Overview of Hemlock Health

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Hemlock is very sensitive to stress—particularly insect defoliation

Although many insects and diseases are associated with hemlock, we will, ironically, draw our first conclusion, that hemlocks are very sensitive to the stress of insect defoliation, from a tale of gypsy moth defoliation. The unprecedented gypsy moth (*Lymantria dispar* L.) outbreak of 1981, when nearly 13 million acres were defoliated in the Northeast (Fig. 1), resulted in hemlock snags throughout the hardwood forest at West Point, New York (and many other locations), in 1986. There were so many larvae in May 1981 that all the preferred hardwood leaves were eaten and the caterpillars still needed more foliage. They turned their hungry attention to the white pine (*Pinus strobus* L.) and eastern hemlock (*Tsuga canadensis* (L.) Carriere) trees that grew in association with the hardwoods and, in many cases, defoliated these conifers completely. Hemlock and white pine responded to this defoliation in very different ways (Stephens 1984). Hemlock trees died within 1 year and most of these were dominant or codominant trees. In contrast, many fewer white pine trees died and the trees that did die succumbed slowly—within 5 years. In addition, these white pine were mostly intermediate or suppressed trees. Stephens (1984) hypothesized that the species impacts were caused by differential bud development patterns and by how much bud (1982 growth) damage each species sustained.

In 1953, a smaller gypsy moth outbreak caused similar damage to white pine and hemlock throughout New England. When House (1960) analyzed the impact of the outbreak on these native conifer species, he found that the results were clear-cut and identical to what Stephens would see decades later. When trees were completely (100%) defoliated, 74% of the canopy hemlocks were dead within 1 year. In contrast, only 28% of the white pine understory trees were dead within 5 years of the defoliation. House noted that the impacts decreased dramatically if defoliation was less than 100%. For example, only 9% of hemlocks that were 90% defoliated died and no hemlocks that were 80% defoliated succumbed. Clearly, 100% defoliation is a critical threshold for severe damage in hemlock.

Multiple stressors have significant effects on hemlock

Our second conclusion, that multiple stressors have significant effects on hemlocks, can be drawn from the image of an entire hillside of dead hemlock trees at Devil's Hopyard State Park in Connecticut. From 1989-1993, hemlock looper (*Lambdina fiscellaria* (Guenee) and *L. athasaria* (Walker) outbreaks occurred throughout the New England states and caused significant damage. For example, Maine's hemlock looper outbreak resulted in statewide defoliation of about 500,000 acres. The Maine Forest Service evaluated this outbreak's impact and found, quite surprisingly, that severe impacts (>30% of canopy hemlock dead or with dead tops) occurred on only 28,319 acres (Trial and Devine 1994). The acreage represented only 6% of the defoliated area. Additionally, the severely damaged areas were widely scattered and in small polygons (5 to 100 acres). Trial and Devine focused on the common denominators in the severely damaged areas and found several variables (Fig. 2). The first three variables are related to site conditions and/or microclimate conditions. The last two variables are related to other stressors besides hemlock looper defoliation. Interestingly, the Pennsylvania Bureau of Forestry found a similar list of other stressors when they investigated severe impacts on state lands associated with gypsy moth defoliation in oak stands in the 1980s (Quimby 1986). In fact, when they overlaid recent shelterwood cuts (partial harvesting on the Maine Forest Service list) with severe oak impacts, the correlation was striking. Similar lists of other stressors are associated with severe impacts for different defoliators and tree species. In the case of Devil's Hopyard State Park, hemlock looper defoliation coincided with the presence of and damage by hemlock woolly adelgid. In other parts of Connecticut, scale insects—elongate [or fiorinia] hemlock scale (*Fiorinia externa* Ferris), and shortneedle evergreen scale (*Nuculaspis tsugae* (Marlatt)—combine with hemlock woolly adelgid and/or looper to cause severe damage.

