
RECOVERY AND ESTABLISHMENT OF INTRODUCED PREDATORS OF HEMLOCK WOOLLY ADELGID IN THE SOUTHERN APPALACHIANS

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ABSTRACT

Since its introduction from Asia, the hemlock woolly adelgid (HWA), *Adelges tsugae* Annand (Hemiptera: Adelgidae), has gradually spread into 17 states in the eastern United States (Trotter et al. 2008). A classical biological control program to introduce a complex of natural enemies has been implemented as part of an integrated management program against HWA. *Sasajiscymnus tsugae* (Sasaji and McClure) (Coleoptera: Coccinellidae), which is native to Japan, was the first introduced species of natural enemy selected for mass rearing and release against HWA in the United States beginning in Connecticut in 1995 (Cheah et al. 2005). Since 2002, more than two million *S. tsugae* beetles have been reared in insectaries in several states and released throughout the eastern United States, with many of the releases made in the southeastern United States (Grant 2008; Salom et al. 2008). Of these, approximately 350,000 were released from 2002 to 2007 at ca. 150 sites in the Great Smoky Mountains National Park (GRSM), where HWA was first documented in 2002 (Lambdin et al. 2006). In addition, about 7,000 adults of another predatory species, *Laricobius nigrinus* Fender, native to the Pacific Northwest, has been released against HWA at 21 sites in the GRSM. However, limited information exists on the establishment of these introduced natural enemies in areas of the releases in the GRSM, as well as in the eastern or southeastern United States (Cheah and McClure 2000; Grant 2008; McClure and Cheah 1998; McDonald et al. 2008).

In 2008, a study was initiated to evaluate the establishment of *L. nigrinus* and *S. tsugae* released against HWA in GRSM. The objective of this study was to determine the presence and extent of established populations of these two introduced predatory species at multiple release sites in GRSM.

Sampling was conducted at 56 *S. tsugae* and 11 *L. nigrinus* release sites in 2008 (5 May to 7 July), 2009 (25 February to 16 June), and 2010 (19 February to 30 June) in GRSM. At each release site, four hours of sampling using beat-sheets was conducted. All release sites were identified using Park records which provided GPS coordinates; sites were located using a Garmin® GPS map 60 CSx GPS unit. Original release trees, which were identified by an aluminum tag, at each site were sampled where possible. On all hemlock

trees in the release site area, accessible branches from ground level to 2.5 m were sampled by tapping them five to eight times with a wooden rod while holding a white beat sheet (71 x 71 cm) beneath the branch to catch dislodged predators. Depending on the size of the tree, one to three beat-sheet samples were collected per tree. All *L. nigrinus* and *S. tsugae* observed during beat-sheet sampling were recorded, and representative specimens of suspected adults and larvae were taken to the laboratory, where larvae were reared in glass jars (2.64 L) on HWA-infested hemlock until pupation and emergence as adults. Field-collected and laboratory-reared adults were identified in the laboratory, and species identification was confirmed by James Parkman at the Lindsay Young Beneficial Insects Laboratory (University of Tennessee). Voucher specimens are housed in the Integrated Pest Management and Biological Control Laboratory at the University of Tennessee. Additionally, data describing general characteristics of sites at the time of release, as well as several years after release, was obtained from Park personnel.

Ten release sites (17.8%; 10 of 56 sampled sites) were positive for presence of *S. tsugae*, and 103 adults and 152 larvae were recorded. A significant inverse relationship between year of release and number of *S. tsugae* larvae (Pearson = -0.316; $P = 0.029$), adults (Pearson = -0.447; $P = 0.003$), and adults and larvae combined (Pearson = -0.440; $P = 0.003$) was documented. In other words, recovery of *S. tsugae* was greater at the older release sites. Trees in the *S. tsugae* release sites were rated healthier than those in the non-release sites during 2009. The attributes of sites positive for *S. tsugae* included: an average of 2,377 adults released per site, adults released from June 3 to July 10, average temperature at the time of release was ca. 27°C, average elevation was 900 m, average new growth was about 72.5%, and the HWA infestation at time of release was estimated to be slight to high. On the other hand, the attributes of sites where *S. tsugae* were not collected were: an average of 3,452 adults released per site, adults released from June 2 to June 26, average temperature at the time of release was ca. 26°C, average elevation was 719 m, average new growth was only about 55.0%, and the HWA infestation at time of release was estimated to be medium to high. In general, a comparison of trends suggests that temperature was slightly higher at the time of release at positive release sites, elevation was higher at positive release sites, new growth was considerably higher at the time of release at positive release sites, and HWA infestation was lower at the time of release at positive release sites.

