

HARVARD FOREST

SUMMER RESEARCH PROGRAM



*Abstracts from the 12th Annual
Harvard Forest Summer Research Program
19 August 2004*

TWELFTH ANNUAL HARVARD FOREST SUMMER RESEARCH PROGRAM

19 August 2004

HARVARD FOREST FISHER MUSEUM

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*Photography by Jimmy Tran, Marlon Ortega and
Peter Bettmann-Kerson*

INTRODUCTION TO THE HARVARD FOREST

Since its establishment in 1907 the Harvard Forest has served as Harvard University's rural laboratory and classroom for research and education in forest biology and ecology. Through the years researchers have focused on forest management, soils and the development of forest site concepts, the biology of temperate and tropical trees, plant ecology, forest economics, landscape history, conservation biology and ecosystem dynamics. Today, this legacy of activities is continued as faculty, staff, and students seek to understand historical and modern changes in the forests of New England and beyond resulting from human and natural disturbance processes, and to apply this information to the conservation, management, and appreciation of natural ecosystems. This activity is epitomized by the Harvard Forest Long Term Ecological Research (HF LTER) program, which was established in 1988 through funding by the National Science Foundation (NSF).

Physically, the Harvard Forest is comprised of approximately 3000 acres of land in the north-central Massachusetts town of Petersham that include mixed hardwood and conifer forests, ponds, streams, extensive spruce and maple swamps, fields and diverse plantations. Additional land holdings include the 25-acre Pisgah Forest in southwestern New Hampshire (located in the 5000-acre Pisgah State Park), a virgin forest of white pine and hemlock that was 300 years old when it blew down in the 1938 Hurricane; the 100-acre Matthews Plantation in Hamilton, Massachusetts, which is largely comprised of plantations and upland forest; and the 90-acre Tall Timbers Forest in Royalston, Massachusetts. In Petersham a complex of buildings that includes Shaler Hall, the Fisher Museum, and the John G. Torrey Laboratories provide office and experimental space, computer and greenhouse facilities, and lecture room for seminars and conferences. Nine additional houses provide accommodations for staff, visiting researchers, and students. Extensive records, including long-term data sets, historical information, original field notes, maps, photographic collections and electronic data are maintained in the Harvard Forest Archives.

Administratively, the Harvard Forest is a department of the Faculty of Arts and Sciences (FAS) of Harvard University. The Harvard Forest administers the Graduate Program in Forestry that awards a masters degree in Forest Science and faculty at the Forest offer courses through the Department of Organismic and Evolutionary Biology (OEB), the Kennedy School of Government (KSG), and the Freshman Seminar Program. Close association is also maintained with the Department of Earth and Planetary Sciences (EPS), the School of Public Health (SPH), and the Graduate School of Design (GSD) at Harvard and with the Department of Natural Resource Conservation at the University of Massachusetts, the Ecosystems Center of the Marine Biological Laboratory and the Complex Systems Research Center at the University of New Hampshire.

The staff and visiting faculty of approximately fifty work collaboratively to achieve the research, educational and management objectives of the Harvard Forest. A management group meets monthly to discuss current activities and to plan future programs. Regular meetings with the HF LTER science team, weekly research seminars and lab discussions, and an annual ecology symposium provide for an infusion of outside perspectives. The six-member Woods Crew and Facilities Manager undertake forest management and physical plant activities. The Coordinator of the Fisher Museum oversees many educational and outreach programs.

Funding for the Harvard Forest is derived from endowments and FAS, whereas major research support comes primarily from the National Science Foundation, Department of Energy (National Institute for Global Environmental Change), U.S. Department of Agriculture, NASA, Andrew W. Mellon Foundation, and other granting sources. Our summer Program for Student Research is supported by the National Science Foundation, the A. W. Mellon Foundation, and the R. T. Fisher Fund.

Summer Research Program

The Harvard Forest Summer Student Research program, coordinated by Edythe Ellin and assisted by Tracy Rogers and Jimmy Tran, attracted a diverse group of students to receive training in scientific investigations, and experience in long-term ecological research. All students worked closely with researchers while many conducted their own independent studies. The program included weekly seminars from resident and visiting scientists, discussions on career issues in science, and field exercises on soils, land-use history, and plant identification. An annual field trip was made to the Institute of Ecosystem Studies (Millbrook, NY) to participate in a Forum on Careers in Ecology. Students presented major results of their work at the Annual Summer Student Research Symposium in mid August.



John O'Keefe, Edythe Ellin and David Foster.

**12TH ANNUAL HARVARD FOREST
SUMMER RESEARCH PROGRAM SYMPOSIUM
FISHER MUSEUM
19 AUGUST 2004**

	Speaker	Title	Mentor(s)
	Kathleen Donohue	Welcome	
Session I.	Plant Populations (Kristina Stinson, Moderator)		
	Cynthia Chang	Effects of Varying Environmental and Maternal Habitats on the Performance, Demographic Structure, and Population Dynamics of <i>Alliaria petiolata</i>	Kathleen Donohue
	Kelsey Glennon	Investigating Genetic Variation and Natural Selection of <i>Alliaria petiolata</i> in Different Light Environments	Kristina Stinson
	Marlon Ortega	Population Attributes of Garlic Mustard in Three Different Ecoregions in Massachusetts	Kristina Stinson
	Allison Rosenberg	Is Physiology Color Blind? How Color Affects <i>Saracenia purpurea</i>	Aaron Ellison
	Kelley Sullivan	The Seed Bank Spatial Distribution of Hemlock Forests	Audrey Barker Plotkin and Aaron Ellison
	Sarah Truebe	Investigating Links Between Climate and the Mid-Holocene <i>Tsuga</i> Decline	Wyatt Oswald
	Kirsten McKnight	Harvard Forest Plant Inventory in Geographical and Temporal Context	Glenn Motzkin and Jerry Jenkins
Poster	Robert Hanifin	First Year Reproductive Responses of Two Forest Herbs to Experimental Soil Warming	Jacqueline Mohan
	Break		
Session II.	Landscapes Patterned by Land Use (Glenn Motzkin, Moderator)		
	Bethany Burgee and Thaddeus Miller	The Role of Environment and History in Controlling the Abundance and Distribution of Invasive Plants at Highstead Arboretum	Betsy von Holle
	Sara Clark	Ecological Legacies of the Invasion of Black Locust (<i>Robinia pseudoacacia</i>) on Cape Cod National Seashore	Betsy von Holle
	Michelle Ziegler	Oak Regeneration in the Connecticut River Valley and Central Uplands of Massachusetts	Glenn Motzkin and Jerry Jenkins
	Kelly Grogan	An Examination of the Relationship Between Parcelization and Timber Harvest	Dave Kittredge
	Daniel Gonzalez-Kreisberg	Effects of Two Large-Scale Overstory Disturbances on Understory Species Composition and Ground Cover at Harvard Forest	Steve Wofsy
	Peter Bettman-Kerson	Natural Mystery: Uncovering Historic Land Use at the Simes Tract	Audrey Barker Plotkin and Aaron Ellison

Lunch

Session III. Ecosystem Physiology: Nutrient, Water and Energy Flows

(Betsy Colburn and Bill Sobczak, Moderators)

Kathryn McKain	Carbon Accumulation at the Harvard Forest: a Comparison of Measurement Methods and an Investigation of Temporal and Spatial Trends	Steve Wofsy
Rose Phillips	Reconciling Soil Respiration Estimates with Eddy Covariance Estimates of Ecosystem Respiration	Eric Davidson and Kathleen Savage
Chrisopher Miwa	Coarse Woody Debris: The Effects of Moisture and Species on CO ₂ Efflux	Julian Hadley
Chelsea Kammerer-Burnham	Ants Marching: The Effects of <i>Aphaenogaster rudis</i> on Soil Nitrogen Processes	Aaron Ellison
Bridget Collins	Ecology of Subsurface Flow in a New England Headwater Stream	Betsy Colburn and Bill Sobczak
Gavin Ferris	The 'Smorgasbord Effect' – Deciduous Leaves in a Hemlock Stream	Betsy Colburn and Bill Sobczak
Thomas Mulcahy	Whole-Forest Evapotranspiration Rates of a Hemlock and Deciduous Forest Under Similar Climatic Regimes	Julian Hadley
Jennifer Clowers	Effects of Irradiance Threshold and Time of Day on the Interpretation of Sunfleck Regimes	Tim Sipe
Mary Anderson	Creating Allometric Equations for Light Mapping in Mapped Stands	Paul Moorcroft Marco Albani

Break

Session IV. Integrating Ecological Studies: Effects of the Hemlock Woolly Adelgid

(Dave Orwig, Moderator)

