Hemlock Woolly Adelgid Initiative: Progress and Future Direction

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ABSTRACT

In 2001, the USDA Forest Service in cooperation with the National Association of State Foresters and the National Plant Board proposed a five-year program that would accelerate development and implementation of management options to reduce the spread and impact of hemlock woolly adelgid. From 2003-2007, this "Hemlock Woolly Adelgid Initiative" has involved researchers and resource managers from four federal agencies, 20 state agencies, 24 universities, seven institutions in China and Japan, and more than nine private companies. Accelerated research and technology development during the five-year initiative resulted in a significant increase in our knowledge of hemlock woolly adelgid and its impact on hemlock resources. New management strategies have improved short-term control and provided opportunities for a potential long-term solution for this devastating pest. Although the Initiative has been highly successful, the job is not done. Recommendations for future program direction and priorities are discussed.

KEYWORDS

HWA Management Initiative, priorities, accomplishments, management tools, research, technology development

KEY ISSUES

Reducing the rate of artificial spread and overall impact of hemlock woolly adelgid (HWA) have become primary management goals. During the first five years of the Initiative (2003-2007), state officials reported newly found HWA infestations in 74 new counties (for a total of 303 counties) and two additional states (South Carolina and Kentucky). HWA currently infests nearly one-half of the native range of hemlock in the East. It can be found from southeastern Maine to northeastern Georgia and as far west as eastern Tennessee and Kentucky (Figure 1). HWA continues to spread at an average rate of 12.5 km per year, primarily by wind and birds. Slowing the natural spread of HWA is not likely to occur given the relative randomness of movement and difficulties in early detection of initial infestation in forest settings. Controlling artificial spread (movement of infested nursery stock or other hemlock products from infested to uninfested areas), however, can reduce the occurrence of isolated infestations. Regulating movement and quick response to newly discovered infestations is necessary.

Isolated infestations have occurred in Vermont, Ohio, and Michigan as the result of infested nursery stock being transported from the generally infested area. Forestry and agriculture officials have undertaken eradication efforts in Maine, New Hampshire, Vermont, Ohio, Wisconsin, and Michigan and have implemented quarantines. See Figure 1 for a map of the currently infested area.

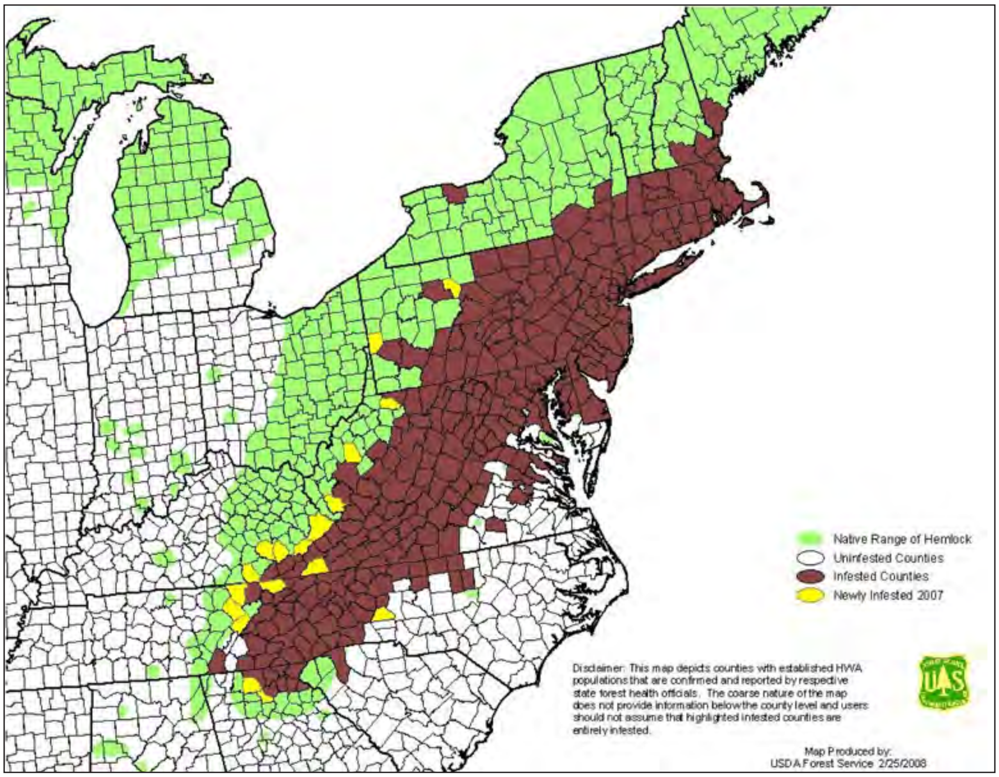

Figure 1. Hemlock woolly adelgid infestation, 2007.