Hemlock woolly adelgid is the newest, major stressor of hemlock

Our last conclusion is that the hemlock woolly adelgid (*Adelges tsugae* Annand), a native of China and Japan, is the newest major stressor of hemlock. Native hemlock species in both countries are resistant to hemlock woolly adelgid (HWA) damage—they generally support only low population levels and show no growth loss or tree mortality when infested. However, high HWA population levels occasionally are present on heavily stressed trees (Mark McClure, personal communication). HWA was first reported in the United States in the Pacific Northwest in the 1920s. We do not know how it arrived there. However, western hemlocks (*Tsuga heterophylla* (Rafinesque) Sargent and *T. mertensiana* (Bongard) Carriere) were and are resistant to HWA damage. This is difficult to explain because western hemlocks and HWA had no time to co-evolve yet the tree species were already resistant. As a result, even though HWA arrived in North America by the 1920s, it was not yet a problem.

In the spring of 1953 or 1954, HWA was first reported in Virginia (Miller 1988). It was initially observed in a row of

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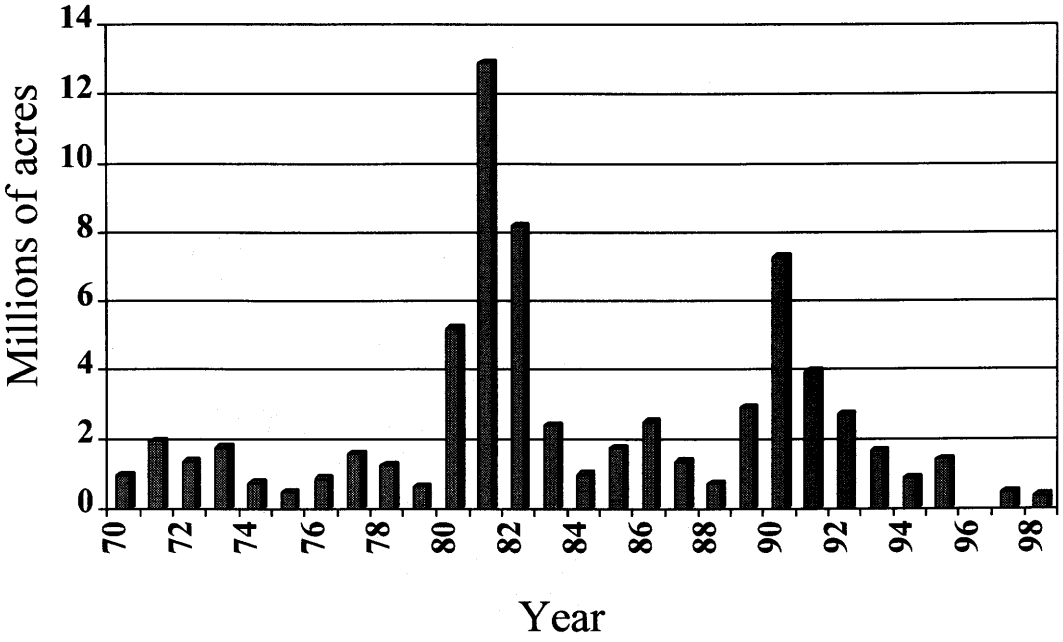

Figure 1.—Gypsy morh defoliated acres, 1970 - 1997.

- DRY SITES WITH EXPOSED LEDGE
- WET, POORLY DRAINED SITES
- CLOSE TO WATER (POINTS AND ISLANDS)
- PARTIAL HARVESTING
- TWO DEFOLIATIONS OR INSECTS

Figure 2.—Other hemlock stressors.

hemlock trees in Maymont Park (a large municipal park) in Richmond. Previously, the park had been the elaborate estate of an avid plant collector who sometime, perhaps early in the century, traveled to many parts of the world. Although the collector may have transported HWA to Virginia, we will never really know. We do know that this was the first report of HWA on the East Coast. Now for the first time, HWA existed in proximity of two hemlock species (*Tsuga canadensis* and *T. caroliniana*) susceptible to its feeding activities (Fig. 3). The HWA moved slowly westward, spreading from ornamental trees to the natural range of hemlocks in the Blue Ridge. Once there, spread and impacts accelerated through the early 1980s.

