Hemlock Woolly Adelgid Newsletter

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The Hemlock Woolly Adelgid (HWA) Newsletter is a service of the USDA Forest Service, Northeastern Area in support of the HWA Working Group. This informal newsletter is intended to provide brief updates to those interested in activities associated with the hemlock woolly adelgid. For purposes of brevity, some of the articles may have been edited. Readers are encouraged to contact the individual authors if more detailed information is desired. The HWA Newsletter will be prepared and distributed at least annually or as sufficient new information becomes available. Comments, questions, and contributions for future newsletters are welcome and may be submitted to:

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Stepping up the Battle Against HWA

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In 2000, both **The National Plant Board** and **The National Association of State Foresters** passed resolutions that expressed their concern regarding the impact of HWA on hemlock forests. Both organizations formally requested the USDA Forest Service to prepare, seek funding, and implement a strategic pest management plan. The resolutions demonstrate that these prominent organizations view this exotic pest as a high priority item for the USDA Forest Service.

In response, members of the HWA Working Group recently outlined the technical components that would be used to formulate a comprehensive strategic plan. Although much of the knowledge base needed to fully implement a plan is currently lacking, the plan would guide research and development efforts over the next five years. The plan's goal is to *reduce the impact of HWA and slow its spread.*

Ten general areas were identified as important components for further consideration and development:

1. Biological Control
2. Host Resistance
3. Chemical Control
4. Silvicultural Management
5. Regulatory Control
6. Public Awareness
7. Impact Assessments
8. Survey and Monitoring
9. HWA Biology
10. Other Pest Interactions

Technical committees consisting of representatives from various state and federal agencies, universities, and the private sector are currently involved in establishing specific goals, objectives, and action items for each component. Each committee will identify the research or methods development needed for implementation as necessary. Until the plan is finalized, program areas such as the biological control efforts described in this newsletter will continue. We look forward to expanding these efforts once the plan is complete and sufficient funding becomes available.

A draft of the HWA Management Plan is expected by early February 2001.

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Biological Control

Biology of *Scymnus (Neopullus)* Lady Beetles Imported for the Control of the Hemlock Woolly Adelgid

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Explorations in China found 54 species of lady beetles (Coccinellidae), 26 of which were previously unknown species. Three of the most promising species were imported for further evaluation as biological controls for the hemlock woolly adelgid (HWA). These lady beetles are in the subgenus *Scymnus (Neopullus*) and are small, 2 mm long, and brownish in color. They were the most abundant predators of HWA in each of three provinces. All three species are univoltine and prefer to feed on HWA. *Scymnus camptodromus*, from Sichuan Province, is unique in that its oviposition begins later in the spring and lasts through summer and its eggs diapause and do not hatch until the next spring. *Scymnus sinuanodulus* from Yunnan has been studied the longest in our laboratory and field tested for two years. Although it appears to be an effective predator, it has been difficult to mass rear. *Scymnus ningshanensis* is from the most northern province, Shaanxi, and is the species imported most recently. Like the previous species, it lays eggs within a week of overwintering emergence, but only if HWA eggs are present. Its larval development is faster and it has been easier to rear than *S. sinuanodulus*. The timing of oviposition by the predators and prey appears to be very important. Because of the broad season of HWA egg laying, a multi-species complex of predators may be necessary to achieve control of HWA. Future research will be directed to development mass rearing capability and the predator/prey phenology.

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Numerical Response of a Chinese Lady Beetle Imported for Control of the Hemlock Woolly Adelgid

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The lady beetle, *Scymnus (Neopullus) ningshanensis* Yu et Yao, was imported from China in fall 1998. Evaluations were made this past year in the laboratory on its ovipositional response to density of hemlock woolly adelgid ovisacs. Mated, individual female beetles were confined on foliage with 0, 8, 16, 32, or 64 ovisacs. The foliage was changed at weekly intervals for eight weeks and the beetle eggs were counted. Beetles given hemlock foliage with no ovisacs did not lay any eggs. Beetles given 64 ovisacs laid five times more eggs than the beetles given eight ovisacs. Beetles given eight ovisacs laid eggs for only five weeks, whereas beetles given 64 ovisacs were still laying eggs after eight weeks. At the highest prey denisty, the average total number of eggs laid was 116 with a weekly maximum of 21. The numerical response of *S. ningshanensis* is density dependent, which is often considered an attribute of a good biological control agent. Future research will examine numerical response at even higher adelgid ovisac densities, numerical response in the field, and numerical response of the larvae.

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Initial Field Evaluations of a Lady Beetle Imported from China for Control of the Hemlock Woolly Adelgid

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Two years of cage field studies were reported on the impact of *Scymnus (Neopullus) sinuanodulus* Yu *et* Yao on the population dynamics of the hemlock woolly adelgid (HWA). In April, the number of ovipositing HWA (sisten generation mothers) were counted on the distal 0.3-0.6 m of eastern hemlock branches. A single, mated female beetle was placed in treatment bags and bags without beetles and branches without bags were used as controls. One-half of the branches were collected in late May or early June and the other half were collected in early

July. The number and stage of adelgids and beetle progeny were counted. The first collection examined the population change between sisten mothers and their daughters (progredien nymphs) and the second collection examined the population change between sisten mothers and their granddaughters (aestivating sisten nymphs). In 1999, branches with beetles, which produced progeny, had 66 percent and 20 percent fewer adelgid nymphs in May and July, respectively, compared to branches with empty bags. In 2000, bags with beetle offspring again had lower numbers of adelgids, 16 percent and 48 percent in the first and second collections, respectively. Reduction of the adelgid population was greatest when the adelgid population increase was the greatest. Negative density feedback, host tree condition, and phenology also seem to influence the results. Future research will further define the influence of these and other factors on the effectiveness of this adelgid-eating lady beetle.

