UNIVERSITY of NEW HAMPSHIRE
COOPERATIVE EXTENSION

Hemlock Woolly Adelgid

This is the forest primeval. The murmuring pines and the hemlocks,
Bearded with moss, and in garments green, indistinct in the twilight,

Henry Wadsworth Longfellow, ***Evangeline****, 1847*

The Canadian hemlocks (*Tsuga canadensis*) immortalized in Longfellow's poem still murmur throughout New Hampshire's forests. Though individual hemlock trees have relatively low timber value, their sheer abundance in our forests makes them an important living resource. In addition to their aesthetic value in our natural and human-created landscapes, hemlocks provide wildlife habitat, contribute to water quantity and quality, and play an important role in maintaining forest biodiversity.

A century and a half after Longfellow penned *Evangeline*, a small, aphid-like insect native to Japan and China threatens our hemlocks. The hemlock woolly adelgid (HWA, *Adelges tsugae Annand*) feeds on ornamental hemlocks as well as native trees, damaging the plants by mechanisms not yet completely understood.

Discovered in the Pacific Northwest in 1924, HWA turned up in Virginia in the early 1950s. Lacking natural predators, the insect spread gradually through the Smoky Mountains, north to the Hudson River Valley and into southern New England as far north as southern New Hampshire and the southern coast of Maine. It has devastated native hemlock stands in states south of New Hampshire, especially Virginia, New Jersey, Connecticut, Pennsylvania and parts of New York.

The first New Hampshire HWA sighting occurred in a home landscape in Merrimack in 1999. The following year, an alert citizen noticed infested hemlocks in Portsmouth's Elwyn Park. Since then state officials have recorded more than two dozen HWA sightings, seven of them on native trees, the rest on ornamental hemlocks. Although the insect has been found in Merrimack, Hillsboro and Cheshire Counties, Rockingham has reported most HWA sightings.

Entomologists don't know if HWA can survive northern New England's cold winters in sufficient numbers to kill our stands of native hemlock, as they have in Connecticut and states further south.

Life cycle

Reddish-purple and only about 1/32 of an inch long, the adult HWA reveals its presence most of the year by a dry, white woolly substance it secretes after it settles on young hemlock twigs. The "wool" becomes most abundant and conspicuous during spring, when it forms a mass protecting the egg clusters. Found at the base of the needles, the egg mass resembles the tip of a small cotton swab.

HWA completes two generations per year. During March and April, adults of the overwintering generation lay 50 to 300 eggs in a cottony mass on the young twigs. First instar nymphs, often referred to as *crawlers*,

hatch from these eggs over several weeks in April and May. Within a few days of hatching, the crawlers settle on the twigs near the base of the needles and begin to feed.

HWA molts four times to reach the adult stage. The castoff skins of its four nymphal stages typically appear on the twig close to a newly molted adult, indicating that the insect usually does not move very far once it has settled.

The spring generation matures by the middle of June. Some of the new adults have wings, but these winged individuals cannot reproduce on hemlock. They leave the tree in search of spruce, but since North America has no suitable spruce host species, the winged adelgids soon die.

The wingless females of the spring generation do reproduce on hemlock. In the middle of June each wingless female lays 50 to 300 eggs on a twig in a single cluster protected by a cottony mass on the twigs. Crawlers hatch in early July and settle on the new growth, entering a non-feeding dormant period until October, when they resume feeding. They develop throughout the winter and mature by spring.

Unattached to the plant by mouthparts, the HWA eggs and crawlers abundant from March through June may get dispersed by wind, birds, deer and other mammals, including humans. Humans can also disperse the insect throughout the year by moving infested plant material.

HWA feeding behavior

Newly hatched HWA crawlers insert their long, thin, flexible mouthparts, called the *stylet bundle*, into epidermal cells in the leaf cushion—the tissue that extends from the shoot to the base of the needle. The stylets probe within the plant tissue until they reach the vascular bundle, then travel along the vascular bundles, probing continually until they reach and ultimately penetrate xylem ray parenchyma cells. After depleting the cell contents—a mixture of stored carbohydrates and other nutrients and water—the stylet bundle continues probing, entering other ray parenchyma cells and sucking out their contents.

