

Hemlock Woolly Adelgid Threatens Eastern Hemlock in Shenandoah National Park

By J. Keith Watson, Entomologist

In the winter of 1988-1989, Shenandoah National Park (SNP) personnel observed many dead Eastern hemlock, *Tsuga canadensis* (L.) Carriere, in Thornton and Frazier Hollows of the North District. Later investigations conducted in the winter of 1990 detected many defoliated hemlocks while many others had partial foliage loss and exhibited chlorosis. Several dozens of trees in both hollows were affected to varying degrees and many trees estimated to be approximately 200 years old were dead. Close examination of the foliage revealed the presence of woolly masses at the base of the needles and twigs (Fig. 1). Each woolly mass enclosed a small soft-bodied rounded aphid-like insect suspected to be, and later identified as, the hemlock woolly adelgid, *Adelges tsugae* (Annand)(hereafter referred to as HWA).

Entomologists believe this species was introduced from eastern Asia where they have found endemic, innocuous populations of this adelgid infesting Asian hemlock species in Formosa and Japan (Takahashi 1937, McClure 1987). This insect was first reported by P.N. Annand (1928) to infest *T. heterophylla* Sargent in the Pacific Northwest of the United States. The first detection in the East was recorded from Richmond, VA in 1953 (Anhold 1990), but the exact time of the adelgids introduction into the United States remains unknown. From these suspected entry points in the United States, the range of the insect has gradually spread and in many parts of its



Figure 1. Egg masses produced by overwintering adults (Used by permission of Mark McClure).

range has caused extensive mortality of both ornamental and forest hemlocks (McClure 1987). Range extension has occurred through diverse mechanisms and McClure (1990) provided data that showed wind, birds, deer, and human activity were primary factors in HWA dispersal.

The HWA is a sap-sucking insect of the Order Homoptera, family Adelgidae, closely related to aphids, whiteflies, and scales. Adelgids are typically a two host species, with spruce (*Picea* spp.) species being the primary hosts. However, no native *Picea* have been shown to support the HWA. Twelve *Picea* spp. were tested (six native and six non-native) by McClure (1989) for adelgid suitability and none were able to sustain reproductive populations. The complex life cycle of the HWA makes management difficult, but allows several opportunities to direct management tactics. Life history of the HWA can be obtained from McClure (1989) and is summarized in Figure 2.

The adelgid extracts fluids from the tissues of the inner bark or phloem by inserting its stylet-like mouthparts through the outer bark of small twigs and branches. Damage to the host occurs as a result of stress induced when heavy infestations withdraw large

amounts of life sustaining fluids from the tree. Additionally, some scientists believe that a toxic saliva is injected into the tree during feeding that disrupts plant growth hormones and modifies vascular tissues in the tree (Puritch and Petty 1971). However, this mechanism has not been documented with the HWA. Still, the trees lose vigor and become susceptible to additional and often more damaging stresses, especially drought, hemlock borer (*Melanophila fulvoguttata* Harris; Coleoptera: Buprestidae), and Armillaria root rot, *Armillaria mellea* (Vahl ex Fr.) Karst.

Dr. Mark McClure, HWA authority at the Connecticut Agricultural Experiment Station, believes that heavy infestations alone can cause hemlock mortality. He also reported on the stand and tree condition of forest hemlocks in Connecticut and discovered that when healthy vigorously growing uninfested trees became infested with HWA, they declined gradually and all were dead within four years (McClure 1991). Heavy HWA populations along with other stress factors could contribute to the death of infested hemlocks in SNP.

In SNP, the HWA has been found in all districts, elevations, and aspects in 88 percent (n = 49) of the surveyed hemlock stands. Mortality has become widespread throughout the park and little can be done to prevent the continued spread and impact of the HWA. Data collected in February 1992 from Frazier Hollow indicated a 100 percent decline in the number of hemlock crowns that received a healthy rating (Class 1) in July 1990. Furthermore, the number of hemlocks with lower crown ratings (Class 2 and 3) increased 178 and 1400 percent respectively. The number of adelgid related deaths (Class 4) increased 100 percent (Fig. 3). Although this evaluation was based on a small sample size, the condition of the hemlock stands in the park is similar to Frazier Hollow. Data to evaluate stand condition and mortality rates are presently being collected parkwide. Presently, about 10% of the hemlocks in Thornton and Frazier Hollows are dead due to stresses associated with HWA. Considering the degree of infestation and additional stresses in SNP, a large number of Eastern hemlocks could be lost. If the prognosis is severe as McClure hypothesizes all hemlocks may be in jeopardy of being lost.

