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Eastern Hemlocks Under Siege by Tiny Insects

Invasive species have been characterized as a "catastrophic wildfire in slow motion."

National Strategy and Implementation Plan for Invasive Species Management, USDA Forest Service, 2004

In the forests, parks, and backyards of 17 eastern states, hemlock trees are under siege. Small white fuzzy clumps on the twigs contain a tiny invasive insect from Asia, the hemlock woolly adelgid (HWA). This insect sucks nutrients from the hemlock trees, slowing growth and causing needle-drop. If the infestation is not controlled, the hemlock trees fade away and die. Forest scientists, land managers, and many citizens are increasingly worried that the HWA may endanger the viability of hemlock species in eastern forests, and thus remove a critical element of forest ecosystems.

Hemlocks Are an Important Component of Forest Ecosystems

The scientific name for hemlocks is *Tsuga*, a Japanese word meaning "tree-mother," an appropriate name because hemlocks provide a distinctive environment for many plants and animals. For example, ancient hemlocks are the preferred birthing places for pandas in China. In the eastern United States, hemlocks provide hibernation places for black bears in the southern Appalachians, thermal cover for deer in Vermont, shade to keep Pennsylvania trout streams cool in summer, nesting habitat for warblers in New Jersey, and suitable habitat for endangered salamanders in West Virginia.

Hemlock is our most shade-tolerant conifer and can grow to great age and size: records are 988 years and 160 feet tall; typically, ages approach 400 and heights above 100 feet. The trees are tall, straight, late-successional evergreens, with conical crowns and slender horizontal to pendulous branches, that

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NE Forest Science Review is dedicated to presenting clear and concise information on current problems and issues relating to forests and forestry in the Northeast and the role of the nearly 100 scientists in the USDA Forest Service's Northeastern (NE) Research Station in exploring these topics and finding solutions for problems.

We hope that land managers, policymakers, science communicators, extension specialists, environmental advocates, and educators, as well as conservationists and all others interested in the health and productivity of forests in the Northeast, will find our quarterly newsletter useful and informative.

The NE Research Station is part of the USDA Forest Service's Research & Development national network of six regional research stations, the Forest Products Laboratory, and the International Institute of Tropical Forestry. NE scientists work at research sites in 13 states—Hamden/Ansonia, CT; Newark, DE; Amherst, MA; Baltimore, MD; Bradley, ME; Durham, NH; Burlington Co., NJ; Syracuse, NY; Delaware, OH; Warren and Newtown Square, PA; Burlington, VT; and Morgantown, Parsons, and Princeton, WV.

NE scientists work in laboratories and a wide variety of field sites, including eight experimental forests (several of these maintain long-term data sets that are unique to science) and six research natural areas, sited on National Forest System lands. Two important research locations are the Forest Service's only primary quarantine laboratory on the continental United States (Hamden/Ansonia, CT), a facility certified for biological control research on non-native forest pests and their natural enemies as well as the Baltimore (MD) Long Term Ecological Research Site, where NE scientists and other cooperators study the ecology of an urban forest.

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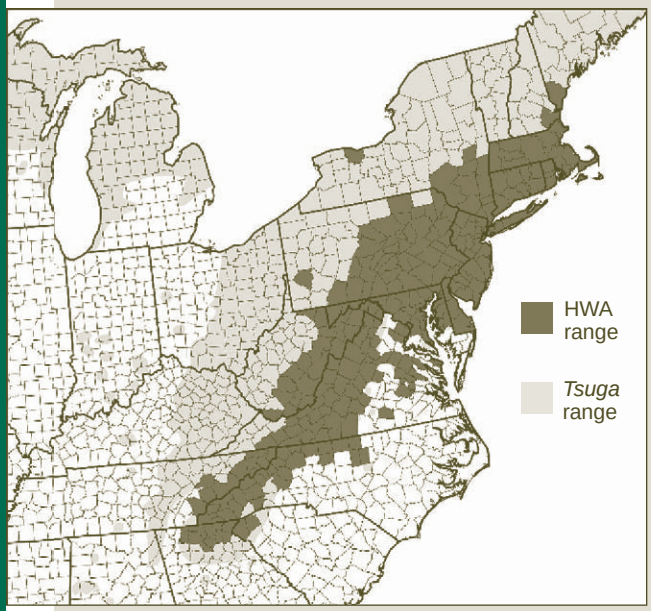
grow in areas with moist soil. Hemlocks are also important in landscaping as specimen trees and hedges. Globally, there are only nine species of hemlock: four are native to North America (two in the West, two in the East) and five in Asia (southern Himalayas, China, Taiwan, and Japan). In eastern North America the species are eastern hemlock (*Tsuga canadensis*), which occurs from Canada to Georgia and west to Minnesota, and Carolina hemlock (*T. caroliniana*), a smaller tree with longer needles and cones, which is restricted to portions of Georgia, North Carolina, and Virginia.

