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Hemlock Woolly Adelgid

A little insect that means big trouble for hemlock trees in Michigan

Hemlock woolly adelgid (*Adelges tsugae* Annad) has been on Michigan's "most unwanted" list for years. This invasive forest insect has killed hundreds of thousands of hemlocks (*Tsuga canadensis*) in eastern states. It threatens more than 170 million hemlock trees in Michigan forests, and if not controlled, it will also kill hemlock trees in landscapes.

Small, localized infestations of hemlock woolly adelgid (HWA) were recently discovered in western lower Michigan. Evidence suggests that some of these infestations are at least 10 years old and probably originated when infested hemlock trees from other states were planted in landscapes. Surveys are continuing, and additional HWA infestations may yet be found. This bulletin is designed to help you learn to recognize HWA and understand the potential impacts of this invader in Michigan.

Michael Montgomery, USDA Forest Service, Bugwood.org

Hemlock shoot with hemlock woolly adelgid.

Invasion history and current HWA distribution

Hemlock woolly adelgid is native to Japan and possibly China, where it feeds on Asian hemlock and spruce species in forests and landscapes. Asian species of hemlock and spruce are quite resistant to HWA and rarely sustain serious injury. In addition, several predatory insects attack HWA in Japan and probably help to control HWA populations there. In North America, HWA attacks only hemlock trees; spruce trees are not suitable hosts. Areas in the Pacific Northwest and California were invaded by HWA in the 1920s. Western hemlock (*Tsuga heterophylla*), however, is resistant to HWA and sustains little damage.

In the eastern region of the United States, however, HWA has been a devastating pest. Eastern hemlock and the relatively rare Carolina hemlock (*T. caroliniana*), which grows in North Carolina, are much less resistant to HWA than western or Asian hemlocks. Hundreds of thousands of eastern hemlock trees growing under a wide variety of conditions in forests and in landscapes have died. The first report of HWA in the eastern United States came in 1951, when infested hemlocks were observed in Virginia. Since then, HWA has spread up and down the east coast and to the west. Currently, HWA populations are present in at least 19 states, from Georgia to Maine and west into Pennsylvania. Infested landscape trees have been reported in two counties in southeastern Ohio. Areas of extensive tree mortality and decline are found throughout the infested region, but HWA impacts have been especially severe in areas of Virginia, New Jersey, Pennsylvania and Connecticut.

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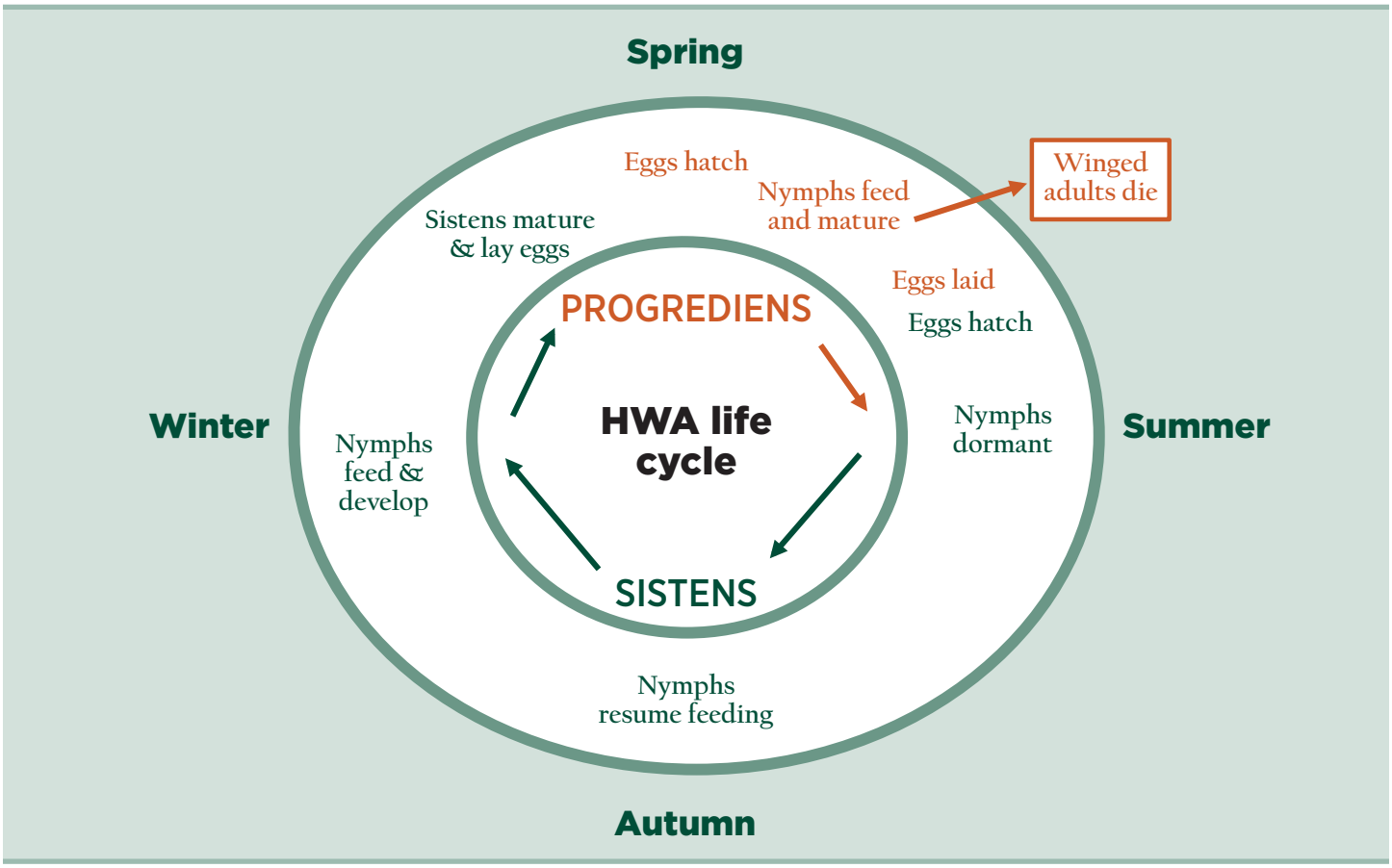
HWA Biology and Life Cycle