Three sites (27.3%; 3 of 11 sampled sites) were positive for presence of *L. nigrinus*, and 23 adults were recorded; adults were recovered from 2004, 2006, and 2007 release sites, suggesting that length of time since release did not greatly influence recovery. In addition, 18 adult *Laricobius rubidus* LeConte (a native predator) were recovered from 18.2% (2 of 11) of the *L. nigrinus* release sites. Both *L. nigrinus* and *L. rubidus* were recovered from the same two sites. Research to assess hybridization of these two species in GRSM will be pursued.

This ongoing study documents the presence of *L. nigrinus* and *S. tsugae* persisting at numerous locations in GRSM. *S. tsugae* may take longer (as many as 6 to 7 years) than anticipated for populations to establish and attain readily measurable levels, as relatively greater numbers of *S. tsugae* were recovered from releases made in 2002 compared to releases made in subsequent years (Hakeem et al. 2010). Recovery of introduced predators provides essential information on species presence, establishment, distribution, dispersion, seasonality, density, and alternate hosts. However, recovery data do not provide

insight into impact of these natural enemies on hemlock growth, tree health, tree survival, or adelgid populations. Further research is necessary to fully assess establishment of these introduced predators in GRSM and their impact on HWA.

KEYWORDS

Sasajiscymnus tsugae, *Laricobius nigrinus*, *Laricobius rubidus*
hemlock woolly adelgid, predators, biological control

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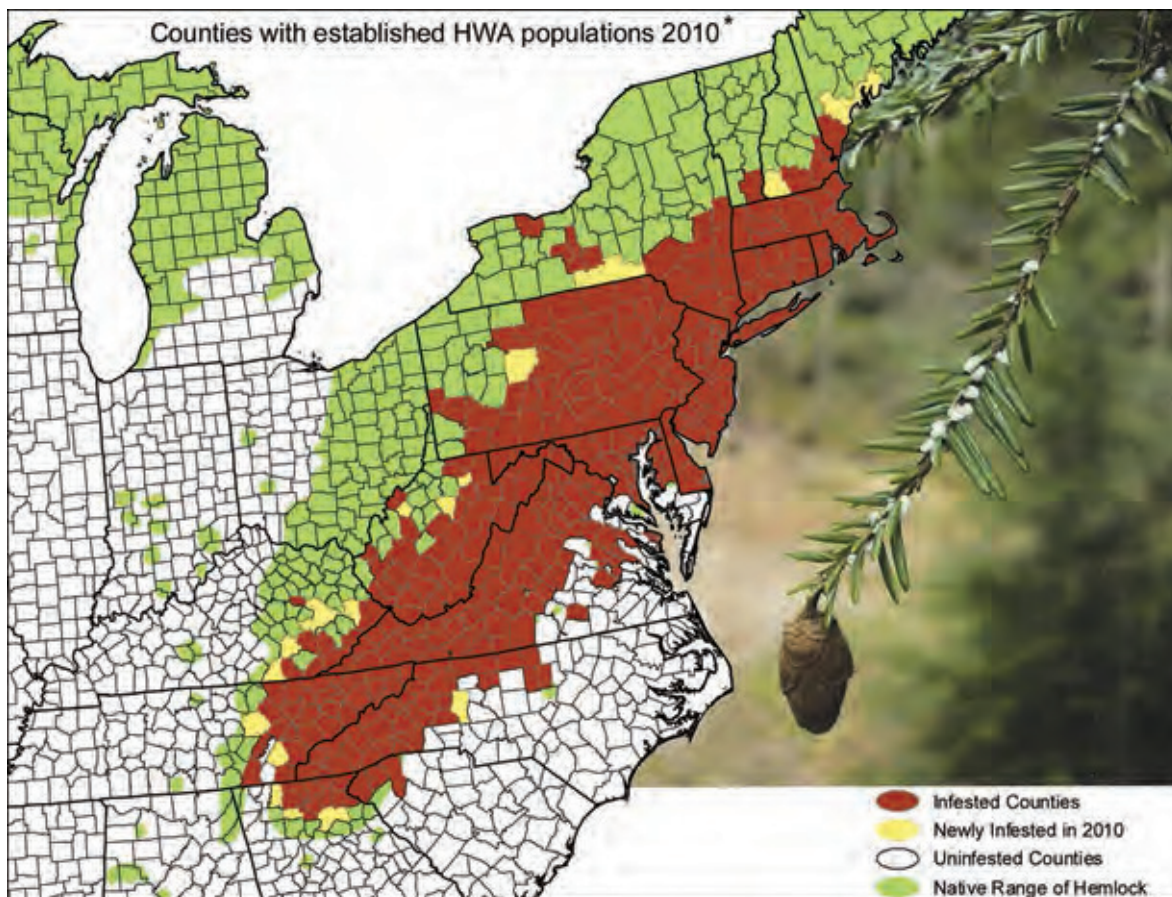
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TECHNOLOGY
TRANSFER