Donald Niebyl	The Future of Hemlock: A Three-Year Study on the Movement and Landscape Effects of Hemlock Woolly Adelgid	Dave Orwig
Megan Manner	Applying Graph Theory to the Spread of Hemlock Woolly Adelgid in Central Connecticut & Massachusetts	Dave Orwig
Diana Barszcz	Incidence of Hemlock Woolly Adelgid (<i>Adelges tsugae</i>) at Harvard Forest	Scott Costa and Joe Elkington
Anne-Marie Casper	The Impact of Hemlock Woolly Adelgid, <i>Adelges tsugae</i> , on the morphology of <i>Tsuga canadensis</i>	Missy Holbrook and Kristen Lewis
David Diaz	Ant Diversity in the Wake of the Hemlock Woolly Adelgid	Aaron Ellison
Matthew Waterhouse	The Effects of Hemlock Woolly Adelgid on Ectomycorrhizal Communities of Hemlock Stands	Dave Orwig

BARBEQUE

Creating Allometric Equations for Light Mapping in Mapped Stands

Mary Anderson

The spatial distribution of light environments is a critical component of the forest resource environment that determines stand composition and structure. In this research project, we developed a calibrated canopy light interception model that uses a three-dimensional model of canopy structure derived from individual tree measurements to predict the spatial distribution of light environments within forest stands. Specifically, we collected tree architecture data (diameter at breast height (DBH), tree height, crown depth, and crown diameter) for 266 trees stratified by species and DBH class within 12 mapped plots in the Simes and Tom Swamp tracts of the Harvard Forest. These measurements were then used to develop species-specific allometric equations for tree height, crown depth and crown diameter as functions of DBH. We are currently using these allometric relationships measurements in conjunction with a ray-tracing light interception model to reconstruct the light environment within the mapped stands. These predicted spatial distributions of light will then be tested against field measurements of light availability within the mapped stands obtained from hemispherical photographs.

Incidence of Hemlock Woolly Adelgid at Harvard Forest

Diana Barszcz

The recent infestation of Harvard Forest by hemlock woolly adelgid (*Adelges tsugae*) creates an opportunity to examine the dynamics of range expansion of an invasive species as it enters its potential range limits. Baseline data on the present infestation levels were collected. Maps of hemlock stands on the Harvard Forest land tracts were drawn based on available topographic maps depicting hemlock stands. The stand characteristics, A) hemlock composition > 50% or B) hemlock composition < 50%, and natural boundaries were used to divide each tract into separate plots (total = 21). Each plot was surveyed using a binomial sampling plan, developed from past HF-REU research, that provides a 75% probability of detecting at least one infested tree when $\geq 1.8\%$ trees are infested. One hundred randomly chosen trees per plot, each separated by 25 paces, were sampled by examining two 1-meter sections of lower branch per tree for signs of infestation, as indicated by the presence of white woolly masses at the base of needles. Adelgid were found in all four tracts that have mapped hemlock stands (Prospect Hill, Tom Swamp, Simes, and Slab City) -- three were previously thought uninfested. Infestation levels ranged from 0 to 10% per plot, but locally higher infestations reached 20% of trees infested. The data was incorporated into a GIS layer and manipulated via GEO processing. The compiled data on the incidence of *Adelges tsugae* at Harvard Forest will form a foundation for development of research projects examining the dynamics of the spreading infestation.

Natural Mystery: Uncovering Historic Land Use at the Simes Tract

Peter Bettmann-Kerson

As research on the Simes Tract of the Harvard Forest in Petersham, Massachusetts accelerates, the land use history is critically important to each of the projects at the site, especially the long term Hemlock Woolly Adelgid effect simulation. Determining the history of the site allows for a better understanding of the factors that created the forest we are now working with, allowing for more accurate interpretation of results, with fewer unaccounted-for variables.

Methods of determining the history were broad ranging. Archival and public records searches yielded plot descriptions from previous owners, historic surveys of forest makeup and dates of transition between owners. Very simple dendrochronology yielded the time of reforestation, as well as indications of growth trends throughout the past century. Field checks of these data with GPS allowed me to identify and map faded roadbeds, pasture boundaries, and land use in specific areas. The tract appears to have been intensively used until the 1920s. Elmer Towne and George Ayers (Fig. 1) actively farmed the land, which is also true for their parents, suggesting that the most intensive landscape alterations happened during the nineteenth century. There is no indication that either Olive or William Simes used the land for anything more than recreation, with occasional timber harvest in the case of Olive. As Harvard begins research in the 300 acre Simes tract, this knowledge will prove invaluable as a foundation for further investigation.

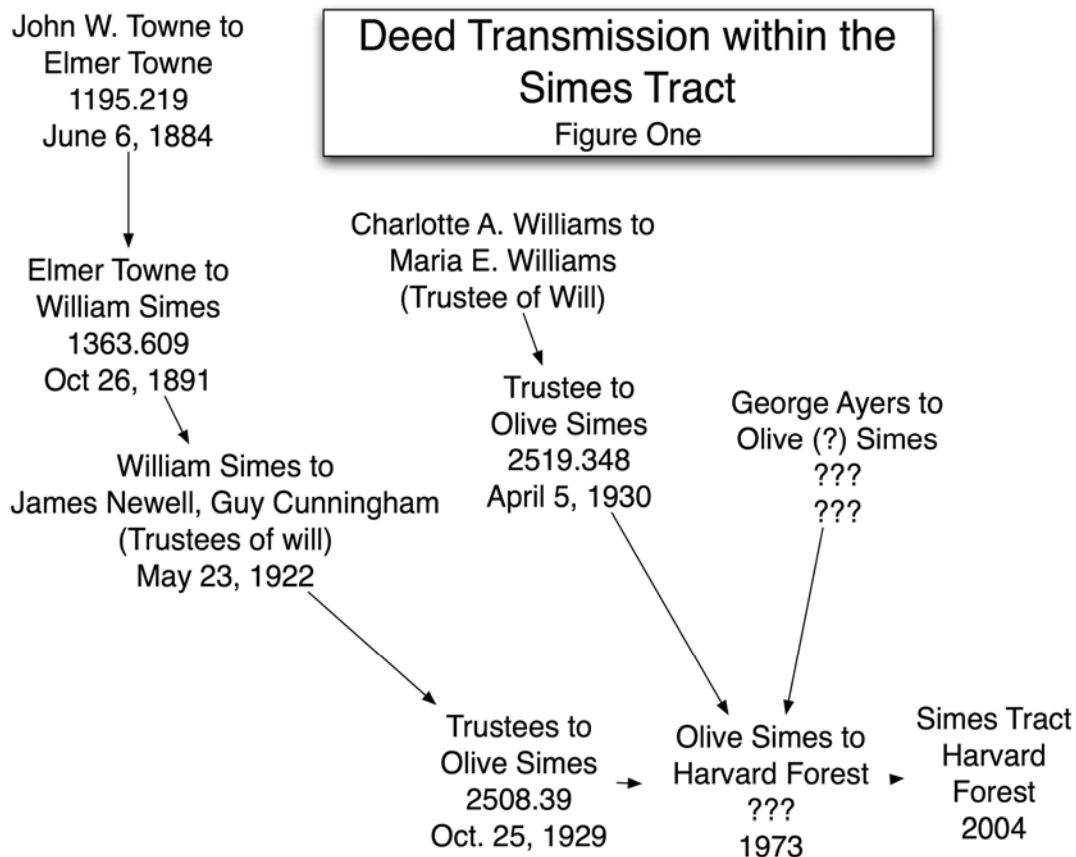


Figure 1. (Bettmen-Kerson)

The Role of Environment and History in Controlling the Abundance and Distribution of Invasive Plants at Highstead Arboretum

Bethany Burgee and Thaddeus Miller

The upland forests of Highstead Arboretum, in Redding, Connecticut, present a landscape in which the climate, wildlife, native and exotic species are identical but the site geology, soils, overstory composition and land use history strongly contrast. The Arboretum is surveyed into a grid system of 219 plots measuring 200x200 feet with the northeast corner of each plot marked with a stake. We surveyed 20 by 20 meter plots at each stake that was under forest canopy. In every plot, we recorded relative abundance of all plants. In addition, we measured tree height and diameter, and took cores from the four largest trees. We also measured slope and aspect, and recorded evidence of disturbance. We determined land-use history by analysis of the soil profile, and collected soil samples for nutrient analysis. Data analysis using two-way analysis of variance shows significantly higher richness of both native and non-native species in formerly plowed plots, compared to unplowed plots. Native and nonnative species richness and abundance values are no different across burned and unburned areas. When formerly plowed plots were removed from the analysis of burned plots, nonnative richness shows no response in burned areas, while native richness was statistically significantly higher (Fig. 1) in burned areas.