The year 1985 was a very significant one for HWA. In January, a severe cold wave occurred in Virginia with unprecedented low temperatures. At elevations above 2,000 feet, temperatures of -20 to -28°F were common. Surveys conducted in the spring/summer of 1985 revealed a complete absence of HWA above 2,000 feet (Miller 1988). Below 2,000 feet, HWA was present, but in greatly reduced numbers. Since 1985, HWA populations have slowly but steadily increased, as has its distribution in Virginia. Significant overwintering HWA mortality and subsequent population recovery are themes we would see again in Connecticut after the winter of 1993-1994.

Another significant event in September of 1985 was that Hurricane Gloria might have transported HWA across Long Island Sound to Connecticut. This could explain why Mark McClure first observed and reported HWA in Connecticut in 1986—the first report of HWA in New England. Although HWA had been an East Coast resident for over 30 years, the attention and concern over its impact on our forests and ecosystems began to accelerate with McClure's initial report and subsequent research activities and results.

Currently, Massachusetts is the northernmost state where HWA occurs (Fig. 4). The first report was of an HWA-infested backyard tree adjacent to a large, heavily used municipal

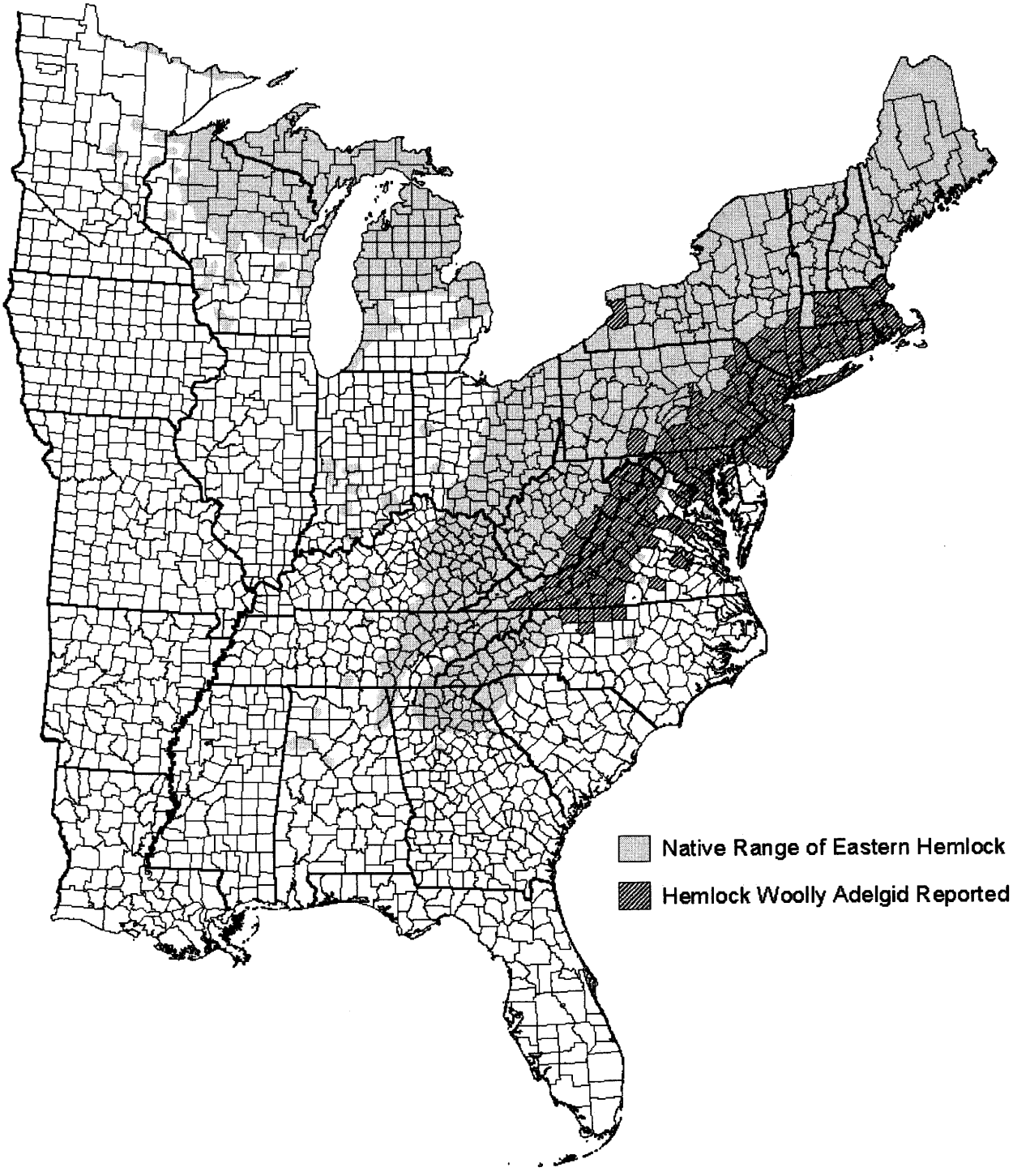

Figure 3.—Native range of eastern hemlock and hemlock woolly adelgid distribution - 1998.