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West Virginia Department of Agriculture HWA Activities

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The WV Department of Agriculture made four additional releases of approximately 2,500 beetles each at: a site near Hedgesville in Berkeley County, at the Fort Mill Ridge Wildlife Management Area at Romney in Hampshire County, at a site near Milam in Hardy County, and at a site near Franklin in Pendleton County. Baseline adelgid counts and tree health data were recorded in early spring on the Hanging Rock site and just prior to the *Pseudoscymnus tsugae* adult releases on May 18 (Berkeley and Hampshire Counties) and May 25 (Hardy and Pendleton Counties). The plots were visited in May, June, July, August, and September to observe and record numbers of predator adults and larvae. Limited numbers of *P. tsugae* adults were observed at some of the plots throughout the course of the summer. No larvae were observed.

The 2000 detection survey located areas of infestation in two new counties this year: Mercer and Summers Counties. WVDA field agents visited HWA permanent study plots at Greenland Gap in Grant County, Cathedral State Park in Preston County, and Blackwater Falls State Park in Tucker County in June. Yearly and fifth year data were collected and submitted to the USDA-FS for inclusion in the database.

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Hemlock Woolly Adelgid Biocontrol With *Pseudoscymnus tsugae* in Landscape Settings

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We have two goals for our efforts with *Pseudoscymnus tsugae*. First, we want to quickly distribute the predator throughout the state to affect hemlock woolly adelgid (HWA) control before the trees die. Secondly, we want to do this in a landscape setting where the hemlocks are particularly valuable and where we have a better chance of evaluating the impact of the predators. To this end, we reared 8,000 *P. tsugae* in 1999 and released them on 38 landscape trees in four locations throughout the state. Initial results look promising: HWA populations on these trees declined in proportion to the numbers of *P. tsugae* released on each tree. To overcome variability in tree size, health, infestation level, and proximity to other trees, we planted 41 healthy, uninfested Canadian hemlocks in March 2000. These 6-8 ft. trees were planted along the edges of URI agricultural fields, each 100 meters from other hemlocks. In late April we infested 25 of these trees with HWA by attaching small branches, heavily infested with eggs throughout the canopy. On June 8 we released *P. tsugae* on these trees in densities of 0, 50, 100, 200, and 300 per tree with 5 replicates of each density. Samples on June 26 indicated that predators were still on trees in proportion to release densities and none moved to the controls. Samples of HWA densities taken throughout the season (to September) show a substantial HWA increase on trees where no predators were released, but a net decrease of HWA populations on trees receiving 50 or more predators. We will follow HWA and *P. tsugae* populations on these trees next season.

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Rearing and Release of *Pseudoscymnus tsugae* by the New Jersey Department of Agriculture, Phillip Alampi Beneficial Insect Laboratory (PABIL)

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On May 14, 1997, Dr. Mark McClure of the Connecticut Agricultural Experiment Station (CAES) shipped 100 adult *Pseudoscymnus tsugae* to the PABIL so that we could begin developing mass production methods. That year, PABIL staff was able to produce 600 adults before HWA went into aestivation in mid July. Since that time, the laboratory has produced 346,100 adult *P. tsugae*, of which 190,500 were released in 41 sites in NJ and 132,700 were shipped to nine states and one National Park.

During the period of peak production, March-May, between 75-100 egg laying containers (gallon jars) are set up. Each jar contains 10 female and five male *P. tsugae*, hemlock twigs infested with HWA, wheast, and a honey strip. In addition to the hemlock twigs, a piece of gauze is placed in the jar and is used for oviposition. Once a week the hemlock twigs and gauze, containing *P. tsugae* eggs, are removed from the jars and replaced with new infested twigs and a fresh piece of gauze. At that time, the wheast and honey are also replenished. The twigs and gauze that have been removed from the jars are placed in Plexiglas rearing boxes, estimating 2,500 eggs per box. About 16 boxes are set up each week. The adults develop in five weeks, at which time they are collected from the rearing boxes and released or held in storage until it is time to release them. Between 5,000 and 10,000 beetles are held in each storage box.

Overwintering recoveries have been made from a total of ten 1998 and 1999 NJ release sites. Adult recoveries have been made from all 13; year 2000 sites and larvae were recovered from two of the 13 sites. Dispersal from the release tree has been documented at approximately 100 meters the year of release and up to 300 meters the second year following release. Plans for 2001 include continuing the cooperative agreement with the USDA Forest Service, mass-producing *P. tsugae*, and releasing it in infested healthy stands of hemlock in NJ as well as shipping the beetle to other states within the region.