Hemlock Woolly Adelgid Is Spreading in Eastern Forests

The hemlock woolly adelgid now occurs in all countries where hemlock species are native, but only the hemlock species in the eastern United States are damaged. It was first observed in the east near Richmond, VA and was likely brought there on nursery stock from Japan (a Forest Service cooperator, Nathan Havill of Yale University, recently matched the DNA from HWA in the eastern U.S. to one of several populations in Japan). HWA is spread when the eggs and "crawlers" (the first-stage nymphs that hatch from the eggs) are carried by birds, deer, or the wind. It can be also transported on nursery stock.

For the first 30 years, the adelgid spread slowly in ornamental plantings and urban forests and was considered innocuous. However, during the 1980s, the HWA entered the native range of eastern hemlock and has spread rapidly since then. It now infests about a quarter of that species' native range and most of the range of Carolina hemlock. In some areas, healthy hemlock are entirely absent and tree mortality is increasing dramatically. Remembering the drastic ecological changes to the eastern hardwood forests resulting from the loss of the American chestnut to chestnut blight, scientists, land managers, and all those concerned about healthy eastern forests have an increased sense of urgency about controlling the HWA in forests.



"One of the four major threats to America's forests is the spread of invasive species. These are species that evolved in one place and wound up in another, where the ecological controls they evolved with are missing... We are losing our precious heritage—at a cost that is in the billions."

Dale Bosworth
Chief, USDA Forest Service

Can Eastern Hemlocks Be Saved?

The Northeastern Research Station is at the forefront of research on the HWA. Based on our current knowledge, the only natural phenomenon reducing the spread of HWA in eastern forests is cold winter temperatures. Dr. Kathleen Shields at the Center for Forest Health Research in Hamden, CT, and cooperator Dr. Carole Cheah of the Connecticut Agricultural Experiment Station have recently documented greater winter mortality in northern areas, suggesting a possible limit to the HWA's northern spread. However, while cold winter temperatures may limit spread of the HWA, occasional warm winters may allow this pest to cross thermal barriers such as ridgetops and invade new territory. In the South, active management is needed to mitigate the impacts of HWA on hemlock. Although spraying trees with horticultural oils and drenching or treating soils or trees with the systemic insecticide imidacloprid can be effective techniques to kill HWA in landscape trees, these methods are not appropriate for forested regions.

Forest Service scientists are focusing their efforts on two alternative control strategies. The first is to find and release additional biocontrol agents—natural enemies from HWA's native range that could help to maintain HWA populations below damaging levels. The second strategy is to determine why different species of hemlock show differing host resistance and to use this information to develop HWA-resistant hemlocks for the eastern United States.

Forest Service Entomologist Importing Natural Enemies from Asia

Northeastern Research Station entomologist Dr. Michael Montgomery, at the Center for Forest Health Research, and cooperating scientists have searched extensively in China for insects that feed on HWA. They only look for predators since adelgids have no known parasites. They have been very successful, finding more than 100 species of insect predators on hemlocks infested with HWA. Many of these were previously unknown to science and to date more than 30 new species have been described and named. From the many species collected, Montgomery selected fewer than a dozen that seem the most promising for biological control of HWA in the eastern U.S and imported these to the Station's secure quarantine laboratory in Ansonia, CT, for rearing and further study. The most promising are lady beetles in the genus *Scymnus* (see page 5). One of these, *Scymnus sinuanodulus*, has made it through extensive testing for safety and suitability and has been released in six states. With the knowledge that Japan is the source of the strain of HWA present in the eastern United States, our search for new species has now expanded to Japan.

One of the difficulties in establishing biological controls is that the climate range of the pest is often much broader than that of any one species of its natural enemies. For example, *Scymnus sinuanodulus* is found in only one province in China, whereas HWA is found in eight. A new scientist at the Center for Forest Health Research, Dr. Talbot Trotter, is generating landscape models to match predator species to regions of HWA-infested landscapes where those predators are likely to successfully establish.

Forest Service Funds Research to Improve Hemlock Resistance

Only the two species of hemlock native to eastern North America are damaged by HWA; species endemic to Asia and western North America are resistant and/or tolerant to the adelgid. Where the adelgid has been present in eastern forests for some time, it has been noticed that some trees suffer more damage

Chinese hemlock (*Tsuga chinensis* var. tchekiangensis)

than others. To identify, increase understanding, and develop more resistance to HWA in eastern forests, the Northeastern Research Station, along with the Southern Region and Northeastern Area State and Private Forestry, solicited and evaluated proposals from research institutions. Seven of these were funded in 2005 for a total of $371,578 to provide a multi-faceted approach ranging from studies on phytochemistry, identifying resistance in eastern hemlock and hybrid species using DNA and traditional observation and screening, and propagation and planting of promising clonally produced seedlings. Shields explains, "the goal of this program is to focus the best research on identifying, propagating, and establishing resistant hemlock cultivars, hybrids, and species in eastern forests as an additional means of reducing the impact of HWA and maintaining hemlock as a component in eastern ecosystems."