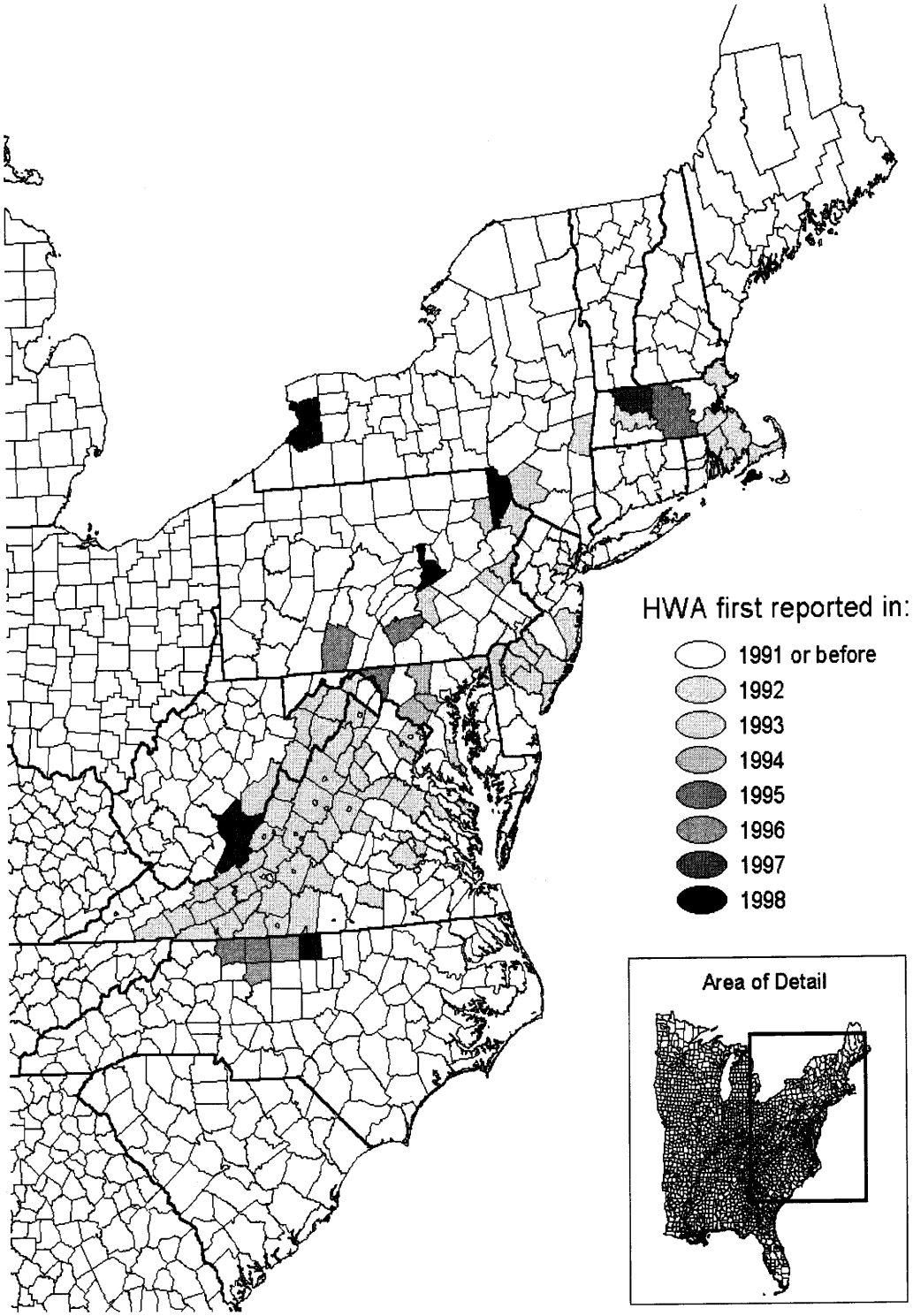

Figure 4.—Hemlock woolly adelgid distribution by year reported 1991-1998.

park (Forest Park) in Springfield. We do not know how HWA arrived there, although some entomologists suspect birds transported it. This initial location (municipal city park) does remind us of the initial observation in Richmond, VA. Massachusetts is a significant case study to observe for those who ask, how many more states and Canadian provinces will become infested by HWA? Or even more importantly, how far north will significant impacts to hemlock health occur and can we predict the location of those impacts?

The northern spread of HWA up the Hudson River Valley in New York has stalled at 42 degrees latitude, near the border of Dutchess and Ulster Counties (Michael Birmingham, personal communication). The most recent, northernmost HWA infestation in this area was reported in 1991. Since then, no new infestations have been discovered farther to the north. What is intriguing is that this same location is the northernmost stopping point for the spread of four other forest insect pests in New York: elongate hemlock scale, shortneedle evergreen scale, red pine scale (*Matsucoccus resinosae* (Bean and Godwin), and red pine adelgid (*Pineus borneri* Annand). We can only hope that this location represents the first geographic limit to HWA's northward spread.

The characteristic that most concerns us about HWA is its chronic nature. For example, both gypsy moth and hemlock looper outbreaks can spectacularly erupt and collapse from one year to the next. Many years can pass between outbreaks allowing trees and stands time to recover, if weather is good and other stressors absent. In general, this