Hemlock Woolly Adelgid Impact Assessment Survey

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Abstract

The impact of hemlock woolly adelgid has been varied among the sites followed in this study of the mid-Atlantic region. It appears that in some sites, the insect has not yet had an impact while in others it has killed or put the hemlock in such a state of severe decline that death is imminent.

Keywords:

Impact assessment, crown variables, tree vigor, dieback.

Introduction

The hemlock woolly adelgid (McClure et al. 2001) has been recognized as a significant problem causing widespread damage in the northeastern United States, particularly in the Connecticut River Valley of New England (Orwig and Foster 2000, Bonneau et al. 2000). As concern grew that damage seen in New England could spread, the impact assessment survey was initiated in 1993 in an attempt to understand the current and potential impacts of the hemlock woolly adelgid to hemlock in the mid-Atlantic region. In this study, data has been collected annually and consists of tree and crown variables as well as indexes to assess foliage growth and adelgid numbers on associated branch tips.

Hemlock Wooly Adelgid. The hemlock woolly adelgid (HWA), *Adelges tsugae,* is an introduced invasive species that was first recorded in the western United States in 1924 and on the east coast in the 1950s near Richmond, Virginia (Miller 1988). The insect spends the majority of its life in a fixed location except during the crawler stage when it moves to new growth. It is a sucking insect that feeds from the tissue of young hemlock (*Tsuga canadensis*) twigs; more specifically, on stored nutrients in the xylem ray parenchyma cells. HWA is bivoltine (two generations per year) and is parthenogenic, producing from 50 to 300 eggs/adult. Consequently, HWA populations can explode to extreme levels quickly where conditions are favorable.

Damage. As HWA populations increase, the ability of hemlocks to continue to produce new growth is significantly reduced and the current foliage becomes less functional in photosynthesis. Foliage grays and prematurely drops. After just a few years, the infested branches often lose the majority of their needles. Impacts to stem and branch growth typically progress upward from the lower crown and if the HWA populations remain high, trees will die. This study will provide information on the growth impacts of HWA on trees where we have both HWA population index and crown health rating histories. These plots cover the range from light to severe damage to hemlocks. Early reports by McClure (1991) were that hemlocks succumb within four years and yet some hemlocks were known to have survived a much longer period of infestation. The primary purpose of the study was to determine rates of tree mortality and determine if hemlocks are able to survive or recover following a HWA infestation.

Methods

The HWA impact assessment survey was developed under the leadership of the Forest Health Protection staff of the Northeastern Area, State and Private Forestry, USDA Forest Service. The survey was designed to assess changes in crowns of overstory trees as HWA became established. Initially plots consisted of 10 dominant/codominant trees that were permanently tagged for annual remeasurement of crown health variables.

Crown Variables, Forest Health Assessment. Each year recording each of the following five variables assessed the crown health for each sample tree:

Diameter	Measured along its widest axis and again at 90^{o} to that axis (cm).
Ratio	The ratio of crown height to total tree height. *
Density	Part of expected total crown silhouette that is present. *
Dieback	Branch tip loss of foliage or fine twigs. *
Transparency	Loss of expected foliage density in existing branches. *

* Measured to the nearest 5 percent.

Three of these crown variables: density, dieback, and transparency, along with tree vigor, best describe changes in crown health due to HWA. Vigor is a subjective rating of tree health that considers crown fullness, foliage color, and presence of any damage that may lead to decline.

Branch Tip Assessments: 1993-1997. Where possible, 30-cm branch tips were selected from plot trees. If plot-tree crowns were not accessible from the ground, trees close by were used for branch-tip sampling. At least 10 branch tips per plot were to be sampled each year. All shoots are counted on each tip. A shoot consists of the outermost branch stem section that derives from a single bud and resulted in a single year's growth, and which, in the absence of HWA, would be expected to contain needles or fruiting structures. The number of shoots, the number of shoots that produce new growth, and the number of shoots that have HWA present are recorded. The fact that new growth production is recorded requires that these data be collected in late spring or early summer when bud flush can be determined. It should be noted that we were not counting the number of new buds or new shoots but rather the number of current shoots that produce new growth. Similarly, the HWA index is the number of infested shoots. Thus the number of shoots will always be equal to or greater than either of these counts, as it serves as the base for these counts. For example, out of 47 shoots on a branch tip, 32 produced new growth and 38 were infested (with one or more HWA).