Continued on page 10

Water Rights

Continued from page 8

mitted to adjudicating all water rights by the close of this century. Preparing for the court battles that inevitably await will require herculean efforts by the NPS and other federal agencies.

Conclusion

The legal doctrine that governs most water use in the west conflicts with the "fundamental purpose" of the NPS. This doctrine arose, in the absence of federal guidance, to meet the needs of commerce in a semi-arid setting at a time of rapid and almost chaotic development. It served its intended purpose well, but it did not provide for the unanticipated needs of a growing and increasingly sophisticated nation. The requirements of legislation and Proclamation created conflicts that culminated in a retrofit of the doctrine using Court-created "implied rights."

The NPS employs both the Federal Reserved Water Rights Doctrine and the Doctrine of Prior Appropriation to accomplish its mission. The process of securing and protecting water rights is demanding, requiring in-depth scientific investigations and complex legal argument. However, even though the investment to protect water rights may be high, the cost of not protecting them likely would be higher. This becomes ever more apparent as water development and municipal growth place increasing demands upon the same water sources as are relied upon by the fragile ecosystems of Parks, Monuments, and other NPS units.

The opinions expressed are those of the author and do not necessarily reflect those of the Department of the Interior or the National Park Service.

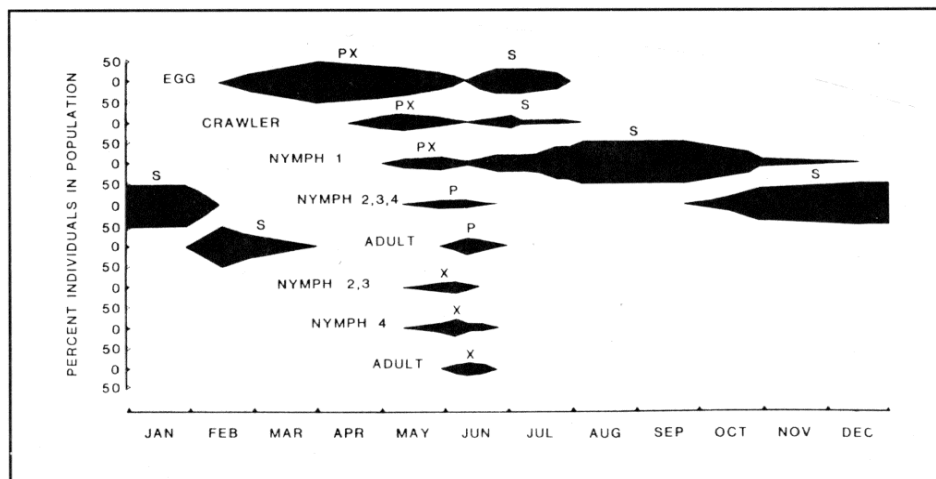


Figure 2. Seasonal life cycle of the HWA. S = wingless overwintering generation; P = wingless forms of spring generation; X = winged migratory forms of spring generation (Used by permission of Mark McClure).

Woolly Adelgid Threatens Shenandoah Hemlock

Continued from page 9

In SNP, the hemlock mortality associated with HWA was apparently initiated by drought induced stresses during 1986-1988. The combined stresses of drought and HWA infestation attracted the hemlock borer, a cambium feeding beetle, which girdled and ultimately killed many of the hemlocks. Evidence of secondary beetle invasion was indicated by the presence of emergence holes and the outer bark being flaked from the tree by woodpeckers probing for borer larvae, revealing the deep rust color of the inner bark. Hemlock mortality caused by the secondary invasion of the hemlock borer has been a well documented phenomena (MacAloney 1967). However, several dead hemlocks in SNP did not show evidence of attack by the hemlock borer, suggesting death occurred from drought and adelgid infestation, and possibly Armillaria root rot. Additional stresses from gypsy moth defoliation and acid deposition may have contributed to the hemlock decline.