KEY ACCOMPLISHMENTS

Over the last five years:

- Two new predatory beetles (*Laricobius nigrinus* and *Scymnus sinuanodulus*) for HWA biological control have been established and the range of *Sasajiscymnus tsugae* has been expanded to 15 states.
- Six laboratories (four at universities and two at state agencies) are now actively rearing three predator species.
- A systemic insecticide (imidacloprid) has been registered for use in the forest environment, and methods that increase its effectiveness have been developed.
- Resistant hemlock genotypes identified from devastated landscapes or through breeding with resistant species are under evaluation and development.
- Molecular genetics has been used to pinpoint the origin of HWA in the eastern U.S. and suggest that several distinct populations of HWA occur worldwide.

- Improved assessments of impact have been developed through classical economics and remote spectral sensing.
- Several survey methods have been developed that can be tailored to specific objectives.
- Silvicultural studies were initiated on public lands to determine whether thinning hemlock-hardwood stands to improve tree vigor in advance of HWA will minimize hemlock mortality once infested.

Information transfer has greatly improved access to available information: a website dedicated to HWA is in place that provides both the public and researchers up-to-date information, three symposia were held that provided a forum for managers and researchers to find out what is being done over the full range of topics, and proceedings from the symposia were published.

FUTURE PROGRAM DIRECTION

The knowledge base needed to develop and implement an effective HWA management program was increased significantly during the 2003-2007 period of this initiative. Progress in managing HWA has been made, but additional investments in research and technology development are needed to advance long-term management strategies, particularly in the areas of biological control and insecticide management. The recommended future program activities that follow provide general program direction regarding needed research and methods development over the course of the next five years and is not intended be a comprehensive list. Specific program activities will often change as new information becomes available.

Biological Control

Although three predatory beetles have been established for biological control of HWA, their ranges are spreading slowly. Additional species and better methods are needed to accelerate spread and to increase populations to levels that can maintain HWA below damaging levels. Two additional beetles have been approved for release, and better methods of mass rearing them need to be developed. Several candidates in quarantine or in the western U.S. need further evaluation and development of rearing methods. Priorities include:

1. Conduct extended-length (at least one-year) studies to assess the impact of natural enemies on HWA populations in their native habitat, such as in Japan, the source of HWA in the eastern U.S.
2. Continue quarantine screening of newly discovered predators and begin field evaluations of promising biological control candidates.
3. Continue development of artificial diets suitable for mass rearing of predators, and transfer developed technology to rearing facilities.
4. Phase-out mass rearing and release of *S. tsugae* in the southern range as other predators become available for rearing and release.
5. Phase-out mass rearing of *L. nigrinus* in the laboratory, and rely more on field collections from western North America for establishing healthy beetles and field insectaries.

This phase-out should be concomitant with the build-up of mass-rearing capacity for the Japanese *Laricobius* predator beetle when it becomes available for release.

6. Assess the cold-hardiness of *L. nigrinus* collected in Idaho, and determine whether it will improve establishment success in colder climatic regions in the East.
7. Continue rearing and establishment of *S. sinuanodulus* in southern range.
8. Begin mass rearing, release, and evaluation of *S. ningshanensis* in northern regions and higher elevations in the South.
9. Continue studies of biology and develop rearing methods for *Leucopis argenticollis.*
10. Continue to monitor all natural enemy species released, and assess their ability to establish, disperse, and impact HWA across the pest's geographic range. Part of this effort includes requiring all cooperators to input release data (e.g., site and predators) into an online predator-release database currently being developed.
11. Develop genetic identification tools (as there are no morphological methods for species identification for the larvae and pupae) and more information on the population structure of the natural enemies being released and evaluated.

Insecticidal Management

Soil application to manage HWA on individual, high-value trees or groups of trees has been shown to be effective, but the cost is high and alternatives for environmentally sensitive areas are needed. More efficacious methods for stem application are needed. Aerial application options are needed to treat large or otherwise non-accessible hemlock stands. Protection of high value hemlock trees and groups of trees should continue until natural enemies become established and provide control of HWA. Priorities include:

1. Continue evaluating new insecticide formulations and application methods for efficiently and effectively treating hemlock stands
2. Continue ground-based field trials of fungal pathogens, including *Lecanicillium lecanni* (Verticillium) using newly developed formulation technology.
3. Conduct pilot project to evaluate treatment efficacy of aerially applied insecticides including fungal pathogen formulations.
4. Evaluate the efficacy and application of the newly developed tablet formulation of imidacloprid.
5. Continue studies on optimal dosage and uptake of systemic insecticides.
6. Continue studies on movement and persistence of imidacloprid in soils.
7. Continue studies on methods to measure low levels of imidacloprid and its metabolites.