Forest Service Ecologist Tracks Hemlock Health from the Sky

The large scale of the HWA infestation and its potentially severe consequences require scientists and land managers to identify new infestations early on. Field-based methods are time consuming and only offer localized information. Having the ability to detect trees in the very early stages of decline across entire landscapes is crucially important to implement integrated pest management strategies for managing HWA infestations. Dr. Jennifer Pontius of the Station's Louis Wyman Forestry Sciences Laboratory in Durham, NH, has found that hyperspectral remote sensing can assess not only defoliation but also detect early signs of stress. Pontius' work has shown that special sensors mounted on satellites, airplanes, or helicopters can be used to identify hemlock stands in the very early stages of decline, often before visual symptoms are apparent on the ground.

Resources for Further Information

Publications

McClure MS, Salom SM, Shields KS. 2003. **Hemlock Woolly Adelgid.** FHTET-2001-03. Morgantown, WV: USDA Forest Service, Forest Health Technology Enterprise Team. 14 p.

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Ward JS, Montgomery ME, Cheah CAS-J, Onken BP, and Cowles RS. 2004. **Eastern Hemlock Forests: Guidelines to Minimize the Impacts of Hemlock Woolly Adelgid.** NA-TP-03-04. Morgantown, WV: USDA Forest Service, Northeastern Area State and Private Forestry. 28 p.

Websites

USDA Forest Service's Northeastern Research Station
www.fs.fed.us/ne

USDA Forest Service's Northeastern Research Station, Northeastern Center for Forest Health Research
www.fs.fed.us/ne/hamden/projects/4501.html

USDA Forest Service's Northeastern Area State and Private Forestry
www.fs.fed.us/na

USDA Forest Service's invasive species program
www.fs.fed.us/invasivespecies

USDA National Agricultural Library
www.invasivespeciesinfo.gov/profi les/hemlockwa.shtml

University of Georgia's Bugwood Network
www.invasives.org

Connecticut Agricultural Experiment Station
http://www.caes.state.ct.us/factsheetfi les/entomology/fsen012f.htm

Hemlock woolly adelgid (*Adelges tsugae*), or HWA, is a tiny insect (adults are 2 mm; "crawler" nymphs are 0.25 by 0.15 mm) related to aphids. It feeds at the base of hemlock needles and produces fluffy wax to cover itself and its eggs. The adelgids on hemlock are all females and produce viable eggs without mating. There are two generations each year, a longer-lived one that over-winters and one that completes development quickly in late spring. Adelgids suck nutrients from the tree, resulting in needle loss, reduced shoot growth, and seriously impaired health. The HWA mostly infests new foliage growth. Foliage loss and dieback of branches becomes visible in 2 to 4 years. If not treated, infested hemlocks lose vigor and usually die in 5 to 10 years. Hemlocks in the South decline and die more quickly than those in the North, making the situation there even more serious.

The Adelgid's Natural Enemies — *Scymnus sinuanodulus*, nicknamed Ss, is a tiny, russet-brown lady beetle with black spots found in Yunnan Province in southwestern China. Another, closely related lady beetle from China, *Scymnus ningshanensis*, is being mass reared and will be released in 2006. Several other species are currently in the quarantine laboratory. Other research organizations have studied and released *Sasajiscymnus tsugae*, a tiny black lady beetle from Japan, and *Laricobius nigrinus*, a small derodontid beetle found in western North America. Additional natural enemies are being identified in Asia that have potential as additional biological controls. Since there are many natural enemies of HWA in its native homelands, it is unlikely that one or two will be sufficient to control HWA below damaging levels in the eastern United States.

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Dr. Michael E. Montgomery received his Ph.D. in entomology from Cornell University in Ithaca, NY. Mike began working as a research entomologist at the USDA Forest Service in 1977, concentrating on the influence of primary and secondary plant chemicals on the feeding and growth of insects and the role of site factors on host-plant relationships. Since 1995, he has focused on identifying and developing biological controls for the hemlock woolly adelgid.

Dr. Kathleen S. Shields is a supervisory research entomologist and project leader at the Northeastern Research Station's Center for Forest Health Research, where she has been located since 1969. Kathleen received her Ph.D. in insect physiology from the University of Connecticut. She works on the biology and biological control of invasive forest insects, currently focusing on the hemlock woolly adelgid. She is a member of the USDA Forest Service's HWA Coordinating Committee.

Dr. Jennifer X. Pontius received a master's degree in forestry (1998) and her Ph.D. in natural resources (2004) from the University of New Hampshire. Jenifer has been part of the remote sensing team at the Station's Louis Wyman Forestry Sciences Laboratory at Durham, New Hampshire since 2001.

Dr. R. Talbot Trotter III began work as a research ecologist studying the biology and biological control of destructive invasive forest insects for the USDA Forest Service in March 2005. He is co-located at Hamden and at Yale University's School of Forestry and Environmental Studies. At Northern Arizona University, where he received his Ph.D. in forest ecology, Talbot developed models of the spatial response of arthropods in pinyon–juniper communities to climate change.

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