Hemlock Ecosystems and Spatial Patterns of *Adelges tsugae* Infestation in Northwestern North Carolina

James Graham, Gary Walker, Ray Williams, Zack Murrell, and Arthur Rex

Appalachian State University, Boone, North Carolina

ABSTRACT

Hemlock (*Tsuga spp.*) ecosystems and associated plant assemblages are at risk of decline across the Southern Appalachians. Grandfather Mountain, Linville, Lutherock, and northern Watauga County in North Carolina harbor excellent examples of these ecosystems. If not suppressed, the hemlock woolly adelgid (HWA), *Adelges tsugae* Annand, may facilitate the destruction of native hemlocks in the region. The goals of this project are: 1) identify biotic and abiotic interrelationships within hemlock ecosystems, 2) assist the surrounding communities in employing an effective system for conserving biodiversity in hemlock ecosystems using a geographic information system (GIS), and 3) develop a methodology for permanently monitoring hemlock ecosystems. Study sites are located within 20 hemlock forests in five localities to maximize combinations of age, elevation, slope, and aspect. Surveys were conducted at these sites using the North Carolina Vegetation Survey methodology, with the addition of woody seedling surveys, arthropod inventories, and age class analysis. The results indicate there were unique plant assemblages within these hemlock ecosystems. Preliminary data suggests that high HWA infestation levels within these ecosystems occurred in areas closest to roads and streams. Plots at the highest elevations had lower HWA infestation levels than those at lower elevations. Results from this study can be used as a reference by researchers, land managers, and conservationists to prioritize Southern Appalachian hemlock forests for conservation and/or restoration.

KEYWORDS

Tsuga, hemlock, adelgid, ecosystem, Southern Appalachians.

INTRODUCTION

The diversity of plant assemblages in the Southern Appalachians is strongly influenced by elevation and moisture (Braun 1950, Whittaker 1956). Within the Southern Appalachians, the hemlock ecosystems of northwestern North Carolina are exceptional because they provide unique niches for a diversity of flora and fauna. Only a few scattered fragments of undisturbed or old-growth ecosystems still remain in the region. Grandfather Mountain, Linville, Lutherock, and northern Watauga County in North Carolina harbor excellent examples of these ecosystems. If not suppressed, the hemlock woolly adelgid (HWA), *Adelges*

tsugae Annand may facilitate the destruction of these native hemlocks. In order to facilitate the present management techniques and restoration efforts we must understand the composition and design of the hemlock ecosystems in northwestern North Carolina in part by asking these questions: 1) What are some ecological indicators that differ between healthy and declining hemlock ecosystems? 2) How do species richness, basal area, importance values, and soils vary within or among these ecosystems? 3) Are roads and streams the important vectors of HWA transmission? 4) What elevations are HWA infestation levels highest? The specific goals of this project are to: 1) identify biotic and abiotic interrelationships by gathering baseline ecological information within hemlock ecosystems of northwestern North Carolina, 2) Assist surrounding communities in employing an effective system for conserving biodiversity in hemlock ecosystems using a geographic information system (GIS), and 3) Develop a methodology for permanently monitoring hemlock ecosystems.

MATERIALS AND METHODS

This study identified, classified, and mapped the patterns of infestation and mortality of hemlocks due to HWA. This project collected data both in the field and in the laboratory regarding the vegetation structure of hemlock ecosystems. A total of 16 permanent plots at five sites have been analyzed. Surveys on four additional plots will be performed by spring 2005. All sites were located on private lands within Avery and Watauga counties, North Carolina. The five sites surveyed were Linville (LINN), Grandfather Mountain (GFM), Appalachian State University Tater Hill Bog (THB), Appalachian State University Gilley Property (GP), and Lutherock Camp (LR). Plot site selection and data collection followed the North Carolina Vegetation Survey Protocol (Peet et al. 1998) (Figure 1). Individual hemlock trees within permanent plots were monitored for HWA, measured diameter at breast height (DBH) in centimeters, estimated height, and estimated amount of defoliation (Mausel 2003). The composition of hemlock forests was compared to the composition of similar forests in the Southern Appalachians. Infestation was monitored by sampling hemlock limbs in fall of 2004. Sampling will occur again in 2005. Plot environmental variables were derived from 10-meter resolution digital elevation model (DEM) using ArcGIS 9.0 software. We analyzed streams and roads at a scale of 1:250,000 using data from the Southern Appalachian Assessment (SAA) GIS database (Herman 1996). The landscape survey of plots was conducted with rigorous field work, GIS, and remote sensing techniques.

RESULTS

A total of 16 hemlock plots were surveyed (Table 1). Hemlock woolly adelgid (HWA) occurred in 81% of the plots. Infestation levels ranged from 0 (no infestation) to 4 (heavy infestation). The average infestation level for all plots surveyed was 1.94 (light infestation). The elevation of plots ranged from 996 m at GP3 to 1348 m at GFM3. Average elevation was 1175 m. Slope of the plots ranged from 1° at GP4 to 34° in LINN1. Average slope was 17°. The minimum distance to a stream was 73 m at LINN1. The maximum distance to a stream was 1348 m at GFM3. Average distance to a stream was 466 m. The minimum distance to a road was 74 m at LINN1. The maximum distance to a road was 1177 m at GFM3. The