*Hemlock Woolly
Adelgid*

Fifth Symposium on Hemlock Woolly Adelgid in the Eastern United States

Asheville, North Carolina
August 17-19, 2010



*See inside cover.

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***Cover map:** Produced by USDA Forest Service, 2010. The map depicts counties with established populations of hemlock woolly adelgid (HWA) that have been confirmed by state forest-health officials. The coarse nature (scale) of the map does not provide information below the county level; highlighted counties are not necessarily entirely infested with HWA.

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FOREWARD

This is the 5th HWA symposium; the first meeting was held in Charlottesville, Virginia in 1995. Over the past fifteen years we have seen HWA spread like wildfire in the south, invade six additional states, and cause extensive tree mortality throughout the mid-Atlantic and southern regions. Sounds rather hopeless and yet we remain optimistic, and here's why.

During the first seven years (1995-2002), there were but a handful of scientists, forest health specialists and resource managers working on the HWA research and management issue. Investigations into biological control were limited and in its infancy, there were no chemical control options for protecting hemlocks in a forest environment, no standardized sampling methods, impacts to hemlock forests remained scattered regionally and until the late 1990s, some forest health specialists were even skeptical that HWA was really that big of a threat to hemlocks! Our basic knowledge of HWA biology was limited as was the consistency of funding to support the needed research and methods development. In 2001, a formalized plan, *An Exotic Pest Threat to Eastern Hemlock: An Initiative for Management of Hemlock Woolly Adelgid* was put forward and more stable levels of funding were made available annually by the USDA Forest Service beginning in 2003. This was the beginning of the HWA Initiative and the accelerated effort to research and develop management solutions. An effort that now involves 24 universities, seven institutions in China and Japan, 20 state agencies, four federal agencies and nine private institutions.

In the last eight years we have seen several effective systemic insecticides become labeled for forest applications resulting in tens of thousands of hemlocks treated and protected annually. Standardized survey methods have been developed, and thanks to investigative DNA technology, we now know that all HWA are NOT created equal and that the origin of HWA found in the East is southern Japan. We now have six institutions rearing HWA predators and we are seeing predators becoming established in many areas from Maine to North Carolina. The cold tolerant *Laricobius nigrinus* found in the interior west has been recently released is now becoming established in areas where the coastal strain of this beetle was difficult to establish. With all this, we also have approval to begin rearing and releasing the newly discovered beetle predator from Japan, *Laricobius osakensis* which has proven to be very promising.

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