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Biological Control of Hemlock Woolly Adelgid Connecticut Update 2000

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The ladybird beetle, *Pseudoscymnus tsugae* Sasaji and McClure, is being reared and studied at the Station's Valley Laboratory in Windsor. During 2000, >35,000 adults were reared and released in Connecticut; 22,000 were released at two new sites, and the remainder at previous release sites. During the past five years, the Windsor team has released more than 131,000 adult beetles in 18 hemlock forests in all eight counties in Connecticut, and nearly 30,000 more at one site in New Jersey, and two in Virginia to evaluate *P. tsugae* as a biological control agent. Initial results were encouraging, because adelgid numbers were reduced 47-87 percent on release trees after only five months. Unfortunately, the relatively mild winters from 1996 to 1999 were conducive to the survival and growth of adelgid populations, and the health of infested hemlocks generally declined during that period. However, several days during January 2000 had temperatures below 0^0F, which killed more than 90 percent of the adelgids throughout the northern half of Connecticut. At two of our major northern study sites (Granby and Union), adelgid density, which had increased sharply during 1999, crashed in response to >93 percent mortality during January 2000. Mortality was significantly lower in coastal areas, in northern sites immediately adjacent to open and fast-moving bodies of water, and on branches buried in snow, where temperature was less severe. The high adelgid mortality during January in many areas enhanced the biological control effort in 2000 because *P. tsugae* was unscathed by the cold weather. The relatively cool, moist weather this past spring and summer has also favored the growth and recovery of hemlocks. Unfortunately, the elongate hemlock scale, *Fiorinia externa*, is present in high numbers at many of our study sites and is contributing significantly to the demise of hemlock health. We are now in the second year of our cooperative multi-state release and long-term study of *P. tsugae* involving 10 states from North Carolina to southern New England.

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Laricobius nigrinus: Laboratory Evaluations and Status

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Laricobius nigrinus Fender (Coleoptera: Derodontidae) has been observed in close association with hemlock woolly adelgid (HWA), *Adelges tsugae* Annand (Homoptera: Adelgidae) populations on western hemlock, *Tsuga heterophylla* (Raf.) Sargent in British Columbia, Canada (Humble, Canadian Forest Service, pers. commun. 1996), and has a known distribution of British Columbia, western Washington, Oregon, and northern Idaho, U.S.A. There are no published reports on the biology and ecology of *L. nigrinus*, or on its relationship with HWA. Because this predator is found with HWA in western North America, where HWA is not considered a pest, we believed that it merited evaluation as a candidate biological control agent for HWA in eastern United States. In our studies we have developed a continuous lab-rearing procedure for *L. nigrinus*, described the insect's life cycle, determine that the predator and HWA progrediens are phenologically synchronous in B.C., determined that the predator prefers to feed and oviposit on HWA over other adelgid and non-adelgid Homopterans, and observed that the predator will complete development only on HWA. Plans are in place to release *L. nigrinus* and study its activity in the field.

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Entomopathogenic Fungi for HWA IPM – What's Next?

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It takes a century for a hemlock tree to reach maturity, yet only 3-6 years for it to succumb to hemlock woolly adelgid, *Adelgis tsugae* (HWA). They say "Time is money." Can we afford to lose that kind of environmental investment to this exotic pest? Several spot infestations of HWA have been found this year in Maine and New Hampshire. This represents a significant expansion of its range. Important northern hemlock stands are at risk. Development of biological control for forest habitats has never been more critical. Entomopathogenic fungi remain a promising component of the biological complex. These microbes have several intrinsic advantages over other exotic natural enemies. They are relatively easy and inexpensive to mass produce on artificial media. They impact the pest population relatively quickly (within 10-14 days), unlike predators or parasites whose numbers build slowly. Several indigenous fungal isolates have been recovered in HWA populations in the East. These fungi occur naturally in this environment and in general are considered environmentally safe. Rarely can one natural enemy alone achieve adequate control of a pest population. Rather, a complex of compatible biological agents must be developed that, in concert, suppress HWA populations below damaging levels. Our goal is to develop these beneficial microbes into safe and effective tools for inclusion in a comprehensive HWA IPM approach.

Developing fungi for IPM is a multi-phase process, beginning with searching for isolates infecting HWA. We conducted searches throughout the range of HWA in the Eastern U.S. and in China and Taiwan. Over 300 isolates were collected, purified, and identified. We tested most of them against HWA, and many provided mortality rates of over 80 percent after 7 days. Because of variation within and between fungal species, promising isolates were characterized to determine their growth, germination time, and spore production rate at a range of temperatures. With this information we can select those with the greatest potential with respect to their ability to be mass-produced and effective at temperatures in the field. We have identified for field-testing six of the most promising isolates in the species *Beauveria bassiana*, *Metarhizium anisopliae Paecilomyces farinosus*, and *Verticillium lecanii*. The next critical step in the development process is to field test these isolates under field conditions and evaluate their compatibility with other non-target beneficials.

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Delaware Water Gap National Recreation Area Releases HWA Biocontrol Beetles

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Biocontrol Beetle Releases: After completing a thorough Environmental Assessment and a Finding of No Significant Impact, we released 15,000 HWA biocontrol beetles (*Pseudoscymnus tsugae*) in the park during June 2000. The New Jersey Dept. of Agriculture and the USDA Forest Service provided the beetles. We released 7,500 beetles at each of two sites: Adams Creek (PA) and VanCampens Brook (NJ). At both sites, we are following USDA Forest Service protocols for monitoring beetles, HWA populations, and hemlock crown conditions. Adult beetles were recovered in late July and August at both sites, but no beetles were found at either site in October. We intend to release more beetles in the park during spring 2001.