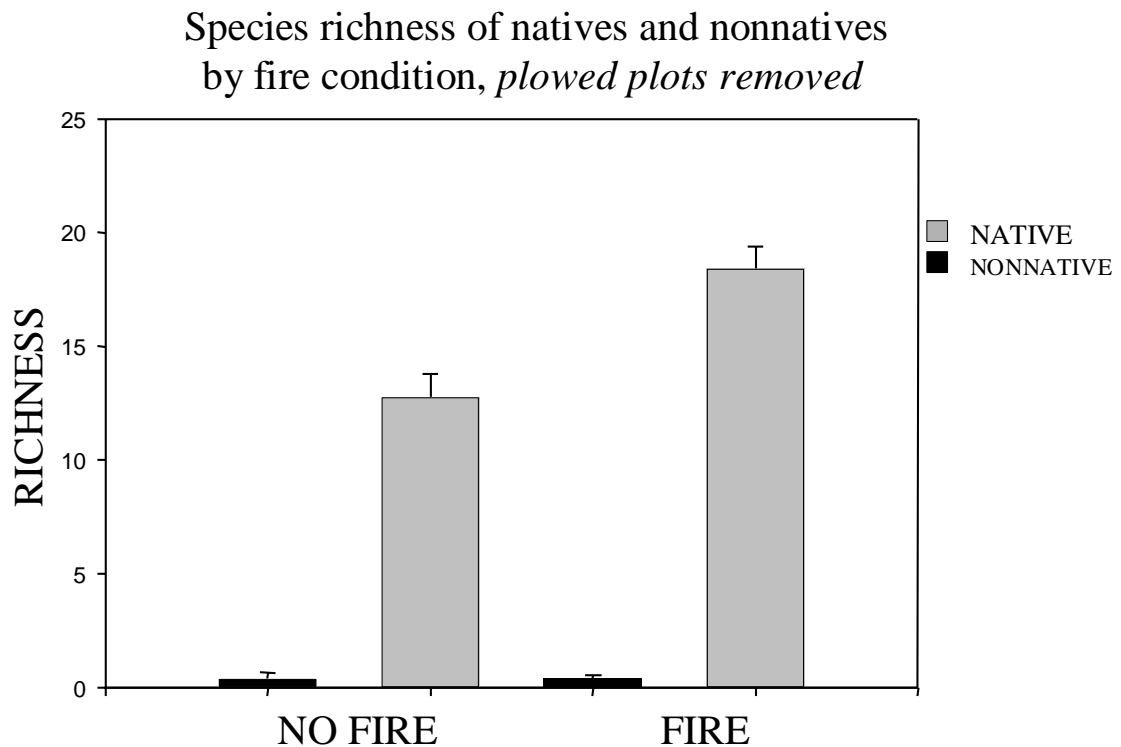


Figure 1. (Burgess & Miller)

The Impact of Hemlock Woolly Adelgid, *Adelges tsugae*, on the Morphology of *Tsuga canadensis*

Anne Marie Casper

The precise mechanism of eastern hemlock (*Tsuga canadensis*) death due to hemlock woolly adelgid (*Adelges tsugae*, HWA) infestation is unknown. The adelgid attacks trees by feeding on stem cells, killing them rapidly. Tree death often happens in four years from initial infestation, and is almost inevitable within ten years. Because adelgids are known to cause nutrient reallocation in their hosts I focused on morphological and carbon to nitrogen ratio (C/N) changes in infested trees. Samples were collected in areas with varying infestation levels (high or low to none) in Connecticut, Massachusetts, New York, and New Hampshire. Needles were separated according to the year in which they were produced (new = this year's growth; old = previous years' growth) to control for age differences. Infested trees had significantly larger needles. There was also a significant difference in leaf water content of infested and uninfested trees; however the water content of new needles decreased with HWA infestation while older needles exhibited the reverse pattern. There were no differences in dry weight or C/N ratio of needles, but the C/N ratio of stem tissues was lower in infested trees. However, because the effects of location and infestation could not be separated in this study, the data on stem thickness are not conclusive. These results demonstrate that HWA infestation influences patterns of growth and allocation in hemlock, including chemical alterations in the adelgids' food source, possibly pointing to reallocation of resources in response to HWA infestation.

Sample type	Mean		t-test p-value
	Infested	Uninfested	
New needle area (cm ²)	0.14 (0.20)	0.090 (0.016)	0.030*
Old needle area (cm ²)	0.17 (0.030)	0.14 (0.063)	0.0035**
New needle % water content	73.7 (3.5)	78.1 (4.5)	0.037*
Old needle % water content	56.5 (8.2)	48.0 (2.5)	0.0070**
New needle dry weight/area (g/cm ²)	0.205 (0.17)	0.130 (0.027)	0.19
Old needle dry weight/area (g/cm ²)	0.406 (0.074)	0.400 (0.023)	0.69
Needle C/N	34.1 (4.0)	33.9 (3.2)	0.99
Stem C/N	60.3 (12.5)	82.0 (13.7)	0.021*

Parentheses show standard deviation. * significant at p< 0.05, ** significant at p<0.01.

Table I (Casper)

Effects of Varying Environmental and Maternal Habitats on the Performance, Demographic Structure, and Population Dynamics of *Alliaria petiolata*

Cynthia Chang

This study investigated the sources and mechanisms for population movement and sustainability in the invasive species *Alliaria petiolata* (garlic mustard). Seeds from sun, intermediate, and forest were reciprocally transplanted to each respective habitat in three replicate plots. Analysis of variance demonstrated that both maternal habitat and treatment habitat influence germination rate ($p=0.0482$ and $p<0.0001$) and number of leaves produced ($p=0.0223$ and $p<0.001$). However, survival rate is more dependent on the seed's maternal habitat ($p=0.0360$) while height is more dependent on treatment habitat ($p<0.001$). Phenotypic traits such as height and leaf number increased in the sun. Germination rate across all three sites is similar in sun and forest habitats but much more varied and depends more on the plant's maternal habitat in intermediate habitats; however, seeds from the sun survive just as well as seeds from the forest in forest conditions, while seeds from the sun survive better than seeds from the forest in sun conditions (Figs. 1a & b). A demographic population matrix model was created using census data from nearby sites in each habitat. Overall population growth rate was found to be highest in the sun and lowest in the intermediate habitat. Seeds from the forest were found to have the lowest population growth rate compared to seeds from the sun and intermediate populations when grown in the forest (Fig. 2). These results indicate that forest populations could either be self-sustaining, or sustained by seeds from the sun population. However, a higher population growth rate and seed production by sun populations is likely to contribute more to forest invasion than the lower population growth rate and seed production by forest populations.

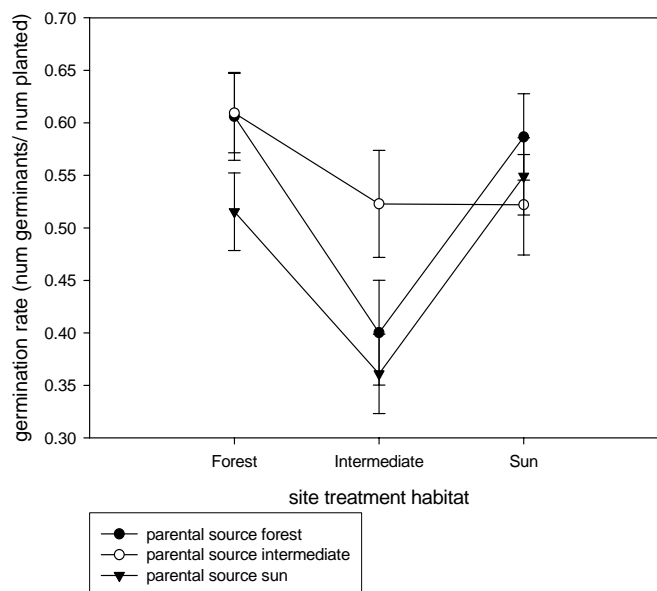


Figure 1a. The average germination rate of garlic mustard.
(Chang)

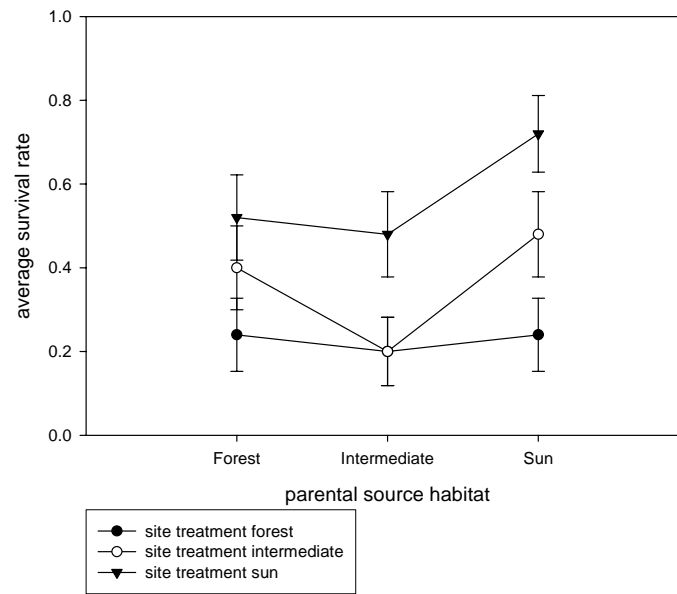


Figure 1b. Survival rate across all three sites.
(Chang)

