2007.

•HWA crown levels have also been reduced to the original levels prior to *S. tsugae* introduction in the majority of release sites (Fig. 6)

•In fact, eastern hemlocks statewide are generally showing healthier crowns; decline is patchy and correlated with the intensity of concurrent elongate hemlock scale infestations

•This is extensive hemlock recovery that is post peak *S. tsugae* introduction. Prior to *S. tsugae* releases, no extensive recovery had been observed when there were also very cold winters to mitigate adelgid spread (Fig. 7). Connecticut's eastern hemlocks are currently healthier than in any prior period during the establishment and spread of HWA with negligible hemlock mortality since 2001. If indeed, *S. tsugae* was as ineffective as is claimed, there would be no hemlock recovery to document. Perhaps Occam's Razor holds true in this case..... **"All other things being equal, the simplest explanation is the best."**

Fig. 8. Density-dependent field oviposition by *S. tsugae*



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