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Want To Know More About Biological Control of Hemlock Woolly Adelgid?

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You can read more about biological control of HWA in a USDA Forest Service Forest Health Technology Enterprise Team (FHTET) authored by Dr. Mark McClure. The publication will be available in February and can be obtained by contacting:

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Biology

Pseudoscymnus tsugae: Semiochemical Research, Preliminary Findings

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Pseudoscymnus tsugae Sasaji & McClure (Coleoptera: Coccinellidae) is host-specific to hemlock woolly adelgid (HWA), *Adelges tsugae* Annand (Homoptera: Adelgidae). Therefore, to find its prey, it is likely they use some long-range behavioral cues such as vision or olfaction to locate their host. We have begun to investigate the possibility that *P. tsugae* use olfaction in host-finding. In preliminary experiments, we have used a y-tube walking bioassay to see if *P. tsugae* respond to hemlock foliage or HWA-infested hemlock foliage. So far, we have not observed any response. Further testing and modification of the bioassay are planned in the future. We have also prepared scanning electron microscopic images to survey the sensilla on *P. tsugae* antennae. A majority of the sensilla are on the tip of the antennae and may have mechano- or gustatory functions. A lower frequency of peg sensilla that could have olfactory function was found. Until now, transmission electron microscopic images that allow for higher magnification have not been successful in determining whether the peg sensilla contain pits, which would indicate an olfactory function.

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Impact Assessments

Mesohabitat Use of Threatened Hemlock Forests by Breeding Birds of the Delaware Water Gap National Recreation Area

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To assess avian biodiversity, mesohabitat relations, and the risk of loss of species diversity with declining hemlock forests in Appalachian park lands, 80 10-min point counts of breeding birds were conducted in June 2000 on four forest-terrain types previously sampled (Snyder et al. 1999) in the Delaware Water Gap National Recreation Area (DEWA) for aquatic biota: hemlock and hardwood benches and ravines. Point centers were established randomly within sample units, ground truthed with the aid of Global Positioning System technology, and moved if necessary to avoid habitat edge. Point-count radii were limited to 50 m to minimize differential species detection rates, and all counts were conducted between 0530 and 1000 hours in good weather conditions. Mesohabitat sensitivity was calculated as $(D_b - H_b) + (D_r - H_r)$ for forest type and as $(B_d - R_d) + (B_h - R_h)$ for terrain type, where D, H, B, and R are proportion of points where the species occurred in hardwood (deciduous), hemlock, bench, and ravine habitats, respectively, and D, H, B, and R qualify specific mesohabitats.

We found species richness in hemlock stands to be less than that of hardwood stands (Table 1). Hemlock ravines supported only half the number of species as benches, but little difference was observed in hardwoods. Territories were also denser in hardwood than hemlock stands, with somewhat lower densities in ravine terrains than benches in each case. Species most sensitive to forest type were black-throated green warbler (*Dendroica virens*), American redstart (*Setophaga ruticilla*), red-eyed vireo (*Vireo olivaceus*), Blackburnian warbler (*Dendroica fusca*), blue-headed vireo (*Vireo solitarius*), Acadian flycatcher (*Empidonax virescens*), scarlet tanager (*Piranga olivacea*), eastern wood-pewee (*Contopus virens*), and wood thrush (*Hylocichla mustelina*), while those most sensitive to terrain type were American redstart, red-eyed vireo, ovenbird (*Seiurus aurocapillus*), blue-headed vireo, veery (*Catharus fuscescens*), and Blackburnian warbler (Table 2). Of these only four species showed strong preference for hemlock over hardwood habitat: black-throated green warbler, Blackburnian warbler, blue-headed vireo, and Acadian flycatcher. Of these four forest-type specialists, only two, Blackburnian warbler and blue-headed vireo, showed strong preference for a particular terrain type, the ravine mesohabitat.

These results are similar to those of Benzinger (1994a,b), who reported "almost exclusive" use of hemlock stands by blue-headed vireo and black-throated green warbler in New Jersey, though our data would include Blackburnian warbler in that category. Benzinger also found Acadian flycatcher, winter wren (*Troglodytes troglodytes*), and hermit thrush (*Catharus guttatus*) "usually" in hemlock forest; our data agree with this interpretation except that occurrence of winter wren and hermit thrush was insufficient to be statistically significant. DEWA data do not support Benzinger's assessment for Blackburnian warbler, however, as "often" occurring in hemlock forests (see above). Our data further agree with those of Howe and Mossman (1995) who described five species, red-breasted nuthatch (*Sitta canadensis*), winter wren, blue-headed vireo, black-throated green warbler, and Blackburnian warbler, as significantly associated with hemlock forests in Wisconsin and upper Michigan, except for our failed detection of red-breasted nuthatch.