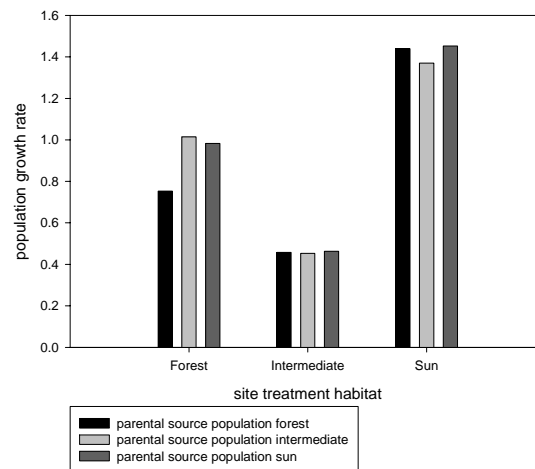


Figure 2. Population growth rate of garlic mustard (2004).
(Chang)

Ecological Legacies of the Invasion of Black Locust (*Robinia pseudoacacia*) on Cape Cod National Seashore

Sara Clark

The non-native, nitrogen fixing tree species *Robinia pseudoacacia* was introduced to Cape Cod National Seashore in the mid 18th and early 19th centuries for human uses. To augment research on stands completed by Betsy Von Holle and her team last summer we sought to answer two questions: do legacy stands (where *R. pseudoacacia* has senesced) remain islands of invasion, with higher non-native species richness and cover, and how does the nitrogen cycle vary between *R. pseudoacacia*, native and legacy stands. To understand the first question, 20mx20m legacy stands were surveyed using the standard Harvard Forest method. Native and non-native species' richness and cover were compared to data gathered last summer in the *R. pseudoacacia* and paired native stands. To help explain the second question, 10 soil samples were collected in each *R. pseudoacacia*, native, and legacy plots, and brought to the lab to perform a KCL extraction of ammonium and nitrate. Ten bags of soil at each plot were also buried for 28-30 days and then analyzed in order to understand nitrification rates. An analysis of variance was performed on the surveying data, and general trends showed that the richness of both native and non-native species is returning to a more "native-like" state in the legacy plots (as shown in Fig. 1). The preliminary results of the nitrate analysis provided a likely reason: the nitrate levels in legacy plots were also at an intermediate level between high levels in *R. pseudoacacia* stands and low levels in the paired native stands. The implications for management are promising, as it appears that following natural senescence of *R. pseudoacacia*, the ecosystem gradually begins to return to a native state without active management.

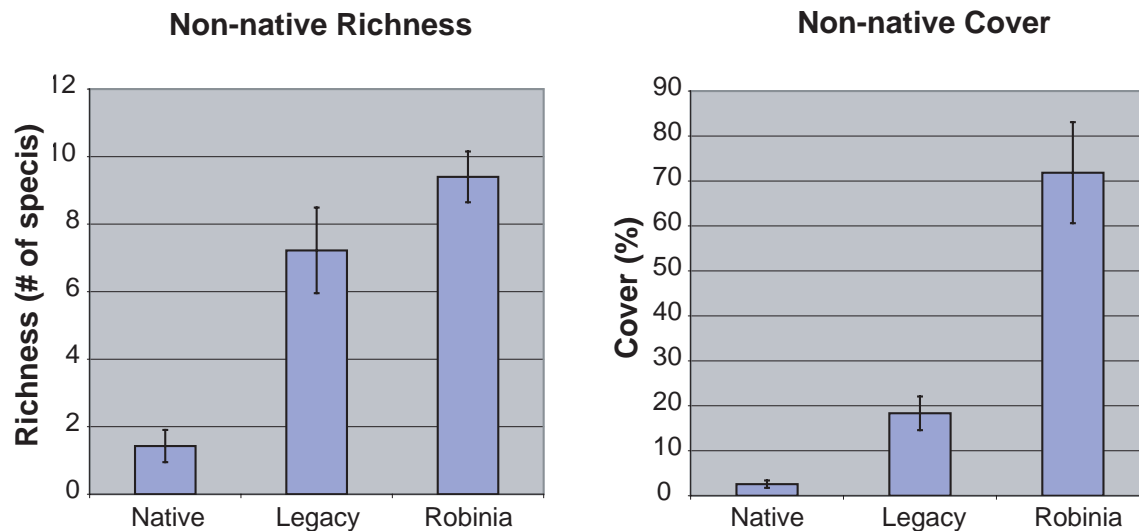


Figure 1. (Clark)

Effects of Irradiance Threshold and Time of Day on the Interpretation of Sunfleck Regimes

Jennifer Clowers

Light availability in the forest understory varies considerably in space and time, with numerous consequences for forest ecology. Although the importance of sunflecks for understory plant photosynthesis and growth have been well documented, there has been little work on how fleck threshold definition and time of day may affect the interpretation of sunfleck regimes. We investigated these relationships for one clear day in July 2003 at a Prospect Hill permanent woodlot site. Photosynthetic photon flux (PPF) (30 cm) was measured simultaneously every 6 seconds over a 14-hour interval (6 am to 8 pm) at 23 sample points spaced regularly across a 30 x 50 m grid. Sunfleck regimes were analyzed hourly, for each of 9 thresholds ranging from 20 to 100 $\mu\text{mol m}^{-2} \text{s}^{-1}$, to generate the following variables: mean number of flecks, mean fleck PPF, mean fleck duration, and mean fleck fluence (= duration x mean PPF). As threshold decreased, mean number of flecks increased and mean fleck PPF decreased, as predicted (Fig. 1). Mean fleck duration was very high for thresholds of 20 (42 min) and 30 (3 min) near midday, but did not vary consistently among thresholds at any other time of day. Mean fleck fluence increased modestly with threshold across the day. Threshold had only minor impacts on total daily fleck duration, except around solar noon (threshold 20 = 11 hours and thresholds ≥ 40 ranged from 6.4 to 15 min). Overall, the impact of threshold is non-linear (stronger impact at lower PPF cutoffs) and is more pronounced near solar noon than other times of day. These results have important implications not only for interpreting forest irradiance regimes but also for using dynamic photosynthetic models that require a user-defined sunfleck threshold for triggering biochemical induction processes and predicting daily carbon gain accurately.

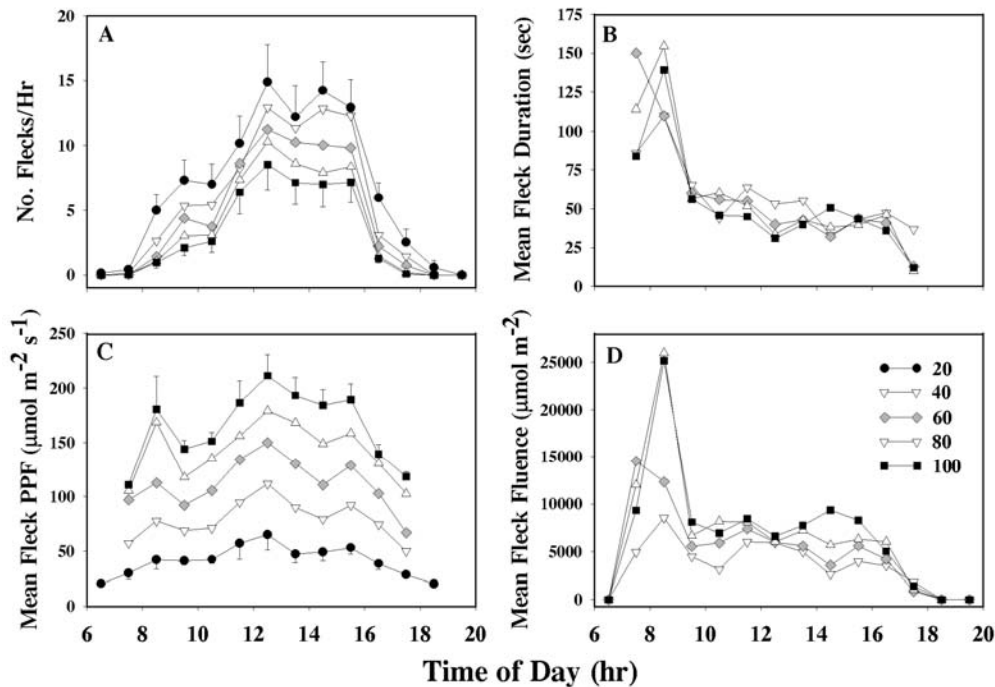


Figure 1. Effects of sunfleck irradiance threshold (20-100 $\mu\text{mol m}^{-2} \text{s}^{-1}$) and time of day on sunfleck regimes in a Prospect Hill permanent woodlot site: (A) fleck frequency, (B) mean fleck duration, (C) mean fleck photosynthetic photon flux, and (D) mean fleck fluence, the product of fleck duration and mean fleck PPF. PPF was sampled at 30 cm every 6 seconds during 6 a.m. to 8 p.m. on one clear day in July at 23 locations regularly spaced across a 30 m x 50 m grid. Representative error bars (1 s.e.) are shown for PPF thresholds of 20 and 100 in (A) and (B). (Clowers)

Ecology of Subsurface Flow in a New England Headwater Stream

Bridget Collins

New England headwater streams are understood to have highly diverse invertebrate communities and to be energetically dependent upon terrestrial organic matter inputs. Headwater streams with subsurface flow (SSF) however, have received little attention and are thus poorly understood. I studied a 400 m reach with considerable SSF in Prospect Hill A, a first-order hemlock dominated stream at the Harvard Forest, by installing 16 PVC wells in 4 transects. Wells were used to sample water temperature, specific conductivity, pH, and dissolved oxygen (DO) in regions of SSF. Three pits were dug near the well transects for sampling macroinvertebrates. In addition, I measured water chemistry variables and collected macroinvertebrate samples in triplicate from sites of surface flow (SF) upstream and downstream from the wells.