The potential impact of hemlock decline and mortality on park resources has resource specialists concerned. Obviously, natural resource components and biotic associations in hemlock ecosystems will be greatly affected. The adelgid has been observed in two high resource value areas in the SNP. One of these is the Limberlost, a 100 acre natural area that contains many virgin Eastern hemlocks saved from the logging industry by George Freeman Pollock. Some trees in this stand are estimated to be near 400 years old. The other unique area where hemlock decline is evident is Camp Hoover, a former retreat for government officials, and a valuable cultural and natural area. President Herbert Hoover established this fishing camp on the Rapidan River and later donated the property to the SNP.

Effects of Control Agents

Though a significant threat to the Eastern hemlock forest exists, it is doubtful that HWA management in a forested ecosystem would be successful although it could be possible in isolated "urbanized" settings in developed zones. Selected individual trees must be saturated with suppression agents from ground based equipment to ensure a high percentage of adelgids are contacted by the treatment. This quickly becomes very expensive, labor intensive, and time consuming.

"Safe" control agents could be used with this method, but they are economically unfeasible and environmentally untested to be effective in long term adelgid management. Injection of pesticides into the cambium where translocation of the pesticide would reach the adelgids is another possibility. Other traditional chemicals proven effective for adelgid control exhibit wide spectrum toxicity to other "non-target" organisms and are unacceptable for use in national park ecosystems. Natural parasitoid and predator complexes are poorly known and their potential as control agents is uncertain.

Programs to monitor populations of the adelgid in SNP and elsewhere should be developed to obtain information on the impacts of this potentially damaging insect. Monitoring is extremely important because populations of this insect can build rapidly on hemlock due to 1) parthenogenesis - the female's ability to produce offspring without the existence of the male, 2) the adaptation of two successful reproducing generations per year, 3) few significant natural enemies, and 4) other prevalent stresses in the SNP ecosystem.

Monitoring Plans

Monitoring the HWA can be incorporated into the

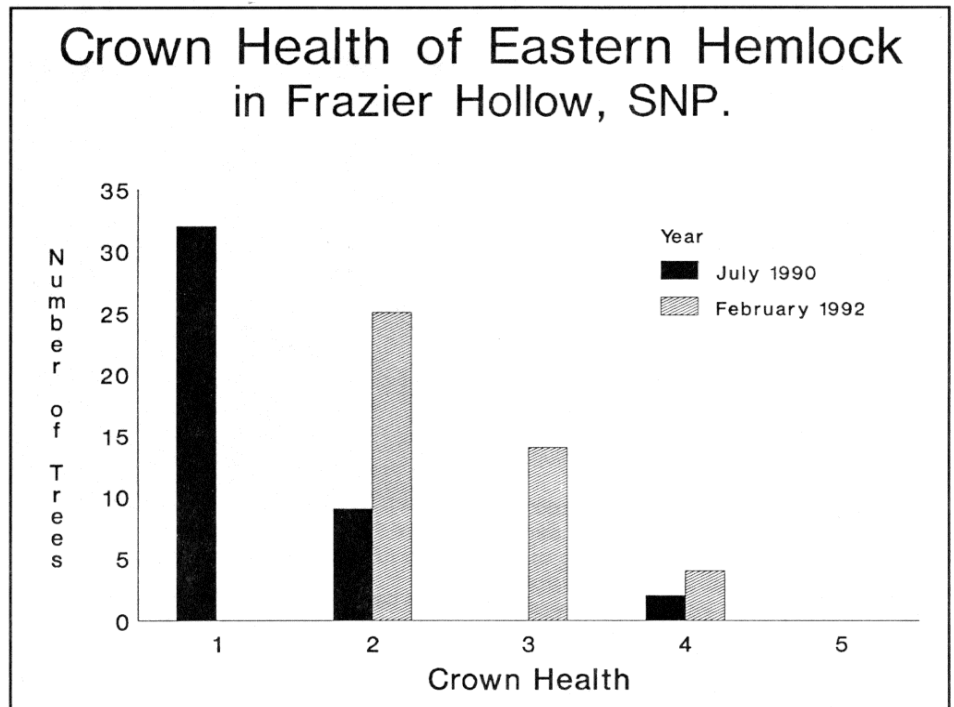


Figure 3. Crown Health of Eastern Hemlock in Frazier Hollow, SNP.