Revised Plan: 1998 - Current. Prior to the 1998 field season, we had seen very few newly attacked hemlock trees in our plot system. In 1998 we added plots where HWA populations could be located in an attempt to better understand the relation between the branch-tip data and the crown rating system. Plots would contain a minimum of five dominant or codominant trees. If no canopy branches could be reached on plot trees, then neighboring trees that had accessible branches were added as plot trees. Branch tips were selected at cardinal directions and tagged to allow for annual remeasurement. Minimums of twelve 30-mm branch tips were selected on each plot, four per tree where possible.

Results

Following is a summary of data and relationships from selected sites across the five areas studied in the HWA impact survey conducted by Forest Health Management State and Private Forestry, National Park Service and the States of Pennsylvania, Maryland, and West Virginia. The information is representative of that is available from this survey. There is a total of 206 plots within 45 study sites that are scattered over these five areas.

LACAWAC Plots, Northeastern Pennsylvania– This site has a mix of hemlock sizes but is dominated by larger trees in the dominant and codominant crown classes.

During the time period that data were collected (1994 to 2000), HWA populations increased and new foliage production decreased; loss in production of new growth on branch tip samples was directly associated with HWA population increase. These associations were all highly significant ($P < 0.0001$).

As we followed the sample branches on plot trees through the study period, dieback increased ($P = 0.003$) and this could be associated directly with the increase in HWA on branch samples ($P = 0.102$).

High Rock Road Plots, Southcentral Pennsylvania – This site consists of intermediate and suppressed hemlocks.

During the time period that data were collected (1995 to 2000), HWA populations increased and new foliage production decreased; loss in production of new growth on branch tip samples was directly associated with HWA population increase. These associations were all highly significant ($P < 0.0001$).

Over the years that the crowns of sample trees were followed, HWA appeared to be more abundant on trees with broader crowns and those crowns produced significantly less new growth; these associations were highly significant ($P < 0.001$). Crown density tended to decrease, crown dieback increased significantly ($P < 0.001$) and foliage transparency increased ($P = 0.0461$) over time.

Cunningham Falls State Park, Northcentral Maryland – This site is generally dominated by hemlocks, consists of a mix of tree sizes with most of the basal area in the larger crown classes, codominant and dominant trees.

Even though HWA populations have not been active as long or reached as high a density as in other sites, there were significant effects seen here. Similar to other sites, during the time period that data were collected (1995 to 2000), HWA increased and new foliage production decreased; loss in production of new growth on branch tip samples was directly associated with HWA population increase. These associations were all highly significant ($P < 0.0001$). Note from the graph that the HWA population index fell in 2000.

Crown diameters reduced significantly over the six years ($P = 0.0075$), while new growth was highest on the broader-crowned trees. No significant relationships were seen for crown density or dieback in this lightly infested site where populations have fallen in 2000 from a high in 1998. Foliage transparency decreased significantly ($P = 0.016$) over this same time period.

Mount Minsi, Delaware Water Gap National Recreation Area – This site was one of the first to be found with high-density HWA populations. The site is mostly pure hemlock and consists largely of codominant and dominant trees in an upper slope and ridgetop location.

During the time period that data were collected (1993 to 2000), HWA populations increased and new foliage production decreased; loss in production of new growth on branch tip samples was directly associated with HWA population increase. These associations were all highly significant ($P < 0.0001$).

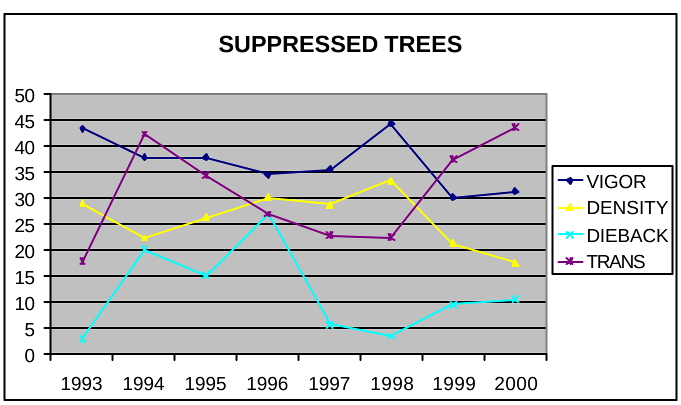

Figure 1. Average tree vigor and crown variables over time for the Mt. Minsi site in Delaware Water Gap NRA, broken out by crown strata.