Flow through the subsurface sections was found in isolated chutes and was at or near saturation for DO. Water temperature, pH and conductivity remained relatively constant along the entire reach. The SSF macroinvertebrate samples had the lowest mean abundance of individuals but had the highest equitability index (E_H). Relative abundances of functional feeding groups differed along the reach, where shredders were virtually absent from upstream SF and SSF sites, filtering collectors dominated in SSF, and all sites had high predator and low scraper abundances.

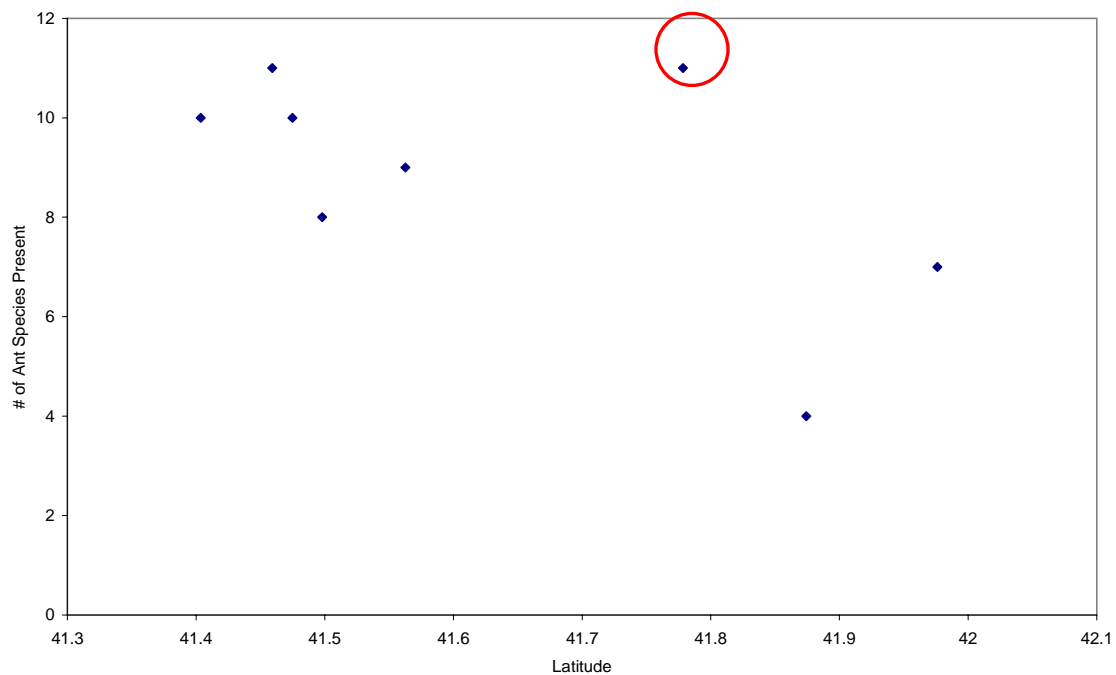
This study represents baseline data for documenting stream ecosystem response to hemlock mortality. Additionally, these findings will help contribute to an emerging conceptual model regarding the structure and function of intermittent headwater streams, which may in turn generate better legal protection for these systems.

Ant Diversity in the Wake of the Hemlock Woolly Adelgid

David Diaz

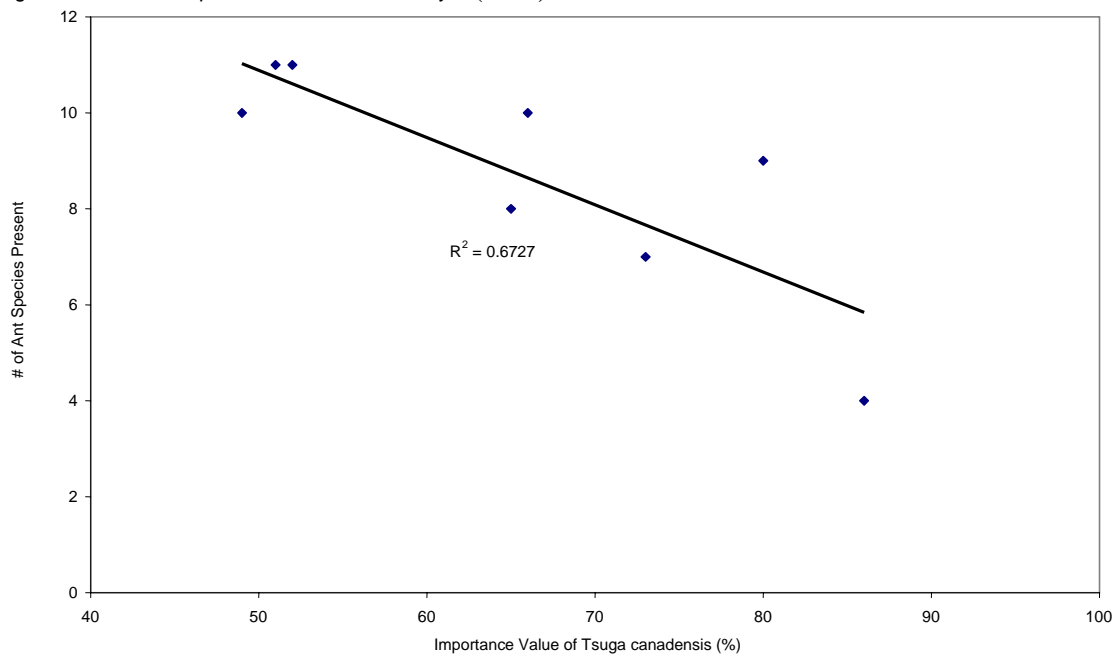
Hemlock Woolly Adelgid (HWA) invasion of New England has initiated large-scale forest succession by provoking decline of the eastern hemlock. Progressing throughout the natural range of the hemlock, changes in forest composition may alter both local and regional plant and animal assemblages. With such a pervasive role in hemlock environments of New England, how HWA will affect local and regional biodiversity in the wake of hemlock decline is still largely unknown and increasingly pertinent. Using ants as a biodiversity measure, we catalogued diversity at 8 sites throughout Connecticut with varying hemlock decline. We collected ants using pitfall traps, baits, and litter and hand sampling. We also measured and characterized the vegetation of each plot. Collecting 18 total species with a maximum of 11 and minimum of 4 per plot, we discovered human and HWA disturbances of hemlock overshadow the role of latitude-related factors. While ant diversity generally increases with lower latitudes, the intervention of landowners in salvage logging one plot demonstrates (Fig. 1) that biodiversity is dependent upon human activities relating to HWA as much as HWA invasion itself. Ant diversity was significantly correlated to hemlock importance value (IV) in each stand, with higher diversity in plots with lower hemlock IV (Fig. 2). These results highlight HWA's potential to significantly alter the biodiversity of the forests, but that it is not the singular force behind biodiversity change related to hemlock decline. Intervention may produce more dramatic and punctuated changes in hemlock IV, consequently altering local biodiversity much more rapidly than could natural progression of HWA-induced hemlock decline.

Figure 1: Ant Diversity with Latitude (Diaz)



The circled point highlights how the salvage logging of hemlock stands can preempt general latitudinal trends with ant diversity. Excluding this point, there is a correlation with $R^2=0.6618$.

Figure 2: Hemlock Importance and Ant Diversity (Diaz)



The ‘Smorgasbord Effect’ – Deciduous Leaves in a Hemlock Stream

Gavin Ferris

Headwater stream ecosystems rely heavily on external input from riparian trees because a lack of sunlight prevents them from generating their own plant matter. Because streams running through hemlock forests receive different types and amounts of leaves than those in deciduous forests, they have very different macroinvertebrate communities and food web structures. To investigate the change in macroinvertebrate assemblage and food web structure that may occur after hemlock Woolly Adelgid invasion, I made leaf packs containing ten grams each of hemlock, black birch, maple, and oak leaves. Three macroinvertebrate samples each were taken from two streams located in Slab City and Erving State Forest prior to installing these leaf packs. Upon collection of the leaf packs, I also collected *in situ* debris packs that formed naturally from the riparian debris found in the stream. Sorting the macroinvertebrates found in these samples allowed me to analyze the proportions of functional feeding groups by abundance as well as overall macroinvertebrate abundance. Differences between the initial stream samples, *in situ* samples, and leaf pack samples suggest that aquatic macroinvertebrate communities may be drastically affected by HWA invasion due to the change in leaf litter that will occur as a result of forest succession. Further and more comprehensive research in this area is greatly needed.

