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Southern Hospitality: The Exotic Hemlock Woolly Adelgid Finds a New Home in the South

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Introduction

In the early 1950's near Richmond, VA, the hemlock woolly adelgid (HWA; *Adelges tsugae*), was discovered on a tree species on which it had not been previously reported. Until that point, it was only known to occur in the Pacific Northwest and parts of Asia. However, the insect found its way to the eastern U.S., presumably on infested nursery stock, and rapidly spread through the range of eastern hemlocks in the eastern U.S. As of 2011, the invasive range of the HWA extends from southern Maine to northern Georgia, leaving a wake of 80-90% hemlock mortality in its rearview mirror. This is one guest the South should not warmly welcome.

The Hemlock Tree

Two species of hemlock occur in the eastern United States. Eastern hemlock, *Tsuga canadensis*, is a widely distributed species that typically inhabits riparian ecosystems from Nova Scotia to Alabama. Carolina hemlock, *T. caroliniana*, has a limited range, most of which occurs in western North Carolina on dry mountain slopes in the southern Appalachians (Figure 1). Both species succumb to HWA infestations, yet research indicates that Eastern Hemlock is the more susceptible of the two.

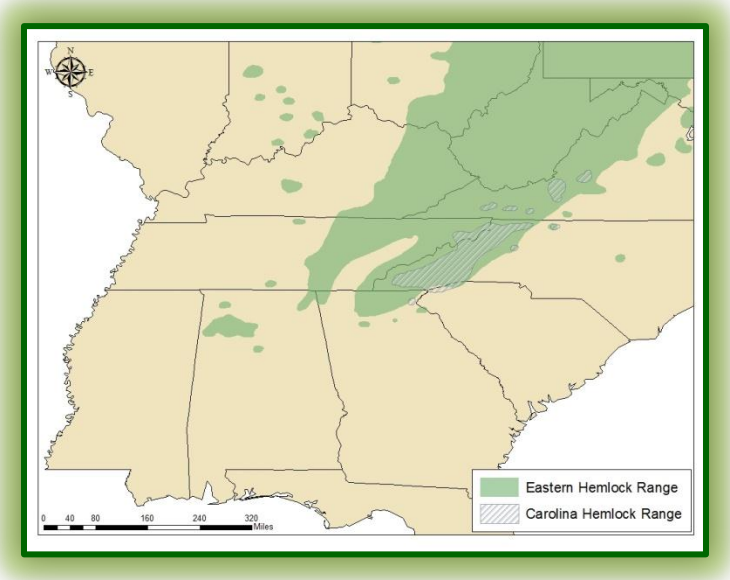

Figure 1. Range of Eastern and Carolina hemlocks in the southeastern United States. [Map courtesy of Robert Jetton, Camcore, NCSU.]

The native range of hemlock is not recognized to extend into Mississippi. However, rich stands of hemlock can be found nearby in William B. Bankhead National Forest in Alabama, which serves as a vacation destination for many Mississippians. Moreover, before the introduction of the HWA, hemlock was a prominent choice as an ornamental tree, shrub, or hedge, with over 250 cultivars. Its suitability to USDA Plant Hardiness Zones 7a and 7b make much of northern and central Mississippi suitable as a planting site. There are likely undocumented ornamental hemlocks throughout Mississippi.

Hemlocks are shade-tolerant and can live over 900 years, making them major components of old growth forest communities. As a foundation species, many ecosystems are affected by the distinctive, acidic microclimates created by hemlocks which affect faunal species composition, forest succession dynamics, primary productivity, decomposition, and nutrient cycling. Countless flora and fauna species have adapted to the distinctive shade that hemlocks provide. One particularly dreaded after-effect of hemlock mortality is the loss of native trout, which are adapted to the aquatic systems defined by hemlock shading.

Signs of Infestation

Infestations of HWA are unmistakable. Often described as snow-like in appearance, the undersides of hemlock branches are covered in woolly masses produced by the HWA as it feeds at the bases of needles (Figure 2). Following infestation, hemlocks exhibit several signs of declining health: needle loss, bud abortion, and lack of new growth. Physiologically, the tree suffers stress similar to drought symptoms. Hemlock death occurs in 4-10 years, but some hemlocks survive longer. Tree death may be hastened by other stress factors, such as drought or other pests.

Figure 2. HWA infestation on Eastern Hemlock.