In summary, breeding bird data from DEWA forests indicate that four insectivorous neotropical species, Acadian flycatcher, blue-headed vireo, black-throated green warbler, and Blackburnian warbler, are essentially obligate hemlock-associated species at risk should adelgid-mediated hemlock decline continue in park lands and similar forests of the mid-

Table 1. Sample sizes, territory densities, and species richness of birds in mesohabitats of forest and terrain type in Delaware Water Gap NRA

Mesohabitat		No. Of Sample Points	Species Richness of Birds	Territory Density
Forest	**Terrain**		**Total species per 16 points**	**Mean no. of individuals per point**
Deciduous	Bench	19	31	9.5
Deciduous	Ravine	16	29	7.2
Hemlock	Bench	16	24	5.8
Hemlock	Ravine	29	13	4.7
Total		80	24.5 (mean)	6.8

Table 2. Mesohabitat sensitivity indices of birds by forest and terrain type

Rank	Species	Index	n
Forest Type			
Deciduous preference			
1	American redstart	0.93	19
2	Red-eyed vireo	0.76	58
3	Scarlet tanager	0.48	35
4	Eastern wood-pewee	0.38	11
5	Wood thrush	0.37	25
6	Tufted titmouse	0.25	13
7	Ovenbird	0.23	58
8	Veery	0.18	9
9	Blue jay	0.14	8
Hemlock preference			
1	Black-throated green warbler	-1.16	30
2	Balckburnian warbler	-0.67	17
3	Blue-headed vireo	-0.61	18
4	Acadian flycatcher	-0.60	20
5	Louisiana waterthrush	-0.08	9
Terrain Type			
Bench preference			
1	American redstart	0.43	19
2	Red-eyed vireo	0.38	58
3	Ovenbird	0.36	58
4	Veery	0.31	9
5	Eastern wood-pewee	0.25	11
6	Blue jay	0.14	8
7	Black-throated green warbler	0.09	30
8	Acadian flycathcer	0.02	20
Ravine preference			
1	Blue-headed vireo	-0.36	18
2	Blackburnian warbler	-0.30	17
3	Louisiana waterthrush	-0.20	9
4	Scarlet tanager	-0.15	35
5	Wood thrush	-0.01	25

Atlantic east slope. Two of these, the blue-headed vireo and Blackburnian warbler, appear to specialize in ravine mesohabitats of hemlock stands, the vireo a low-to-mid canopy species, the warbler a mid-to-upper canopy forager.

Literature Cited

Benzinger, J. 1994a. Hemlock decline and breeding birds I: hemlock ecology. Rec. N. J. Birds 20(1):2-12.

Benzinger, J. 1994b. Hemlock decline and breeding birds II: effects of habitat change. Rec. N. J. Birds 20(2):34-51.

Howe, R. W., and M. Mossman. 1995. The significance of hemlock for breeding birds in the western Great Lakes region. Pp. 125-139 *in* G. Mroz and J. Martin (eds.), Hemlock Ecology and Management. Proc. Regional Conf. Ecol. Mgmt. E. Hemlock, September 27-28, 1995, Iron Mountain, Michigan. Dept. of Forestry, Univ. of Wisconsin, Madison.

Snyder, C., J. Young, D. Smith, D. Lemarie, R. Ross, and R. Bennett. 1999. Influence of eastern hemlock on aquatic biodiversity in the Delaware Water Gap National Recreation Area. U. S. Geological Survey, Leetown Science Center, Kearneysville, West Virginia.

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Influences of Hemlock Mortality on Soil Water Chemistry and Understory Vegetation

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We have been studying the effects of hemlock mortality on soil water chemistry since 1996. In October 1996, we began monthly sampling and chemical analysis of soil water in four healthy hemlock stands in the Catskill Mountains of southeastern New York. In July 1997, hemlock trees in two of the stands were girdled (i.e. bark and cambium severed around the base of the bole) to simulate mortality due to the hemlock woolly adelgid. Girdling of hemlock trees resulted in elevated concentrations of NO_3^- and most cations in soil water within two to three months. We attribute these increases in nutrient loss to fine root mortality, increases in rates of mineralization and nitrification, and reduced nutrient uptake by vegetation. Maximum mean monthly concentrations were generally observed 12-18 months after girdling (e.g. 473-2,272 µeq NO_3^- L^{-1}, 22-126 µeq NH_4^+ L^{-1}). Concentrations generally started to decrease after 18 months, but concentrations of several ions remained high relative to control stands through the 2000 growing season (e.g. NO_3^-, Ca^{2+}, H^+, Mg^{2+}). These data demonstrate that hemlock mortality can lead to significant nutrient losses to soil water. Yellow birch seedling densities and percent cover of several herbaceous species (hay-scented fern, evergreen woodfern, common wood sorrel, New York fern) increased in response to hemlock mortality. Total percent cover of understory vegetation more than doubled in the three years after girdling.