Silvicultural Management

In the face of changing forests, land managers need better analytical tools and experimentally assessed protocols for developing and exploring silvicultural options. To acquire them, we should:

1. Continue efforts to evaluate the effect of pre-infestation thinning of mixed-hardwood stands on vulnerability of hemlock to HWA infestation.
2. Continue modification of the Forest Vegetation Simulator (FVS) to include a HWA extension in cooperation with FHTET and Forest Service Research. Using existing and newly acquired knowledge about the biology of the HWA and its impact on stand structure, this tool will allow forest managers to visualize forested ecosystems after impact by HWA and under various silvicultural treatments.

Host Resistance

There are three approaches to increasing the resistance of hemlocks in the eastern U.S. to HWA. One approach is to incorporate the natural resistance of species that have co-evolved with HWA into the native eastern U.S. species through breeding programs. Another approach is to identify hemlocks with higher resistance among existing growing stocks and propagate them. A third approach would be to identify whether and how the environment may induce resistance.

1. Continue development and evaluation of hybrid *T. caroliniana* and *T. chinensis*, including generation of F_2 and backcross populations.
2. Verify if the above hybrids will naturally hybridize with *T. caroliniana.*
3. Determine nature of incompatibility between *T. canadensis* and other *Tsuga* species and test the means to overcome this incompatibility so that hybrids can be created with *T. canadensis*.
4. Make outplantings of the most promising hybrid crosses over the natural range of eastern hemlocks in order to verify their growth characteristics in a variety of environments.
5. Select specimens of *T. canadensis* that have survived in generally infested areas and verify whether this resistance is genetic.
6. Identify the role of environmental factors on the tolerance of hemlock to HWA.
7. Conserve the gene pool of eastern and Carolina hemlock until biological control and/or other means are available to reduce HWA below damaging levels.

Biology and Ecology

Recent breakthroughs in elucidating the genetics of HWA has helped identify the source of HWA in eastern North America. Important questions of the genetics of HWA populations, its hosts and its natural enemies remain. Additional information is needed on how climate—not only cold winter temperatures but also hot summer temperatures—affect HWA population dynamics. Knowledge of the feeding behavior and nutritional requirements of HWA would help in resistance studies and insecticidal management.

With the identification of the source population, the climatic preferences of the hemlock woolly adelgid can be estimated. Once identified, the key climatic factors that facilitate or limit HWA growth can be used to identify areas with similar conditions, from which biological control agents may be identified. Once identified, analysis of the similarities of requirements between the adelgid and the biological control can help managers tailor the use of specific biological controls to regions of the landscape. These analyses are being based on global climate data sets in combination with custom-built population models. Used in combination with other systems such as the FVS, these tools may assist land managers with selecting appropriate species, timing, conditioning, and distribution of released biological control agents. This work is being integrated with a landscape-wide study of the relationships between the HWA and environment to assist with identifying those areas most at risk for infestation. Information requirements include the need to:

1. Complete a global database on environmental parameters for HWA.
2. Elucidate the population genetic structure of HWA at a sufficiently fine level and link this to life history and host interactions to assist development of management options.
3. Develop models of climate space and HWA development.
4. Define the feeding behavior and nutritional requirements of HWA.
5. Develop DNA barcodes to identify interceptions of adelgids, thus promoting biosecurity.

Host-Pest Interactions

The elongate hemlock scale does not appear to be a significant pest in the southern U.S. or in its native habitat in Japan, but for unknown reasons, does appear to be spreading and impacting hemlock health in the mid-Atlantic and New England regions. Further investigations are needed to determine the cause and if intervention is possible. We still need to:

1. Determine the significance of biological control agents of EHS in southern U.S. and Japan and evaluate potential candidates for establishment in affected regions in eastern U.S.
2. Determine whether the scale parasitoid *Encarsia citrina* found in Japan is genetically different from *E. citrina* found in eastern North America.

Impact Assessments

Methods to evaluate impacts to hemlock resources are currently available using Landsat imagery and hyperspectral remote sensing technologies. The economic damage to property values in residential communities have been assessed in the northern range of HWA but may not be applicable to the loss of hemlocks in communities in the southern range. Furthermore, the socio-economic valuation of the forest resources at risk due to HWA and the value of treatment options in terms of ecosystem response, public acceptance and economic cost/benefit have not been assessed. We need to:

1. Conduct comparable community-based economic assessment in the southern Appalachians.
2. Assess the socio-economic impacts of existing management and no-management options for HWA on a regional scale utilizing current management strategies and available impact information.
3. Assess the socio-economic impacts to primary recreational areas such as the Great Smoky Mountains National Park and Delaware Water Gap National Recreation Area, where significant impacts have occurred and management actions are underway.