Before each molt, the HWA withdraws the entire stylet bundle from the plant, then re-inserts it after molting and begins feeding again. Although the insect generally stays in the same approximate position throughout its life cycle, scientists don't know with certainty if it reinserts its stylet bundle in precisely the same site after each molt.

Adelgid damage: process and pattern

Researchers acknowledge many gaps in their knowledge of how HWA damages and kills infested hemlocks.

Unlike many aphids and other closely related insects, adelgids don't suck sap, the watery solution that circulates through a plant's vascular system (both the xylem and phloem). Although they have similar piercing-sucking mouthparts, adelgids feed on the contents of parenchyma cells. Most adelgids feed on cortical parenchyma; research to date confirms HWA as a xylem-ray feeder.

Research suggests that HWA damages hemlocks by depleting nutrient reserves stored in ray parenchyma, and by making the tree more susceptible to other agents of stress, such as drought or other pests.

As their stylets penetrate the plant tissue, adelgids deposit a sheath of saliva. Besides leaving a record of where the stylets penetrated the plant tissue, the salivary sheaths may seal off cell ruptures and prevent

wound responses; they may also slow or prevent plant defenses by absorbing the tree's protective chemicals. HWA saliva may contain a toxic component or, in large amounts, produce a toxic effect, but scientists currently have no data to support this hypothesis.

An infestation can start anywhere on a given tree depending upon where eggs or crawlers get deposited by the dispersal agent. Typically, the infestation spreads throughout the crown within several years.

Initially only one or perhaps a few individual trees, especially those attractive to birds or exposed to winds carrying HWA eggs or crawlers, become infested. This explains why infested trees may grow close to uninfested trees. In time the infestation will spread throughout the planting. Trees near bird feeders may be more prone to infestation.

The needles on heavily infested branches desiccate, turn a grayish-green color and drop from the tree, usually within months. The adelgids also kill buds, so infested branches produce little new growth. Major limbs may die back within several years.

Even though the infestation may be evenly distributed throughout the tree, dieback generally progresses from the bottom of the tree upwards. Trees may die within four years, although some survive longer in a weakened condition with sparse foliage at the very top of the crown. These weakened trees appear unsightly and often fall victim to secondary pests.

On healthy hemlock, populations of HWA will increase rapidly. However, stressed trees such as those injured by adelgid attack become nutritionally deficient for HWA. This results in high mortality of feeding nymphs, few offspring produced by survivors, and a sudden crash in the HWA population on the injured tree. Unfortunately, many injured trees don't recover afterwards.

N.H. quarantine

The N.H. Commissioner of Agriculture, Markets & Food (NHDAMF) and the N.H. State Forester have imposed a State Exterior Quarantine on hemlock products coming into New Hampshire.

Hemlock seedlings, nursery stock, and uncomposted hemlock chips or bark products require a phytosanitary certificate signed by officials in the state of origin who have inspected the product. The certificate must be faxed to NHDAMF office within five days of issuance. The document must certify the material as (1) grown in the state of origin, (2) free of HWA, and (3) coming from an HWA-free area. The N.H. nursery informs NHDAMF when the trees arrive and NHDAMF sends inspectors to the nursery to examine them.

New Hampshire sawmills must agree not to buy uncertified logs, to examine shipments of hemlock logs for adelgids, and to stack hemlock logs away from any natural hemlock stands.

Chemical treatment for this pest does not constitute freedom from HWA, and will not be acceptable as a substitute for eradication. Any trees state inspectors find infested or comingled with infested shipments will be destroyed. Furthermore, the state quarantine requires that any person who believes he or she has HWA on their premises notify the Division of Plant Industry at NHDAMF (271-2651), or the Division of Forests and Lands (271-7858). If inspectors find HWA on a property, the property is subject to quarantine and eradication procedures.