Investigating Genetic Variation and Natural Selection of *Alliaria petiolata* in Different Light Environments

Kelsey Glennon

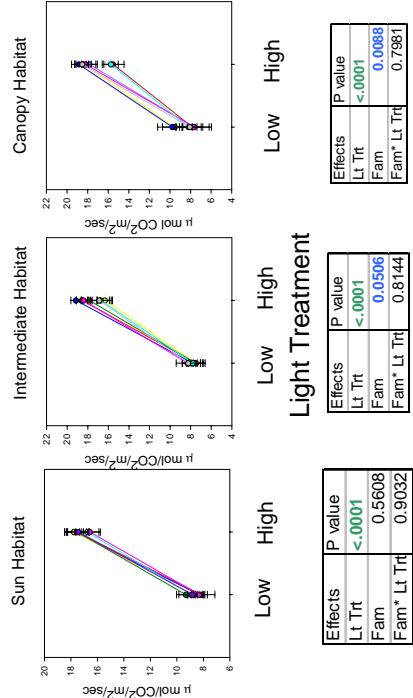
Light environment seems to play a role in how successful the exotic plant, *Alliaria petiolata*, is at becoming dominant in forest edge and understory habitats. My research focused on whether genotype and/or light environment controlled the photosynthetic capacity, leaf weight and estimated fitness of garlic mustard from three different habitats. I also looked for evidence that natural selection in shade habitats contributes to invasion in this species.

We covered four tents with high or low-density shade cloth to represent high and low light environments. We then planted seeds from seven maternal genotypes, from each of the three different habitats (Sun, Intermediate and Forest) into each light treatment. We measured maximum photosynthetic capacity (P_{max}) and biomass allocation to leaves and reproduction over a two-year period. Using analysis of variance, we found strong effects of light on P_{max} and leaf weight indicating plasticity in these traits. We also found evidence for significant genetic variation in P_{max} in plants from Intermediate and Forest habitats and in leaf weight from Sun and Intermediate habitats. Fitness was similar in both light treatments for plants from all habitats (Fig.1).

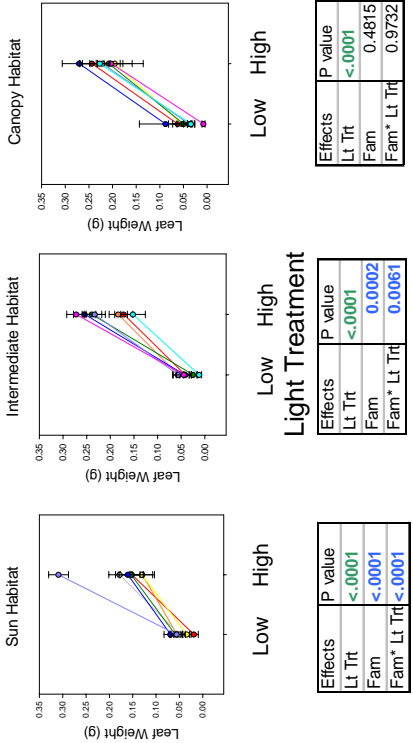
Selection analysis suggested that there is selection for heavier leaves and higher photosynthetic capacity in lower light treatments, while there is selection for lighter leaves and lower photosynthetic capacity in high light treatments. Direct selection indicates that photosynthetic capacity selection significantly influences selection for leaf weight in the low light treatments. Therefore, both phenotypic plasticity and genetic variation appear to contribute to invasive potential in this species.

Figure 1. (Glennon)

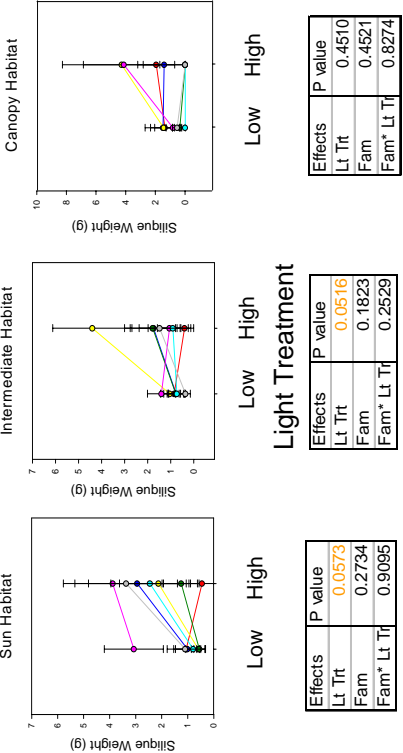
Variation in Photosynthesis between Habitats



Variation in Leaf Weight Between Habitats



Variation in Fitness between Habitats



Effects of Two Large-Scale Overstory Disturbances on Understory Species Composition and Ground Cover at Harvard Forest

Daniel Gonzalez-Kreisberg

This study examined the effects of a selective logging on understory and ground cover at the Harvard Forest, and compared the effects of this disturbance to those of a simulated hurricane, with the goal of identifying possible influence of large scale disturbances on overall forest carbon balance. An introductory ground cover and understory survey was conducted comparing plots that had been selectively logged in 2001 resulting in a 26% reduction of overstory biomass and plots which had last been disturbed in 1938 and which therefore represent local mature growth forest. A statistical comparison of the logged and unlogged plots showed that understory stem density and total basal area significantly increased following the harvest. It also indicated that, while most ground cover species and species classes were unaffected by selective logging, False Solomon's Seal (*Smilacina racemosa*) and fern covered less ground area and Star Flower (*Trientalis borealis*) and tree seedlings covered more ground area in the plots that had been selectively logged. The ground cover results were then compared to results of the 'Simulated Hurricane Experiment – Vegetation Response' survey,* which resulted in damage to 65% of overstory individuals. Significantly, there was no reduction in fern presence after the simulated hurricane. Previous studies have shown that a reduction in fern population can permanently alter overstory species composition. Thus a forest recovered from a selective harvest disturbance may have a significantly different overstory composition than a forest recovered from a natural hurricane, potentially affecting the overall carbon balance of a forest.

*(Harvard Forest online dataset HF002, 1990-present)

An Examination of the Relationship between Parcelization and Timber Harvest

Kelly Grogan

While forest covers 62% of Massachusetts, less than 1% of this forest is harvested each year. This project examined how parcelization relates to the state's low rate of timber harvest. To determine this relationship, we obtained data from forty-six sample towns in Massachusetts. This data included the number of parcels in the town, the lot size and land value of each parcel, population densities, various land use indicators, and a range of other socioeconomic variables. From logging plans collected and compiled from 1984 through 2003, we generated 3 harvest variables for each sample town at the municipal, state, and private level: % of forest area harvested, volume of harvest per hectare of forest, and number of harvest operations per hectare of forest. We were most interested in private timber harvest since 78% of all forest is privately owned and 64% of harvest is done on private forests.

Plotting the parcelization and harvest variables and estimating non-linear models indicates that as the number of parcels per hectare increases, the amount of timber harvest decreases. Private timber harvest is unlikely in towns with more than 3 parcels per hectare. However, private harvest is more closely related to the percent of a town that is forested. If a town is less than 40.9% forested, the probability of timber harvest is low.

Massachusetts imports almost 95% of its timber products, often from sources with less stringent logging regulations. Thus, determining the thresholds beyond which harvest no longer occurs can help inform policies that could encourage increased harvesting and allow Massachusetts to meet more of its timber demand from within the state.

First-Year Reproductive Responses of Two Herbaceous Species to Experimental Soil Warming at Harvard Forest

Robert Hanifin

Global temperatures are rising and an increase of up to 5.5 °C by the end of this century is predicted for the New England region. Increased air and soil temperatures may alter growth and reproductive patterns of forest plant species. Two understory herbaceous taxa common in northeastern forests are *Trientalis borealis* Raf. and *Maianthemum canadense* Desf. We sampled both species at the Barre Woods and Prospect Hill experimental soil-warming sites in Harvard Forest to determine if one year of 5 °C soil temperature increase had caused any alteration in reproductive output. Longer stems of both species were more likely to be reproductive than shorter stems, but *Trientalis* stems >10 cm long were less likely to be sexually reproductive in the heated plot (Fig. 1). *Trientalis* density was higher in the heated treatment in both 2003 (the onset of heating) and 2004 (1-year post-treatment), but increased more in the heated treatment versus the control from 2003-2004. These data suggest an enhanced shift in reproductive effort away from sexual reproduction towards vegetative spread for *Trientalis*. In 2004 a smaller percentage of *Maianthemum* stems were sexually reproductive in the heated versus the control treatment; this trend was also observed in the older Prospect Hill site. An apparent decrease in *Maianthemum* density at Prospect Hill may further indicate lowered reproductive effort at elevated soil temperatures. Overall, soil warming diminished the sexual reproduction of *Maianthemum* and the largest *Trientalis* plants. Additional sampling in subsequent years will highlight the potential long-term nature of these responses.