Survey and Monitoring

Sufficient methods are now available for survey, monitoring, and research purposes. No further methods development is needed. We need to:

1. Continue annual regional assessments of newly infested areas by using current survey methods and supporting county level surveys conducted by states.

Information Transfer

Maintaining an updated USDA Forest Service HWA website and publishing new information related to management of HWA has been an effective way of reaching both resource managers and private land owners. Publishing HWA newsletters and conducting periodic HWA symposia with published proceedings has also proven effective at distributing new information and developing collaboration among researchers and resource managers.

1. Continued support in updating the HWA website with new information as it becomes available.
2. Continued publishing periodic newsletters and conducting HWA symposia in alternating years.

Forest Health Technology
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TECHNOLOGY
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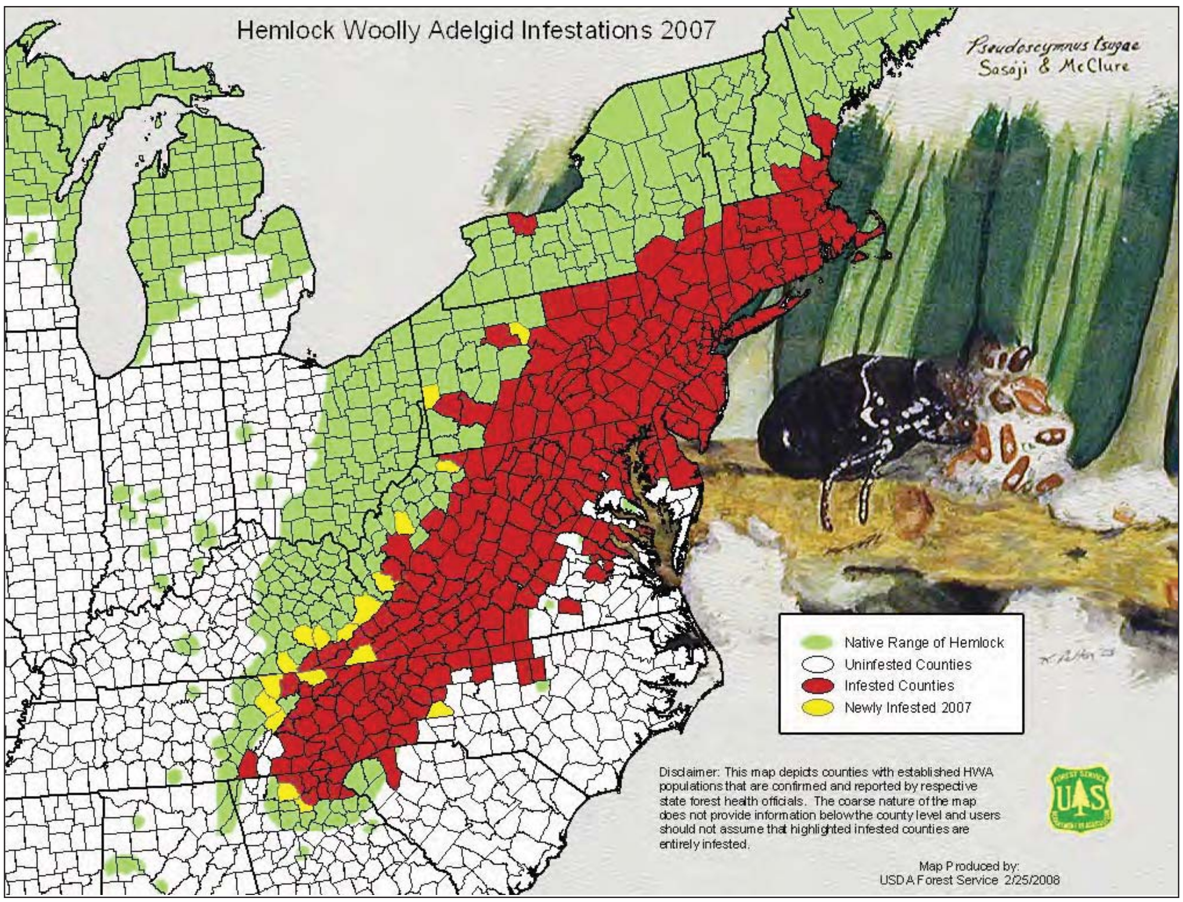
Hemlock Woolly Adelgid

Fourth Symposium on Hemlock Woolly Adelgid in the Eastern United States

Hartford, Connecticut
February 12-14, 2008



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