is the way most forest pests behave. However, HWA is completely different. Once it arrives, it is there for the duration. With such a chronic stressor present, the likelihood that other stressors will eventually coincide with HWA damage and severely affect hemlock health seems quite probable. This may explain why in New Jersey the greatest impacts on hemlock have occurred in the stands that have had HWA the longest (Mayer et al. 1988).

Literature Cited

House, William P. 1960. **Gypsy Moth-White Pine Damage Study.** USDA ARS Plant Pest Control Division, Moorestown, NJ. Final Report-April 1960. 48 p.

Mayer, Mark; Scudder, T; Chianese, R. 1998. **The effect of the hemlock woolly adelgid, *Adelgid tsugae* (Homoptera: Adelgidae), in natural hemlock stands in New Jersey.** New Jersey Department of Agriculture, Division of Plant Industry, Phillip Alampi Beneficial Insect Laboratory, Trenton, NJ. Annual Report 1998. 10 p.

Miller, H. S., Jr. 1988. **Hemlock Woolly Adelgid Report.** Virginia Department of Agriculture and Consumer Services, Division of Product and Industry Regulations, Richmond, VA. Internal report. 2/10/88. 2 p.

Quimby, John. 1986. **Impact of gypsy moth defoliation on forest stands.** Pennsylvania Bureau of Forestry, Division of Forest Pest Management Newsletter. 4(9):1-6.

Stephens, George R. 1984. **Heavily defoliated white pine has lower mortality than hemlock.** Frontiers of Plant Science. 1984(Fall): 4-5.

Trial, Henry, Jr.; Devine, M. 1994. **The impact of the current hemlock looper, *Lambdina fiscellaria* (Guen.), outbreak in selected severely damaged stands of eastern Hemlock.** Maine Forest Service, Insect & Disease Management Division, Technical Report #34, December 1994. 16 p.