current Inventory and Monitoring System established at SNP with only minor modifications to the existing hemlock component protocols. At present, existing plots have been surveyed and 80 percent have HWA infestations. These plots will be monitored for adelgid impacts as well as the standard measurements detailed in the Long-Term Ecological Monitoring System LTEMs manual (Smith and Torbert 1990). Additionally, plots will be established, inventoried, and monitored in uninfested hemlock stands. Data collection will allow resource specialists to detect initial invasion and monitor the spread and effects of the HWA in hemlock stands throughout SNP.

Other Affected Areas

Any NPS units in the eastern United States with a hemlock forest component could potentially be affected by infestations of the HWA. Large stands exist in both the Great Smoky Mountains NP (GRSM), Shenandoah NP, Catoctin Mountain Park (CMP), and Delaware Water Gap National Recreation Area (DEWA). No infestations have been detected in the GRSM (Langdon, personal communication) but many virgin hemlock stands remain that provide both high value aesthetic and ecological resources. Hemlocks forests in DEWA provide one of the area's most valuable visitor use resources and recently have become infested. The infestation is rapidly increasing, causing widespread defoliation that represents a tremendous potential for significant hemlock mortality in the future (Millington, personal communication). Blue Ridge Parkway personnel have reported the HWA at various locations from the northern sections south to Milepost 150 (Teague, personal communication).

Other infestations have been reported in the National Capitol Region where some pesticide treatment has occurred. No other infestations have been reported, but surveys should be conducted to determine the presence of this non-native species in our federal

lands, particularly the National Park System, where a major goal is the preservation of natural ecosystems and processes. If infestations are suspected, samples should be collected and sent to local universities or specialists to confirm identifications. Infestations should be reported to the Regional USDA Forest Service Pest Management Office.

The adelgid has been in SNP for many years, and extensive mortality can be expected, especially when associated with other stress factors. The outlook for the hemlock stands in the park remains unclear due to the uncertainty that surrounds the adelgid's true potential as a contributor to hemlock mortality. What is certain is that the HWA will remain in Shenandoah as long as the hemlocks remain. When the hemlocks become sparse, the complex community of organisms associated with this forest system also change. Extensive efforts should be initiated to develop better management strategies and an understanding of HWA and its role in forest dynamics. It is imperative that efforts be conducted to inventory and monitor our hemlock forests so better assessments can be made toward determining the potential this species has on an extremely valuable natural resource community.

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Continued on page 11

Eastern Hemlock: The Next American Chestnut?

By David Hayes

Most of us are too young to have any memory of the American chestnut (*Castanea dentata*) as a significant component of eastern forests. Once comprising 25 percent of total timber volume, it is now relegated to persistent stump sprouts that survive for a few years before succumbing to the cause of its decline, the introduced chestnut blight fungus (*Endothia parasitica*). A similar fate may await the eastern hemlock (*Tsuga canadensis*) and Carolina hemlock (*Tsuga caroliniana*) at the hands of yet another Asian invader: the hemlock wooly adelgid.

Hemlock wooly adelgid (*Adelges tsugae*) has no known predators or parasites. Within one to four years, most untreated hemlocks are dead. Highly desiccated, the dead trees break apart very rapidly; whole stands have been levelled in Connecticut in just a few years. Since the moisture content of hemlocks that have succumbed to the adelgid is greatly reduced, fire danger is intensified.