Hemlock woolly adelgids are tiny insects, less than 1/16 inch (1.5 mm) long, and typically a dark reddish brown or purplish black. They feed at the bases of hemlock needles, where the needles attach to the woody shoots. As the adelgids feed, they secrete white, fluffy strands of wax from pores on their body. This wax — called "ovisacs" — covers the adelgids, protecting the insects and their eggs from desiccation and natural enemies. The white ovisacs are most obvious from late fall to early summer, especially on the undersides of shoots.

Specialized mouthparts enable the adeglid to pierce the base of a needle, then suck out nutrients from cells in the shoots of their host tree. Each adelgid inserts its long tubelike stylet through the needle and into a shoot. The stylet travels along the vascular bundle until it reaches the parenchyma cells of the xylem rays. These cells function as nutrient warehouses, storing and transferring nutrients within the tree. The adelgid uses its stylet to suck up carbohydrates and other nutrients, depleting the food reserves the tree has stored in these cells. Toxic saliva injected by the adelgids may also trigger a hypersensitive response by the tree, which slows water transport.

In North America, HWA completes two life cycles per year on hemlock trees. Reproduction is asexual — that is, all adelgids are female. In spring, a generation of adelgids called "progrediens" hatch from eggs. The crawlers (first stage) can move about on the tree until they find places to settle. Crawlers can be blown by wind to other trees and can also be transported by birds or other animals that perch on or brush against an infested tree. Most of the progrediens will settle at the base of needles on the previous year's shoots. Once they settle and



Hemlock woolly adelgid completes two generations each year.

insert their long stylets into the woody shoots to begin feeding, they will not move again. As the adelgids feed, they produce the strands of white wax from special glands on their bodies. The word "progrediens" comes from a Latin word meaning "to progress." This generation of HWA does not require a long diapause period, and development "progresses" relatively quickly to the adult stage.

J. Weiferich and D.G. McCullough, Michigan State University

Immature HWA sistens nymphs are dormant and do not feed in summer.

A portion of the progrediens mature into winged adults, which will fly to spruce trees. In Japan, these insects feed on Asian spruce trees, causing round galls to form on the trees. In North America, however, HWA cannot feed on spruce. These individuals die without reproducing. The progrediens that remain on hemlock never develop wings, even as adults.

In early summer, the progrediens produce eggs that will hatch into the "sistens" generation. In Latin, "sistens" refers to "ceasing or halting," and that is effectively what happens. These eggs hatch in early to midsummer. The crawlers move about, then settle, usually on the current year's growth. The immature sistens are dark-colored and may have a thin "halo" of white wax. Once these sistens settle, they enter into a long period of inactivity. This diapause, or aestivation period, lasts through the summer.

In autumn, the sistens resume feeding, producing white waxy ovisacs. Development proceeds slowly during the winter, but by late winter or early spring, the adelgids mature into adults. These adults lay the eggs that will hatch into the progrediens.

Adelgid development rates and the onset of egg laying vary, depending on weather conditions. Generally, sistens begin laying eggs in March in New England, roughly one month later than egg laying begins in Virginia. Adelgid life stages often overlap in the spring and summer because of the long periods of egg laying and hatching.

Hemlock woolly adelgid biology is unusual in that the sistens feed and develop during the winter. Studies in northeastern states have shown that HWA mortality can exceed 90 percent if temperatures drop below -22° F. Winter mortality may be an important factor helping to slow HWA spread and population growth in areas of northern lower Michigan and the Upper Peninsula. It is important to remember, however, that temperatures in a forest can vary considerably, depending on factors such as exposure, aspect or height. The dense mass of white wax produced by the adelgids probably helps to protect them from cold temperatures to some degree. In addition, because all HWAs are female and two generations occur each year, if even a few adelgids survive a cold snap, the population can build up rapidly. There is also evidence that the ability to tolerate cold temperatures is a genetically linked trait that adelgids pass on to their offspring. Populations of HWA in northern latitudes in New England and New York, for example, appear to have become more cold-tolerant than HWA populations in southern states.