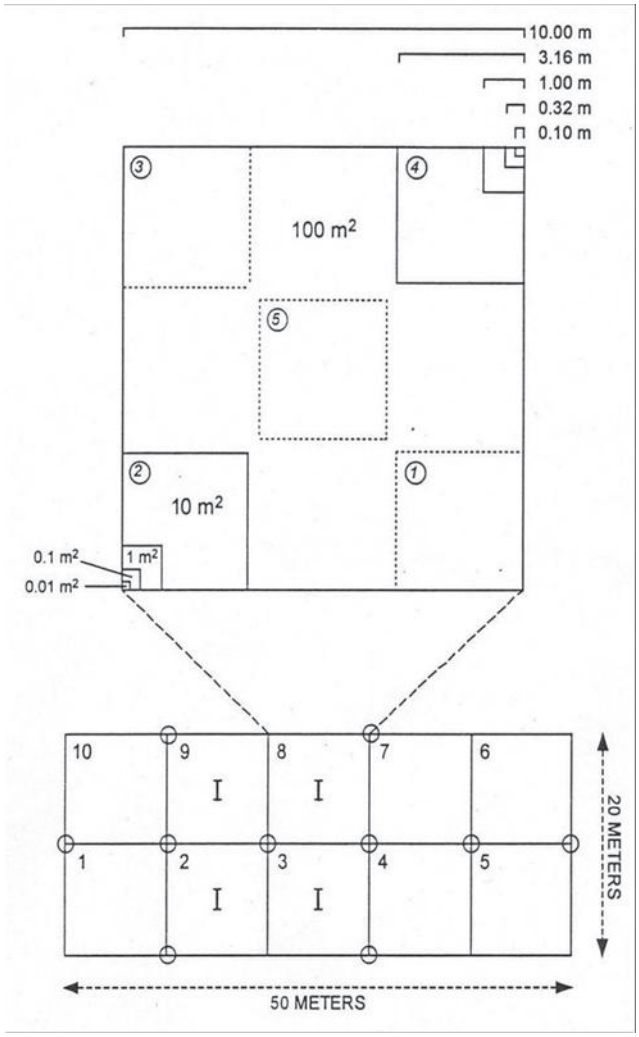

Figure 1. Hemlock permanent plots. Plots were surveyed at the canopy, subcanopy, and herbaceous levels using North Carolina Vegetation Survey methodology (Peet et al. 1998). Layout of 0.1 ha hemlock permanent plot. Each plot was 50 m x 20 m and consists of 10 focus modules. Modules 2,3,8,9 were focal modules with nested quadrats in the corners.

Table 1. Summary of ecosystem characteristics for hemlock ecosystems of Linville (LINN), Grandfather Mountain (GFM), ASU Gilley Research Station (GP), and ASU Tater Hill Bog (THB) within Avery and Watauga counties, North Carolina.

Plot	Aspect	Elevation (m)	Slope (°)	Distance to stream (m)	Distance to road (m)	Infestation Level
LINN1	W	1131	34	73	74	4
LINN2	NW	1111	8	265	505	2
LINN3	W	1100	17	275	134	1
LINN4	E	1179	25	310	261	4
LINN5	NW	1229	21	670	771	3
GFM1	SW	1333	14	1193	171	1
GFM2	S	1347	6	1474	148	0
GFM3	N	1348	31	153	1177	2
GFM4	NE	1234	11	362	412	1
GFM5	N	1220	29	544	120	4
GP1	SE	1038	7	447	456	2
GP2	S	1017	29	380	429	2
GP3	NE	996	20	532	567	1
GP4	NE	1001	1	598	485	4
THB1	N	1259	11	88	441	0
THB2	NW	1252	3	87	586	0
Average		1175	17	466	421	1.94

average distance to a road was 421 m. Preliminary data suggested that high HWA infestation levels occurred in areas closest to roads and streams. Plots surveyed at the highest elevations had lower HWA infestation levels than those at lower elevations.

IMPLICATIONS OF THIS STUDY

Hemlock woolly adelgid (HWA) is responsible for hemlock decline in northwestern North Carolina. Suppression of HWA and the future of hemlock ecosystems in the Southern Appalachians will depend on a mixture of biological control agents and efficient use of insecticides. Early detection and unfavorable climate may assist the suppression of HWA populations in the near future. This study will provide better estimates of habitats vulnerable to HWA infestation and may contribute to protection of this unique ecosystem. Our baseline data can potentially facilitate identification of areas conducive for the release of predator beetles on HWA. The examination of hemlock ecosystems and HWA may furthermore prove constructive for monitoring potential biological impacts of hemlock decline on mammal, avian, amphibian, aquatic, and herbaceous plant communities throughout the Southern Appalachians.

Regardless of our ability to reconstruct forest composition through modeling, there is no substitute for long-term forest data. Data will be used in an effort to facilitate future ecosystem restoration, land and pest management decisions, and to efficiently conserve hemlock forests that are aesthetically and ecologically the most important to the region.

ACKNOWLEDGEMENTS

Appalachian State University Department of Biology and Graduate School, Blue Ridge Resource, Conservation, and Development, Mr. and Mrs. James R. Graham.

REFERENCES

Braun, E.L. 1950. Deciduous forests of eastern North America. Haefner Publishing Co. New York, New York. 326 p.

Mausel, D.L. 2003. Protocol for choosing *Laricobius nigrinus* release trees and data collection. Unpublished protocol. Virginia Polytechnic Institute and State University. 3 p.

Herman, K.A. (ed.). 1996. Southern Appalachian Assessment (SAA) GIS database. Streams, 1: 250,000; Roads, 1: 250,000. SAMAB. Norris, Tennessee.

Peet, R.K. T.R. Wentworth, and P.S. Smith. 1998. A flexible multipurpose method for recording vegetation composition and structure. *Castanea* 63(3):262-274.

Whittaker, R.H. 1956. Vegetation of the Great Smoky Mountains. *Ecological Monographs* 26:1-80.