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Hemlock Ecosystem Inventory and Monitoring Project

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In 1998, John Wood was contracted by the National Park Service to establish a long-term ecological monitoring program within hemlock forests of the New River Gorge National River and Gauley River National Recreation Area. Thirty-six permanent 400m² plots were established during 1998 in Fayette, Nicholas, and Raleigh Counties, West Virginia. Replicated plots (separated by at least 250m for concurrent wildlife-habitat studies), each containing a visibly significant percentage of intact hemlock (*Tsuga canadensis)* tree canopy cover, were randomly chosen across a range of hydric, mesic, and xeric sites. Several of the plots consist of old growth forest, the oldest hemlock trees, over 300 years, were cored in hydric stands along the Meadow and Gauley Rivers. As of November 1999, there was no evidence of hemlock woolly adelgids on any of the live hemlock trees. The 2000 survey is 90 percent complete and trees continue to be free of any HWA. Only seven of the 482 individual, live trees that were sampled during November 1999, had crown-vigor values of <75 percent. Additional baseline plant-community data (hardwood tree density, hardwood and evergreen sapling density, shrub density, and frequency and cover of all vascular species) were collected during July 1999. The contractor has entered baseline data into Statistical Analysis System (SAS) programs developed, and the results summarized in a final report submitted to the park in December 1999.

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Bird Communities in Hemlock Ecosystems

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In 1999, New River Gorge National River entered into a Cooperative Agreement with the West Virginia Cooperative Fish & Wildlife Research Unit, West Virginia University to develop avian monitoring protocols suitable for use in conjunction with the long-term study to monitor vegetation changes in hemlock communities entitled "Hemlock Ecosystem and Inventory Monitoring." Objectives of the study include: 1) Determine the number of bird point count stations needed for statistically valid results; 2) Obtain preliminary data on avian richness and abundance in hemlock communities prior to adelgid infestation; and 3) Use the preliminary data and the sampling protocol to develop a proposal for a long-term study to quantify the effects of hemlock woolly adelgid infestation on avian richness and abundance. A final report on the project is due in January 2001.

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New Jersey Department of Agriculture Phillip Alampi Beneficial Insect Laboratory Permanent Plot Evaluations

Mark Mayer, Robert Chianese and, Thomas Scudder, New Jersey Department of Agriculture

The Phillip Alampi Beneficial Insect Laboratory continued to monitor the plots that were set up in 1988. The plots in Warren, southern Sussex, Morris, and southern Passaic Counties, which were heavily infested by the hemlock woolly adelgid at least twice in the decade, showed an increase in mortality. The drought of 1999 pushed many of the trees that were barely hanging on over the edge. The mortality ranged from 48 to 92 percent of the hemlock trees in those plots. The stands have opened up and broken crowns and fallen trees litter the ground making surveys difficult. The USFS crown ratings have declined in all of the plots that have been heavily infested twice since 1988. We expect mortality to increase in the coming year because of the poor condition of the crowns. *Fiorinia* scale populations are heavy in the affected plots as is hemlock borer damage. There is a gradual decline in the stands that have been infested by the hemlock woolly adelgid where the trees are alternately infested, recover, and are infested again. This is irrespective of site type and the single most important factor in tree mortality in New Jersey is whether there have been heavy hemlock woolly adelgid populations in the stand in the past.

In extreme northwestern New Jersey, in northern Sussex and northern Passaic counties, where the hemlock woolly adelgid is beginning to build up heavy populations, the mortality of the plot trees ranged from 5.3 to 15.8 percent with none of that mortality attributable to the adelgid. One plot, at High Point State Park had substantial mortality of the trees in subplot 2 but that was due to flooding and girdling caused by beavers and not to the hemlock woolly adelgid. The northernmost plots have lower *Fiorinia* scale populations in contrast to the plots with the greatest mortality, and there is little evidence of hemlock borer activity in the northernmost plots.

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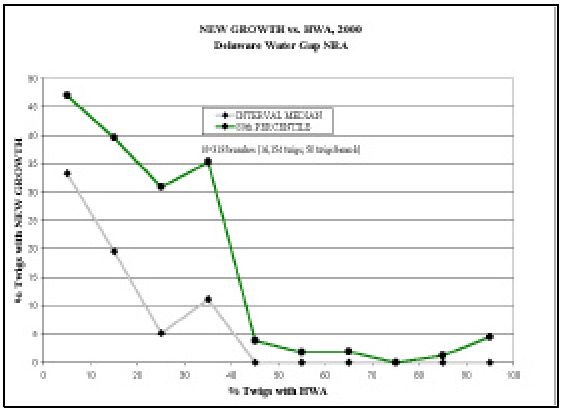
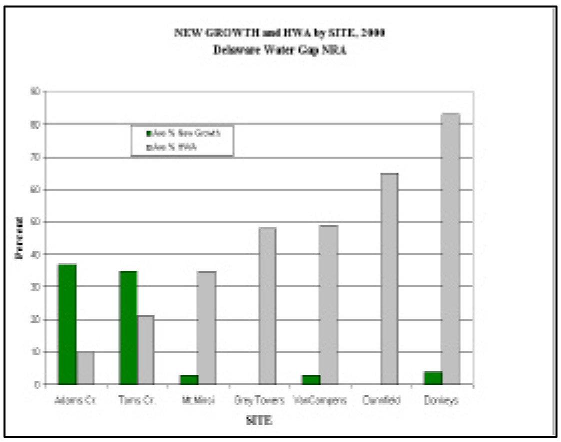
Hemlock - HWA Monitoring

Richard Evans, USDI National Park Service, Delaware Water Gap National Recreation Area

Hemlock Plot Monitoring: During 2000, we completed our eighth consecutive year of monitoring hemlock crown conditions and HWA populations in 81 permanent plots throughout the park. Our data document the impact of HWA infestations on the new growth of twigs, and also document a range of HWA infestation levels and hemlock crown conditions at sites throughout the park. The graph of New Growth vs. HWA (next page) shows that, at the scale of individual trees, the percentage of new twig growth declined sharply as the percentage of twigs infested with HWA increased, and that almost no new growth occurred when 50 percent or more of twigs were infested with HWA. The graph of New Growth and HWA by Site (next page) shows that HWA infestation rates ranged from 10 to over 80 percent at different sites. Furthermore, this graph shows that, at the scale of forest stands, new twig growth was common only at the most recently infested sites, which had the lowest HWA infestation rates (<25percent).