Interior Quarantine
State officials have imposed a State Interior Quarantine on Rockingham County, the area of New Hampshire most heavily infested with HWA. Ornamental hemlocks, hemlock logs and other hemlock products cannot leave the county without having been certified HWA-free by a state official or official designee.

Management
Monitoring
Detecting infestations early and immediately implementing a management program represents the first line of defense against this destructive insect. Frequent visual inspection will determine whether or not a hemlock is infested.

For most of the year the dry, white "wool" produced by the HWA on the twigs will appear conspicuous against the dark green needles, particularly on the underside of the young twigs. Binoculars may prove helpful in locating infestations in tall trees. An infestation may be difficult to detect during July through September when dormant nymphs produce very little wool.
Further evidence of an HWA infestation includes thinning of needles and grayish-green (not red or yellow) needles on some branches. Usually by the time these symptoms appear, the tattered "wool" of a previous HWA generation is also present on the branches.

Cultural control and forest management
New Hampshire forest health experts recommend complete removal and disposal of HWA- infested trees and landscape ornamentals as the preferred means of controlling the pest.

Because birds, squirrels and deer serve as important dispersal agents, any effort to discourage these animals from visiting hemlocks, such as removing bird feeders may help reduce the risk of those trees becoming infested.

Infestations often start on large hemlocks that intercept the prevailing wind or that are especially attractive to birds and other wildlife. These infested trees may serve as an effective launch pad for HWA eggs and crawlers.

Forest landowners who discover HWA in forest stands should consider developing a forest management plan that, in addition to removing the infested hemlocks, favors desirable existing species or encourages regeneration of species appropriate for the site.

Improving tree health
Trees growing in poor sites or those experiencing stress from drought and other factors succumb to HWA attack more quickly than those growing under optimal conditions. Therefore, maintaining good growing conditions can play an important role in the survival of hemlocks in home landscapes.

Its shallow roots leave hemlocks vulnerable to drought stress. Provide one inch of water per week (including rainfall) during droughts. Roots on an established tree extend beyond the spread of its branches, so apply water to the entire root zone. Water deeply as needed and avoid frequent shallow irrigation.

Pruning dead and dying branches may also help improve the health of hemlock. This may help promote new growth by allowing more light to reach the foliage, and may reduce the likelihood of attack by other insect pests and diseases.

Withhold nitrogen fertilizer from hemlocks infested with HWA, as it aids HWA survival and reproduction. A fertilized hemlock becomes more heavily infested and more severely injured than an unfertilized one.

Biological control
Native predators have not had a significant impact on HWA populations, but researchers have introduced predatory insects effective in controlling the insect in their native Asian forests.

Following the lead of other states, New Hampshire has released a small predacious Japanese lady beetle, *Sasajiscymnus tsugae*. Both the beetle and its larvae feed on HWA. Field research has shown that *Sasajiscymnus tsugae* can survive New Hampshire winters. Forest health experts hope a variety of biological controls will eventually control this exotic pest and protect hemlock forests.

Chemical control
Although cultural control measures can significantly reduce HWA numbers on hemlock, infested trees may not survive without applications of insecticides. Hemlocks will need protection from HWA as often as necessary until the danger has passed, perhaps for a period of years.

Once HWA is discovered on a property, state officials will make appropriate chemical recommendations as necessary.

Alternatives to hemlocks in the landscape
Carolina hemlock, *T. caroliniana*, sometimes suggested as an alternative to *T. canadensis*, is also susceptible to HWA and therefore not recommended as a substitute.

A few hemlock species are reported resistant to HWA, but nurseries in New England don't grow or sell them. Chinese hemlock (*T. chinensis*) and Northern Japanese hemlock (*T. diversifolia*) might serve as alternatives in zones 5-6 on a trial basis.

Other needled evergreens such as spruce, fir, pine or arborvitae may serve as alternatives to hemlock in areas threatened by HWA; however, not all perform well in the shade or provide the same aesthetic function. Consider the limitations of each alternative tree species before planting.

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