Growth was stunted. Crown diameters and crown ratios did not increase over the period of study. Crown density decreased and crown transparency increased highly significantly (both with $P < 0.001$) over this same period. Crown density decreased ($P = 0.109$) and foliage transparency increased ($P = 0.0197$) in association with increased HWA. Figure 1 shows the changes in health assessment variables over time by canopy strata. Notice that this site had substantial HWA populations early and showed marked increases in foliage transparency in 1994, particularly in the intermediate and suppressed trees.

Greenland Gap, West Virginia – This site has been followed closely since 1993 and is almost pure hemlock, located along the North Fork of Patterson Creek just east of Scherr, West Virginia. It has had HWA present for eight years and mortality of most plot trees appears imminent. The vigor of plot trees has changed markedly over this period as can be seen in Table 1.

Table 1. Changes in Vigor of Plot Trees From 1993 to 2000 at Greenland Gap, West Virginia.

Vigor Class	Year 1993	Year 2000
	Percent	
Healthy	73	0
Slight decline	27	6
Moderate decline	0	16
Severe decline	0	72
Dead	0	6

Figure 2 shows the changes in HWA and new growth indexes on branches over time. Note that at Mt. Minsi the population declined substantially from its early levels (Figure 1) as can be seen in the tree health variables and has again peaked in 1999.

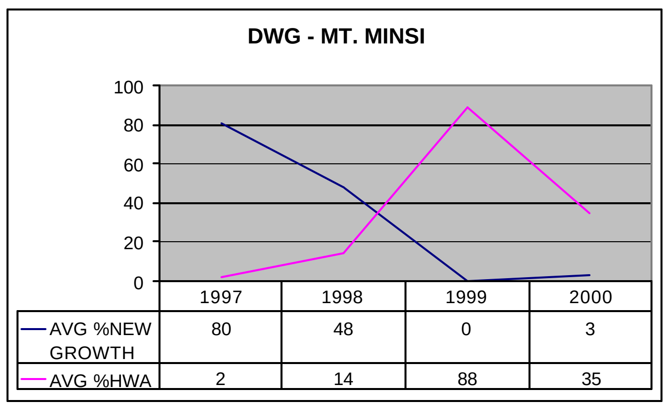

Figure 2. HWA and new growth indexes over time for selected sites. Mt. Minsi, Delaware Water Gap NRA

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References

Bonneau, L.R., K.S. Shields, D.L. Civco, and D.R. Mikus. 2000. Use of satellite image data to identify changes in hemlock health over space and time, pp 175-6. In McManus, K.A., K.S. Shields, and D.R. Souto (eds.). *Proceedings of the Symposium on Sustainable Management of Hemlock Ecosystems in Eastern North America*, June 22-24, 1999, Durham New Hampshire. US Department of Agriculture, Forest Service, Newtown Square, Pennsylvania.

McClure, M.S. 1991. Density-dependent feedback and population cycles in *Adelges tsugae* (Homoptera: Adelgidae) on *Tsuga canadensis*. *Environmental Entomology*. 20: 258-264.

McClure, M.S., S.M. Salom, and K.S. Shields. 2001. *Hemlock Woolly Adelgid*. US Department of Agriculture, Forest Service, Forest Health Technology Enterprise Team, Morgantown, West Virginia.

Miller, H. S., Jr. 1988. Hemlock woolly adelgid report. Virginia Department of Agriculture and Consumer Services, Division of Product and Industry Regulations, Richmond, Virginia.

Orwig, D.A. and D.R. Foster. 2000. Stand, landscape, and ecosystem analyses of hemlock woolly adelgid outbreaks in southern New England: an overview, pp. 123-125. In K.A. McManus, K.S. Shields, and D.R. Souto (eds.). *Proceedings of the Symposium on Sustainable Management of Hemlock Ecosystems in Eastern North America*, June 22-24, 1999, Durham New Hampshire. US Department of Agriculture, Forest Service, Newtown Square, Pennsylvania.