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Hemlock Ecological Research At the Delaware Water Gap NRA

Richard Evans, USDI National Park Service, Delaware Water Gap National Recreation Area

In 1997, the USGS Biological Resources Division (BRD), in cooperation with the National Park Service, developed a landscape-scale sampling design for our park that could be used to assess biodiversity losses that might result from eastern hemlock decline. Fourteen pairs of hemlock and hardwood stands and streams having similar topography (slope, aspect, elevation, terrain shape, light exposure, and stream size) were selected as sample sites in the park for comparative ecological studies. In 1998, the BRD completed studies of stream temperatures, fish, and insects at these sites (report available on the internet at:http://ael.er.usgs.gov/groups/ecology/hemlock/dewa.html). In 2000, we cooperated with several agencies to conduct additional ecological studies at these sites. The Wildlife Conservation Society sampled stream and riparian salamanders, while the BRD surveyed breeding birds at these sites. The USDA Forest Service established FIA/FHM monitoring and research plots at three pairs of sites, and intends to establish plots at more sites next year. During 2001, we will again be working with the SUNY College of Environmental Science and Forestry to collect monthly stream water samples at all these sites, and analyze them for nitrogen and major cations (as we did in 1999).

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Stand, Landscape, and Ecosystem Level Responses to HWA Infestation and Logging in Southern New England Forests

David A. Orwig, Harvard Forest

Dave Orwig, Richard Cobb, and David Foster have continued their study examining the timing, magnitude, and duration of nitrogen cycling changes in eight Connecticut hemlock sites varying in HWA infestation level. Compared to uninfested forests, stands impacted by HWA for several years had reduced vigor and increased canopy openness and soil temperatures. Associated with these microenvironmental changes, we observed increased pool sizes of NH_4^+ and NO_3^- and increased nitrogen mineralization and nitrification rates. Resin bag analysis indicated increased nitrogen capture on impacted vs. uninfested sites, and suggests nitrogen is being lost from sites and is likely being exported to streams. We predict these cycling changes will increase in magnitude with further infestation, and we will continue these analyses to examine the duration of these changes and the impact re-vegetation has on nitrogen cycling.

To complement the ongoing ecosystem study, R. Cobb and others have just completed a 2-year project examining the effect of HWA infestation on hemlock foliar decomposition rates. Stands damaged by HWA typically had lower decomposition rates and foliar C:N ratios than stands with little or no HWA damage. The same trends were observed in foliage collected from uninfested trees at Harvard Forest and placed in our CT sites. This suggests that decomposition in infested hemlock stands is being altered by both changes in microenvironment and reduced foliar quality as a result of HWA infestation. Future work will focus on decomposition in forests with greater HWA damage and over longer time periods.

We will continue to resample the vegetation and monitor overstory mortality in permanent plots established in 1995. Since then, mortality of overstory and understory hemlock has risen to over 60 percent in half of the stands and continues to increase 5 to 15 percent per year. The health and vigor of remaining trees has deteriorated in all stands, with the majority of trees containing less than 25 percent of their foliage. We have observed no sign of tree recovery on these sites over the last 5 years. We are currently writing up our landscape project that examined composition data from 114 mapped hemlock stands located within a 6000 km^2 transect that stretches from Long Island Sound to the Massachusetts border.

As a larger area of the Northeast becomes infested with HWA, harvesting of hemlock is increasing in frequency and magnitude. In order to describe and understand the effects of logging on hemlock dominated forests, Matt Kizlinski's Masters project has focused on 10 stands in CT and MA that were cut at various times during the last 13 years. Data on regeneration, n cycling, and soil processes has been collected. Initial results show a quick establishment of several raspberry species followed by prolific black birch establishment. Data analysis of decomposition rates and nitrogen cycling changes will take place this winter.

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HWA Related Publications

Yorks, T.E., D.J. Leopold, and D. J. Raynal. 2000. Vascular Plant Propagule Banks of Six Eastern Hemlock Stands in the Catskill Mountains of New York. Journal of the Torrey Botanical Society 127: *In press.*

Jenkins, J.C., J.D. Aber, and C.D. Canham. 1999. Hemlock Woolly Adelgid Impacts on Community Structure and N Cycling Rates in Eastern Hemlock Forests. Canadian Journal of Forest Research 29:630-645.

McClure, M.S. and C. A. S-J. Cheah. 1999. Reshaping the Ecology of Invading Populations of Hemlock Woolly Adelgid, *Adelges tsugae,* (Homoptera: Adelgidae) in Eastern North America. Biological Invasions 1:247-254.