The most troubling aspect of this situation is the potential for large-scale loss of hemlocks from eastern forests. In southeastern New York and most of Connecticut this has already begun. *Tsuga canadensis* is often found in great numbers here, sometimes at canopy densities of 80 percent or higher. It is extremely shade-tolerant, and can persist as an understory species for decades; its longevity also allows it to reach the overstory when conditions permit. The shading it provides results in reduced sunlight transmission through the canopy, hence lower temperatures in streams, wetlands, and on the forest floor. It provides roosting sites for woodland birds, including barred owl (*Strix varia*), great horned owl (*Bubo virginianus*), and ruffed grouse (*Bonasa umbellus*).

Since there is no apparent ecological replacement for hemlock, its loss on a large scale will be significant. The cool, moist microhabitats it provides will be greatly reduced. The simultaneous loss of hemlocks growing in dense stands on steep ravine slopes will undoubtedly cause erosion. There is no practical way to control *A. tsugae* in areas not accessible to large hydraulic spray equipment; aerial applications are ineffective since 100 percent foliar coverage cannot be attained.

Wooly Adelgid

Continued from page 10

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Most of the trees in this hemlock-dominated forest at Vanderbilt Mansion NHS are in their first year of infestation. (Photo by D. Hayes)

The northern front of the infestation is moving through New York State and New England. The Roosevelt-Vanderbilt National Historic Sites are near the current northern frontier of the adelgid's spread. *A. tsugae* has invaded the landscaped area at Vanderbilt Mansion NHS, and is being treated with horticultural oil. Landscaped areas in all units of the park, which total 48 ha (119 ac), will be rigorously monitored, and all infested trees will be treated. In the natural forest zones of the park (170 ha = 420 ac), permanent monitoring stations are being established to track changes in species composition of plants, invertebrates, herpetofauna, and birds. Streams and wetlands will also be monitored for changes in physical and chemical characteristics.

While these efforts will add to our understanding of the effects of hemlock population decline or local extirpation, they will be poor consolation for the loss of such an important species from forest ecosystems in the eastern U.S..

Horticultural and resource management personnel from Roosevelt-Vanderbilt NHS attended an April 29, 1992 meeting at Mystery Point in Garrison NY, where site managers, foresters, landscapers, and researchers discussed strategies for dealing with *A. tsugae*. Mystery Point, a 19th Century estate now owned by the environmental organization Scenic Hudson, provided a dramatic setting, with dead and dying eastern hemlocks covering much of the estate's 136 acres.

Mark McClure of the Connecticut Agricultural Experiment Station briefed attendees on adelgid identification, life cycle, and control techniques. Dr. McClure left soon after an a two-month research trip to Japan, seeking natural predators of *A. tsugae* for potential introduction in the U.S.

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book review

WILDLIFE RESEARCH AND MANAGEMENT IN THE NATIONAL PARKS, R. Gerald Wright, 1992. University of Illinois Press, Urbana and Chicago, 224 pages. Cloth, \$32.50. Notes, appendix, figures, tables, bibliography, and index.

Gerry Wright has presented a much needed and long overdue account of the evolution and present day treatment of wildlife research and management in the National Park Service. From the introduction to its conclusion, relatively unusual facts and little known accounts of past actions and deeds are presented. Unpublished literature and incidents that may have long escaped attention, have been forgotten, or have been buried, are here made available. Memories and notes of those managers, biologists, and scientists who have left the Service in body but not in mind are now brought into the light. As Paul Harvey says, "And now, the rest of the story."

Gerry's unique perspective is not only informational and thought provoking, it reflects his personal concerns and commitment for wildlife management and research in the Park Service. While some may argue that he is not critical enough, others will maintain that the book is an expression of sour grapes. It is neither. It is a well written and researched review of the history and evolution of wildlife management and research in the NPS.

The book is an important and valuable contribution to an understanding of the evaluation of NPS wildlife research and management activities ... a must read for everyone who is involved, interested, or concerned with wildlife in our national parks. It is not only for those within the Service, but for those in conservation at the local, state, and federal levels and in the private sector.

While the book is not perfect, the errors are few, the generalizations, data interpretation, and interpretation of past and present literature are neither slanted nor biased pro or con. The availability and use of more current data and information in a number of the tables and figures would greatly have enhanced the book. Read it; you'll enjoy it.

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