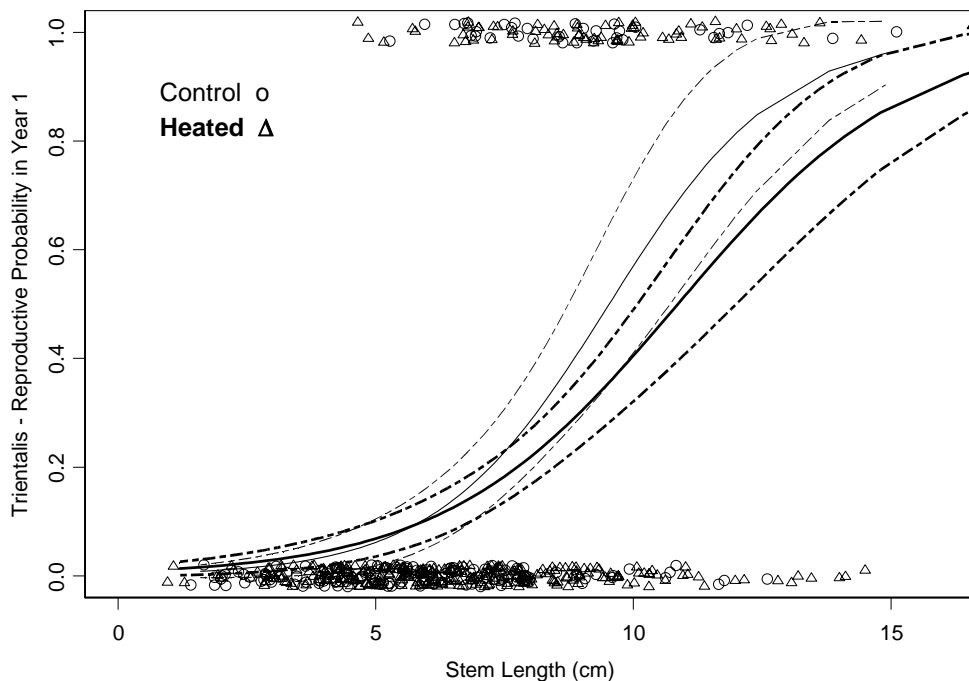


Figure 1. When stem length is >10 cm, *T. borealis* exhibits a decreased probability of sexual reproduction in the heated treatment (bold triangles and lines) relative to the control at Barre Woods. Points represent individual stems. Solid lines represent logistic regression fits; dashed lines represent 95% confidence intervals. Probability data are binary with zero equaling no reproduction. (Hanifin)

Ants Marching: The Effect of *Aphaenogaster rudis* on Soil Nitrogen Processes

Chelsea Kammerer-Burnham

Aphaenogaster rudis is the most abundant and widespread species of ant we have seen this summer in ant diversity sampling. It is a generalist species, establishing nests where other, more specific ants, will not. One such habitat is the soil cores used by Dr. David Orwig's Hemlock Woolly Adelgid (HWA) research team to study the effects of hemlock woolly adelgid infestation on nitrogen cycling in hemlock stands. Little is known about the specific effects ants have on soil, especially in temperate environments. One potential effect is an increase in mineralization due to a higher occurrence of ammonifying bacteria, specifically in the nests of *A. rudis*. To explore this interaction I took fourteen ant-infested soil cores from Dr. Orwig's HWA sites in southern Connecticut and looked at the amount of nitrogen that had been ammonified in a six week period. I compared these amounts to those of soil cores from last summer that had not been infested with ants. Using a T-test, I found that there was not a statistical difference ($t = 0.0074$, $p\text{-value} = 0.9942$) between the amount of nitrogen ammonified in soil cores with ants and soil cores without ants. This could be due to the short amount of time the ants were in the cores (less than six weeks) or the difference in methods of obtaining soil ammonium concentrations. Dr. Orwig's team uses an auto-analyzer, whereas I used a spectrophotometer. More controlled experiments are necessary to determine whether *A. rudis* has an effect on mineralization.

Applying Graph Theory to the Spread of Hemlock Woolly Adelgid in Central Massachusetts and Connecticut

Megan Manner

Graph theory is commonly used in various disciplines where one is concerned with networking flows. Though long used as a framework for food web ecology, graph theory's wide range of potential ecological applications is only beginning to be explored, particularly in applications dealing with metapopulations and conservation biology. A graphical approach defines data as a set of nodes, which may be habitat patches connected to some extent by edges. An edge implies that there is an ecological flux between nodes, and may be defined by minimum cumulative resistance values, which take into account distances, probabilities, and landscape features.

The current data set includes a map of hemlock stands across central Connecticut and Massachusetts. Since 1997, Dr. Dave Orwig has been collecting data on environmental characteristics and hemlock woolly adelgid (HWA) infestation levels for a subset of 114 stands in Connecticut and 123 stands in Massachusetts. Using graph theory and GIS technology, I plan to use this data to examine the effects of patch size, distance between patches, degree of landscape heterogeneity, and HWA density on hemlock mortality and HWA spread, and create minimal cumulative resistance values, which estimate the relative resistance to HWA dispersal of various hemlock stands. When I am finished with this analysis next year, hopefully we will have a clearer picture as to how HWA is spreading across New England, and, at the very least, have a great deal of information on the landscape level characteristics of New England's hemlock stands.

Carbon Accumulation at the Harvard Forest: A Comparison of Measurement Methods and an Investigation of Spatial and Temporal Trends

Kathryn McKain

Although an abundance of data about local forest carbon cycling dynamics exists from the Prospect Hill tract, the relevance of this data depends on our ability to scale individual sites to the larger forested region. From 2000-2002, the Big Foot Project monitored an array of ecological measurement plots centered on the EMS tower over a 25 km² area with the purpose of linking ground-based measurements to Landsat ETM+ data and validating MODLand science products. The continued monitoring of the Big Foot plots by the Wofsy Research Group will provide a valuable opportunity to increase the scale of the Wofsy area of study. However, an initial comparison of the Big Foot and Wofsy plots revealed that while the Wofsy plots yielded an average of 108 ± 33 MgC/ha as of 2002, the Big Foot plots yielded an average of 73 ± 26 MgC/ha. This discrepancy could have resulted from the different measurement methods employed, or may reflect true differences in forest composition. Whereas the Wofsy group uses fixed-radius plots, the Big Foot project used a prism method and variable-radius plots. A resurvey of the Big Foot plots using both fixed and variable radius plots has allowed for an additional comparison of the two methods. Preliminary results reveal that both methods yield equivalent biomass figures, numbers which also correspond with that calculated from the Prospect Hill tract, but not with that of the original Big Foot survey. Further investigation of the 2004 Big Foot data, including the incorporation of mortality and recruitment, will allow for the better use of existing data and thus for regional extrapolation.

The Harvard Forest Flora: 1938-2004

Kirsten McKnight

The vascular flora of Petersham was previously examined in the mid-1930's by Hugh Raup and in the late 1940's by Earl Smith. The latter study, together with herbarium collections, credit 618 species to the Harvard Forest. Thus far in the summer of 2004, vascular plants from 25 of the 36 compartments of the Harvard Forest were identified by on-site and laboratory analysis. A total of 417 vascular plant species were identified, 67 of which were not previously attributed to the Harvard Forest. Compartment diversities ranged from 31 species, in the most uniform habitats, to 187 species in compartments with greater habitat diversity, including fertile outcrops and extensive wetlands. The median number of species was 89, with quartiles of 68 and 102 (Fig. 1). The historical and current lists of the woodland flora are generally consistent, with a few salient differences. Of the one hundred most common species documented this summer, 94 were reported previously. Two of the newly reported plants are invasive weeds: oriental bittersweet and Morrow's honeysuckle. The Harvard Forest plant inventory, besides establishing a framework for continuing ecological investigations, also serves as a baseline for future studies of plant diversity and distribution, including analysis of the importance of roadways in the dispersal of plants throughout the landscape, the replacement of native flora by invasive species, and the relative importance of factors such as hydrology, topography, soil fertility, herbivory and dispersal in controlling species distribution and abundance.