Hemlock – An Important Forest Resource

Hemlock, a notably shade-tolerant, long-lived species, is an important resource for wildlife and plays an integral role in many ecological processes in forests. Dense hemlock canopies provide deep shade, critical winter cover, food and habitat for several bird and mammal species. In the northeastern United States, hemlock mortality caused by HWA altered soil temperatures, nitrogen cycling and decomposition rates. These changes subsequently affected other plants and animals as well as forest structure. Hemlock is typically shallow-rooted and often grows in riparian areas near streams and rivers or on sites with high water tables. In eastern states, widespread hemlock mortality resulting from HWA increased erosion, raised water temperatures, reduced water quality and altered communities of aquatic invertebrates.

Inventory data from 2014 indicate that more than 173 million hemlocks grow in Michigan forests, and thousands more have been planted in landscapes. Though hemlock is most abundant in the extensive forests in northern lower and upper Michigan, it is locally common in other areas of the state in private woodlots, game management areas, public parks and recreation areas. Much of the hemlock resource in Michigan forests consists of relatively old trees. This age-class distribution reflects years of preferential browsing by deer on young, regenerating hemlock. More than 93 percent of the 1.08 billion cubic feet of hemlock volume in Michigan consists of sawtimber-sized trees.

Heidi Frei, Michigan Dept. of Natural Resources

Hemlock trees play key roles in Michigan forest ecosystems.

In trees with heavy infestations of HWA, needles become dry, and many needles will drop from affected trees. As infestations progress, trees may fail to set new buds or buds may be aborted. Over time, trees lose vigor and take on a grayish green appearance. Trees are sometimes killed by HWA in as little as four years; other trees survive HWA infestation for 10 years or more. Other stresses — such as severe drought, poor growing conditions or additional pest problems — can accelerate the rate and extent of hemlock mortality.

For example, the elongate hemlock scale (*Fiorinia externa* Ferris) is another invasive pest that has recently become established in some areas of Michigan. This sap-feeding insect can co-occur on trees with HWA infestations and may accelerate the rate of tree decline. Defoliation by the native hemlock looper (*Lambdina fiscellaria* [Guenée 1857]) or the invasive gypsy moth (*Lymantria dispar* L.) will also stress hemlocks and hasten decline.

Jason Van Driesche, Bugwood.org

Hemlock woolly adelgid can kill hemlocks of any size.

Options for HWA Control and Management

A considerable amount of research on methods to control HWA and protect trees has occurred in the eastern United States over the past few decades. Landscape trees can be effectively protected from HWA with systemic insecticides containing imidacloprid or dinotefuran. These products are typically applied as a soil drench or basal trunk spray, or via trunk injection in the fall or early winter. Many products are available to certified pesticide applicators, and a few products can be purchased and applied by homeowners. Dinotefuran moves into and through hemlock trees relatively quickly, making it an ideal choice for rapid control of HWA, especially on large, old trees. Dinotefuran, however, must be reapplied annually. Imidacloprid moves slowly through hemlock trees but will persist for at least 3 to 5 years. Forest pest managers in several eastern states often recommend applying both products as a tank mix to protect valuable hemlock trees. With these and other systemic insecticides, trees must be treated while they are still healthy enough to transport the product up the trunk and into the canopy. Landscapers, arborists and others who prune, trim or fell hemlock

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Elongate hemlock scale (left) feeds on hemlock needles. Hemlock woolly adelgids (right) feed in white ovisacs at the bases of needles.

Kelly Oten, NC Forest Service

Wax was removed from this adult HWA, photographed at very high magnification.

trees should be especially careful to dispose of this material and clean their equipment to avoid spreading HWA into new areas.

Of course, the millions of hemlock trees in forests cannot be protected with systemic insecticides because of costs and environmental concerns. Efforts to identify, rear and introduce biological control agents to suppress HWA populations in forests have been underway for at least 20 years. Tiny predatory beetles native to Japan or the Pacific Northwest are being studied in eastern states. One or more of these species could eventually be considered for release in Michigan if HWA populations spread.

If hemlocks grow on your property or if you manage hemlock trees in forest or landscape settings, periodically check the shoots for evidence of HWA. If you suspect a tree may be infested, please collect digital images of infested shoots and the tree(s). Also, be sure to note the location of the affected tree(s). Contact the Michigan Department of Agriculture and Rural Development by phone at **800-292-3939** or by email at MDA-Info@michigan.gov. You can also contact the Plant Pest Diagnostic Clinic at Michigan State University by phone at 517-355-4536 or by email at pestid@msu.edu.

Additional information on HWA is available on the Midwest Invasive Species Information Network (MISIN) website at **http://www.misin.msu.edu/**. Other good sources of information include HWA websites hosted by the USDA Forest Service and several universities.

Keith Eldred, MI Dept. of Agriculture and Rural Development

A shoot from a heavily infested tree in Michigan.

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