Life History/Biology

The HWA has a parthenogenetic life cycle, meaning all individuals are female and reproduction occurs asexually. As hemimetabolous insects, they go through three distinct life stages: egg, nymph, and adult. Two generations occur each year. In mid-late spring, the progrediens generation develops, marked by rapid development and reproduction. The sistens generation occurs from late May or June to the following March. In May/June, the HWA hatches from its egg as the "crawler," the only motile stage of the insect that is responsible for locating a suitable feeding site. When successful, the crawler inserts its long stylet mouthparts into host tissues and settles at the base of the hemlock needle (Figure 3). The remainder of their life cycle is spent in this location. They spend the hot summer days as inactive, non-feeding nymphs. During this time, they are not producing the characteristic woolly mass; therefore, HWA infestations are difficult to detect visually. In late October or November, they become active once again and resume feeding. A substantial woolly mass quickly follows, likely serving to protect the insect and her eggs from natural enemies and desiccation. A single female can produce up to 300 eggs in her lifetime.

Figure 3. HWA crawler recently settled at the base of an Eastern Hemlock needle.

As opposed to its aphid relatives who feed on nutrient-rich sap, the HWA feeds on stored starches in the parenchyma cells of the tree. These starches are the primary reserves that contribute to new growth each year. Without these reserves, tree growth and long-term survival are detrimentally affected.

Management

Successful management of the HWA can be attained through chemical applications. Horticultural oils and insecticidal soaps can also be effective as a foliar spray, but must come into contact with the HWA; therefore, trees must be saturated. *Imidacloprid* and dinotefuran are the most commonly used systemic insecticides, typically applied to the soil or injected into the main stem of the tree. Chemical control practices can be useful in ornamental and landscape settings; however, it is not practical in a natural forest setting due to environmental impacts and prohibitive costs. Pesticide applications are expensive, provide ephemeral protection, and are harmful to non-target organisms. Applications are also limited due to geographical and logistical constraints: there are operational difficulties in bringing equipment into a forest and because hemlocks are major components of riparian ecosystems, the danger of environmental contamination is high.

Biological control is another option, and has been given a great deal of attention since the mid-1990s. Native, established predators are not associated with HWA in the eastern U.S., therefore predators released are native to Asia and the Pacific Northwest, the native range of HWA. Several species of beetles have been released in infested hemlock stands. Since 2002, over two million *Sasajiscymnus tsugae* beetles (native to Japan) and over 50,000 *Laricobius nigrinus* beetles (native to the Pacific Northwest) have been released. Several other species have been released in smaller numbers and other species are being researched. As the released beetles begin to establish populations, many are hopeful that HWA infestations will also decrease.

Host-plant resistance is another strategy that has gained attention in recent years. In the wake of widespread hemlock mortality, individuals and stands of native hemlock appear to exhibit a level of innate resistance. Efforts to identify putatively resistant individuals for breeding programs are underway. Attempts to hybridize our susceptible hemlocks with the resistant hemlocks of Asia are being made. The National Arboretum has successfully hybridized Carolina hemlock with Chinese hemlock (*T. chinensis*). The progeny appears to be resistant when challenged with HWA. The mechanism of resistance is currently unknown and is deserving of further research.

Many of the native hemlocks in the invasive range of the HWA have already died. In most cases of widespread plant mortality, this means the native genes are also lost with it. However, gene conservation efforts, carried out by Camcore (North Carolina State University), have preserved many of the Eastern and Carolina Hemlock genotypes through long-term seed storage and the establishment of plantations in South America (where HWA does not occur) and western North Carolina. The resource will inevitably be a source of future hemlock restoration efforts. Moreover, in the event of a resistance breakthrough, this bank of genetic diversity will be a valuable asset to breeding programs.

Lastly, several silvicultural strategies can be used to mitigate spread and infestation severity, particularly in ornamental settings. Preventative measures can be taken proactively to avoid HWA infestations altogether. Many animals, especially bird and deer, are known to spread HWA from one tree to another -- any action taken to prevent them from visiting uninfested hemlocks will reduce their risk for becoming infested. Human mediated dispersal should also be avoided by cleaning vehicles and clothing following a visit to areas with known HWA infestations. One should also inspect plant materials (plants, logs, bark, wood chips, etc.) that are being transported to uninfested areas. In addition, healthy trees succumb less quickly to HWA infestations than those with low vigor. Actions taken to maintain good growing conditions are recommended, such as maintaining soil moisture. It is not recommended to fertilize infested trees since it has been shown to enhance HWA survival and fecundity. However, fertilization may be useful for tree recovery following pesticide use.

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