Biological Control of the Hemlock Woolly Adelgid in the Southern Appalachians

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ABSTRACT

Biological control of the hemlock woolly adelgid is thought to be the most feasible long-term solution to controlling this pest. Two species of imported lady beetles (Coleoptera: Coccinellidae) are currently available for release. *Sasajiscymnus tsugae* has been the most widely released, with over 1 million beetles released throughout the range of the adelgid. However, optimum release densities are unknown. Our study showed no significant differences in adelgid density following releases of 300 or 3,000 adult *S. tsugae*, although adelgid densities were significantly higher at control (no release) sites. A sleeve cage study with *S. tsugae* demonstrated significant control of the adelgid when initial densities were between 0-50 ovisacs per branch. A similar sleeve cage study with *Scymnus sinuanodulus* demonstrated some control of the adelgid when densities were greater than 100 ovisacs per branch. No reproduction was observed for either lady beetle during these studies. In addition to these studies, mass releases of 450 *S. sinuanodulus* and 150 *Laricobius nigrinus* (Coleoptera: Derodontidae) were done, representing the first release of these species together and the first release in the state of Georgia. It is hoped that the combination of these three predators will be effective agains the adelgid.

KEYWORDS

Sasajiscymnus tsugae, *Scymnus sinuanodulus*, *Laricobius nigrinus*, biological control.

INTRODUCTION

The hemlock woolly adelgid, *Adelges tsugae* Annand, continues to spread through the southern Appalachians and the southernmost range of eastern hemlock, causing extensive tree mortality. Biological control is considered the most viable, long-term solution to combating the adelgid since chemical and silvicultural control are ineffective or impractical on a large scale. As natural enemies of the adelgid native or present in the eastern U.S. have little impact, recent efforts have been undertaken to release biological control agents imported from Japan, China, and western North America. So far, three beetle that feed on the hemlock woolly adelgid are being released. One species, *Sasajiscymnus tsugae* (Sasaji and McClure)(Coleoptera: Coccinellidae), is widely available, with over 1 million insects released throughout the range of the adelgid. Two other species, *Scymnus sinuanodulus* Yu et Yao (Coleoptera: Coccinellidae) and *Laricobius nigrinus* (Coleoptera: Derodontidae), have seen limited release but will likely be more widely utilized in the future.

Evaluating the success of these predators has been problematic because the beetles are very small and difficult to find a few months after a release. It is unknown whether these beetles will be effective at suppressing the adelgid to non-damaging levels in the long term. Adelgid populations reach much higher densities on eastern hemlock in North America that they do in Asia or western Northern America, where hemlock species are much less susceptible and natural enemies are more abundant. It is thought that more predator species will need to be introduced to produce an effective and stable natural enemy complex.

Although thousands of *S. tsugae* are typically released at a time, the optimum number of beetles to release is unknown; thus, we replicated and repeatedly sample releases of this beetle at five location at typical number and at a 10-fold less number. Because it is difficult to monitor the impact of free releases, we also conducted caged studies of *S. tsugae* and *S. sinuanodulus* at a range of adelgid densities.

EXPERIMENT SUMMARY

We first compared the effects on the local adelgid population when a typical number of *S. tsugae* (3,000) and a lower amount (300) were released. Both the adelgid and beetle populations were monitored at the release sites and at a nearby control site where no release was made. This was replicated three times throughout Rabun County in northeast Georgia during April 2003. For 16 weekly sampling dates (April-August), adelgid density was significantly lower at both release densities compared to the controls. However, during most sampling dates, there was little or no difference between the 300 and 3,000 release densities. This suggests that the efficacy of the higher releases may be offset by more overcrowding and predator dispersal. Although we examined foliage samples using a microscope weekly (72-108 total twigs collected from the upper and lower crown of each of 18 trees), we were unable

to document any predator reproduction in the form of beetle eggs or larvae. It is uncertain whether this was due to inadequate sampling intensity or simply the absence of reproduction.

At the Coweeta Hydrologic Laboratory in Otto, North Carolina, sleeve cages were used to enclose adults of *S. tsugae* on hemlock branches infested with variable densities of hemlock woolly adelgid to determine the density levels at which these predators are most effective. Adelgid ovisacs were counted on 40 hemlock branches in early April, coinciding with maximum egg production by the adelgid. Adult predators (one male and two females) were placed in each of 20 of these sleeve cages and 20 cages were left empty. These were left for six weeks: enough time for a new generation of predators to be produced. After this time period, sleeve cages and the enclosed branches were harvested and returned to the laboratory, where adelgid ovisacs and the number of predators were counted. At the lowest initial adelgid densities (0-50 ovisacs per branch), adelgid population growth was greatly reduced compared with controls. At higher densities (>50 ovisacs), there was little or no effect by *S. tsugae* on adelgid population growth. No predator reproduction was documented in any of the sleeve cages, for reasons that remain unknown. Therefore, all of the observable effects on adelgid growth can be attributed to feeding by the three adult predators placed in each sleeve cage.

A similar study was performed using mating pairs of *S. sinuanodulus* produced this spring in the laboratory. In contrast to the multivoltine *S. tsugae*, *S. sinuanodulus* is univoltine and hence was not expected to reproduce during the study. Although some of the sleeve cages with beetles were missing, the cages were set up and harvested three weeks later, and had fewer beetles in each cage; the *S. sinuanodulus* had a greater effect on higher initial adelgid populations than *S. tsugae*.

In addition to the releases of *S. tsugae*, smaller-scale releases were made of *S. sinuanodulus* and *L. nigrinus* were done in Rabun County, in northeastern Georgia. In April 2004, 150 *S. sinuanodulus* were released, and an additional 300 were released in October 2004. These beetles were obtained from the Insect Rearing Facility, U.S. Forest Service, Northeastern Research Station, in Hamden, Connecticut. Also at the same location and on the same day in October, 150 adults of *L. nigrinus*, reared at Virginia Tech, Blacksburg, Virginia, were released.

DISCUSSION

Because *S. sinuanodulus* and *L. nigrinus* only have one generation per year and are not as amenable to mass rearing, quantities available for field release are much more limited than with *S. tsugae*. It is hoped that more efficient rearing techniques will improve the output of these species in the near future. A combination of these three predators may be more effective against the adelgid. Furthermore, the sleeve cage studies reported here demonstrate that S. *tsugae* should be released prior to a large buildup of adelgid populations, and more research is needed to define factors that affect its reproduction following release.

The release of *L. nigrinus* and *S. sinuanodulus* was the first time that these species have been introduced into Georgia and will represent one the the first locations where all three predators (including *S. tsugae*) have been released in the same area (Rabun County). This was the first environmental release of *S. sinuanodulus* and sampling in 2005 will need to be inten-

sive to discern if it has established and reproduced. Over 4,000 *L. nigrinus* have been released recently thoughout the central and southern Appalachians, with year-after recovery reported from several locations.

ACKNOWLEDGEMENTS

Funding was provided by the USDA Forest Service, Southern Research Station, Athens, Georgia. Additional support was provided by the USDA Forest Service, Forest Health Protection, Asheville, North Carolina. We would like to thank Hugh Conway of Clemson University, Clemson, South Carolina; Carol Cheah of the USDA Forest Service, Hamden, Connecticut; and David Mausel of Virginia Tech, Blacksburg, Virginia, for assistance with acquiring and releasing the beetles used in this study. In addition, we thank Jime Vose, USDA Forest Service, Otto, North Carolina, for permission to conduct research at the Coweeta Hydrologic Laboratory, and Jim Sullivan, Georgia Forestry Commission, for assistance with locating additional field sites.