McClure, M.S., C. A. S-J. Cheah, and T. C. Tigner. 1999. Is *Pseudoscymnus tsugae* the Answer to the Hemlock Woolly Adelgid Problem?: An early perspective. Proceedings of the Symposium on Sustainable Management of Hemlock Ecosystems in Eastern North America. USDA Forest Service, GTR-NE267: 89-96.

Cheah, C.A. S-J. and M.S. McClure. 2000. Seasonal Synchrony of Life Cycles Between the Exotic Predator, *Pseudoscymnus tsugae* (Coleoptera: Coccinellidae) and Its Prey, the Hemlock Woolly Adelgid, *Adelges tsugae* (Homoptera: Adelgidae). Agricultural and Forest Entomology 2(4): 241-251.

Salom, S.M., M.S. McClure, M.E. Montgomery, G. Zilahi-Balogh, and L.T. Kok. Hemlock Woolly Adelgid in the United States: Status of Ongoing Biological Control Research. Working Party 7.03.07. Biological Invasions of Forest Insect Pests - Agents of Change. XXI International Union of Forestry Research Organizations World Congress. August 7 -12, 2000. Kuala Lumpur, Malaysia.

John J. Battles, Natalie Cleavitt, Timothy J. Fahey, and Richard A. Evans. 1999. Vegetation Composition and Structure in Two Hemlock Stands Threatened by the Hemlock Woolly Adelgid. Proceedings of the Symposium on Sustainable Management of Hemlock Ecosystems in Eastern North America. USDA Forest Service, GTR-NE267: 55-61.

Jennifer C. Jenkins, Charles D. Canham, and Paul K, Barten. 1999. Predicting Long-Term Forest Development Following Hemlock Mortality. Proceedings of the Symposium on Sustainable Management of Hemlock Ecosystems in Eastern North America. USDA Forest Service, GTR-NE267: 62-75.

Dennis R. Souto and Kathleen S. Shields. Overview of Hemlock Health. 1999. Proceedings of the Symposium on Sustainable Management of Hemlock Ecosystems in Eastern North America. USDA Forest Service, GTR-NE267: 76-80.

Mark S. McClure, Carole A. S-J Cheah, and Timothy C. Tigner. 1999. Is *Pseudoscymnus tsugae* the Solution to the Hemlock Woolly Adelgid Problem?: An Early Perspective. Proceedings of the Symposium on Sustainable Management of Hemlock Ecosystems in Eastern North America. USDA Forest Service, GTR-NE267: 89-96.

Michael E. Montgomery, Defu Yao, Hingbin Wang. 1999. Chinese Coccinellidae for Biological Control of the Hemlock Woolly Adelgid: Description of Native Habitat. Proceedings of the Symposium on Sustainable Management of Hemlock Ecosystems in Eastern North America. USDA Forest Service, GTR-NE267: 97-102.

Denise Royle and Richard Lathrop. 1999. The Effects of Site Factors on the Rate of Hemlock Decline: A Case Study in New Jersey. Proceedings of the Symposium on Sustainable Management of Hemlock Ecosystems in Eastern North America. USDA Forest Service, GTR-NE267: 103.

Matthew S. Wallace and Fred P. Hain. 1999. Field Surveys and Evaluation of Native Predators of the Hemlock Woolly Adelgid (Homoptera: Adelgidae) in the Southern United States. Proceedings of the Symposium on Sustainable Management of Hemlock Ecosystems in Eastern North America. USDA Forest Service, GTR-NE267: 104-109.

Gabriella Zilahi-Balogh, Scott M. Salom, and L. T. Kok. 1999. Host Suitability and Preference of Labricobius nigrinus (Fender) (Coleoptera: Derodontidae): A Predatory Beetle for Potential Biological Control of Adelges Tsugae (Annand) (Homoptera: Adelgidea). Proceedings of the Symposium on Sustainable Management of Hemlock Ecosystems in Eastern North America. USDA Forest Service, GTR-NE267: 110.

Kristine D. Johnson, Fred P. Hain, Katherine S. Johnson, and Felton Hastings. 1999. Hemlock Resources at Risk in the Great Smoky Mountains National Park. Proceedings of the Symposium on Sustainable Management of Hemlock Ecosystems in Eastern North America. USDA Forest Service, GTR-NE267: 111-112.

David A. Orwig and David R. Foster. 1999. Stand, Landscape, and Ecosystem Analyses of Hemlock Woolly Adelgid Outbreaks in Southern New England: An Overview. Proceedings of the Symposium on Sustainable Management of Hemlock Ecosystems in Eastern North America. USDA Forest Service, GTR-NE267: 123-126.

Thad E. Yorks, Jennifer C. Jenkins, Donald J. Leopold, Didley J. Raynal, and David Orwig. 1999. Influences of Eastern Hemlock Mortality on Nutrient Cycling. Proceedings of the Symposium on Sustainable Management of Hemlock Ecosystems in Eastern North America. USDA Forest Service, GTR-NE267: 126-133.

John Young, Craig Snyder, James Akerson, and Gary Hunt. 1999. Assessment of Landscape Correlates of Eastern Hemlock Decline Due to Hemlock Woolly Adelgid. Proceedings of the Symposium on Sustainable Management of Hemlock Ecosystems in Eastern North America. USDA Forest Service, GTR-NE267: 134.