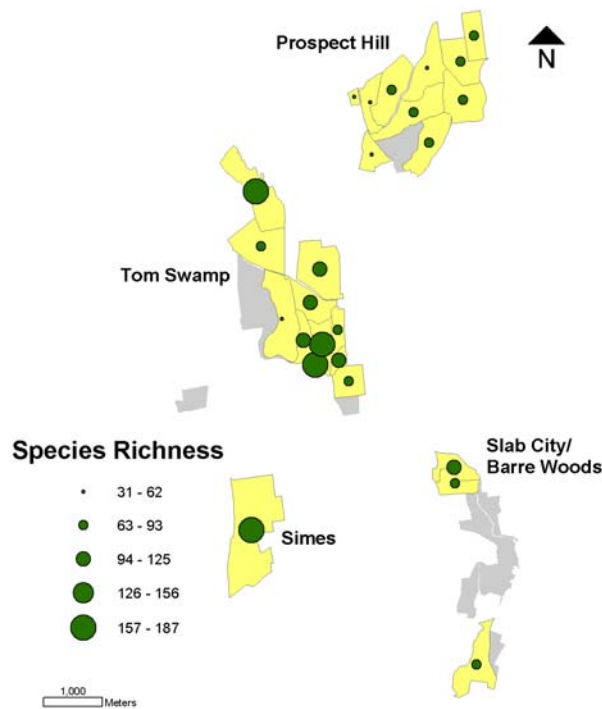


Figure 1. Species richness across Harvard Forest (McKnight)

Coarse Woody Debris: The Effect of Moisture and Species on Carbon Dioxide Flux

Chris Miwa

Coarse woody debris (CWD) has been shown to have long-term effects on several ecosystem processes such as water, nutrient and carbon fluxes; however its role in biogeochemistry remains poorly understood. Microbial respiration from CWD is rarely included in net ecosystem exchange (NEE) models resulting in overestimates of carbon storage. A better understanding of the controls on CWD respiration is needed to accurately model carbon exchange between the forest and atmosphere. CWD respiration was measured at the Harvard Forest for different species along a moisture gradient. Samples were collected from a mixed deciduous forest that had been harvested nine years ago. The samples were cut to 30 cm in length and ranged from three to seven cm in diameter. They were then incubated in 21.1 L, air-tight chambers and 50 ml gas samples were extracted and measured at 0, 1 and 2 hrs for total CO₂ concentration using an infrared gas analyzer.

CWD respiration showed strong linear relationship with moisture for oak, maple and hemlock (average $R^2 = 0.76, 0.88$ and 0.67 respectively). Red oak and red maple respiration responses to wood moisture content were 2.4 and 3.5 times higher respectively than hemlock ($P < 0.01$ for both species contrasts).

Linear regression equations were used to estimate respiration rates in the field from field moisture contents. Red oak had the highest estimated field respiration rate followed by maple and hemlock, although only oak was 1.7 times higher than hemlock ($P = 0.06$). Hemlock samples had lower bulk density values and were generally in a more advanced decay class than the oaks and maples.

Whole-Forest Evapotranspiration of a Hemlock and a Deciduous Forest under Similar Climatic Regimes

Thomas Mulcahy

The predicted hemlock woolly adelgid infestation of forests dominated by eastern hemlock (*Tsuga canadensis*) in central Massachusetts and subsequent replacement by deciduous forests has prompted an investigation of the fundamental hydrologic processes controlling the quantity, quality, and timing of stream-flow in and around Harvard Forest. Whole-forest evapotranspiration is a critical component for evaluating the current and future hydrology of a forested ecosystem. Prior measurements of leaf conductance and sap flow have shown that red oak (*Quercus rubra*) and black birch (*Betula lenta*) have similar leaf conductances to water vapor, and that *Q. rubra* has greater transpiration than *T. canadensis*. This suggests that a forest dominated by deciduous species would have significantly higher evapotranspiration than a forest dominated by *T. canadensis* under similar climatic regimes. Evapotranspiration in a forest dominated by *T. canadensis* and a deciduous forest were compared using data collected from two eddy covariance towers at Harvard Forest from June 16 through July 14, 2004. Peak daily evapotranspiration from the deciduous forest was $\approx 8 \text{ mmol H}_2\text{O m}^{-2}\text{s}^{-1}$ as compared to $\approx 4 \text{ mmol H}_2\text{O m}^{-2}\text{s}^{-1}$ for the *T. canadensis* forest, or $\approx 4.5 \text{ mm H}_2\text{O d}^{-1}$ for the deciduous forest and $\approx 2.0 \text{ mm H}_2\text{O d}^{-1}$ for the *T. canadensis* forest. This translates into a daily evapotranspiration difference of $\approx 300,000$ liters for the 15 ha covered by old-growth *T. canadensis* at Harvard Forest.

Near-ground Carbon Dioxide Patterns in a Central Massachusetts Forest

Jacquelyn Netzer

Understanding the dynamic changes in near-ground enriched carbon dioxide (NEC) is important for understanding the forest environment as a whole, but until now little has been done to profile NEC levels. We expected CO_2 concentrations to show a diurnal pattern, peaking at around midnight, and falling until noon. In addition to the temporal dynamics, we also hypothesized that wind, soil respiration, and carbon fixation by plants in the near-ground region would affect NEC levels.

To study the changes in NEC levels, we measured CO_2 concentrations in six locations in a forest in Petersham, MA. At each location, we measured at four heights (5, 10, 20, and 40 cm above ground) every ten minutes from June 23 to July 14, 2004 with breaks for inclement weather. We measured soil temperature and moisture at the same locations in five minute intervals, and wind speeds at 10 and 40 cm every minute at three of the six sites. We found (Fig. 1) that CO_2 generally rises in the evening, reaching a peak at about midnight to one in the morning, and drops until about noon to one in the afternoon. Concentrations usually show an inverse relation to height, often showing differences of about 50 to 200 ppm between 5 and 40 cm above ground. We attempted to find a correlation between wind and NEC but found no significant relationship. However, further analysis is warranted for the large amount of data collected this summer, and we will continue to search for significant relationships between NEC and wind, soil temperature, and soil moisture and then develop a predictive model for NEC levels.

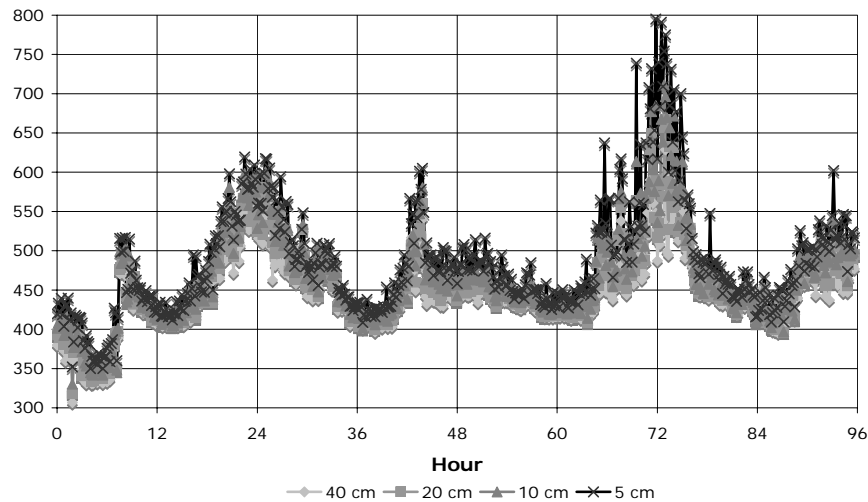


Figure 1: Carbon dioxide concentration versus time from site four of six in Harvard Forest in Petersham, MA. Midnight on July 3, 2004 was set as hour zero. Measurements were taken at four heights every ten minutes.

(Netzer)

The Future of Hemlock Forests: A Three-Year Study of Hemlock Woolly Adelgid's Movement and Effects on Central Massachusetts

Donald Niebyl

Since its arrival in Springfield, Massachusetts around 1989, hemlock woolly adelgid (*Adelges tsugae* Annand), an invasive insect from Asia, has been infesting eastern hemlock (*Tsuga canadensis*) stands across the state. As results from previous studies in Connecticut have shown, HWA can devastate the landscape causing complete hemlock mortality in as little as five years. However, to date, the effects of HWA have not been as dramatic in Massachusetts as in hemlock forests of Connecticut, possibly due to cold winter temperatures slowing down their spread. In this study, we examined the northward versus western spread of HWA, the regeneration of shade intolerant tree species in infested stands, and the correlation of infestation intensity with stand-level environmental characteristics. Over the course of three years, we sampled 123 hemlock stands in our 406,017 ha study area of central Massachusetts. In each stand, we measured hemlock density with several plots using a Cruz-All and one 20 x 20 meter plot where hemlock diameter, vigor, and crown class were recorded along with all understory growth and regeneration. Of all sampled stands, 40% were infested with HWA, with most infestation occurring along the Connecticut border and the Connecticut River valley. This low infestation level after 15 years of presence lends credence to the idea that cold Massachusetts' winters are slowing the insect's spread. Additionally, black birch (*Betula lenta*) had the highest frequency and density of all shade intolerant regeneration. Finally, we found slight evidence of a positive connection between southwest aspects and hemlock mortality.

Population Attributes of Garlic Mustard in Three Ecoregions in Massachusetts

Marlon Ortega

Alliaria petiolata (Bieb.) Cavara & Grande (garlic mustard) populations that have had the opportunity to invade forest were mapped throughout Massachusetts. Three unique ecoregions within this area where invasion has extended into the forest were compared. Population and habitat attributes were also measured, which include percentage of adults and rosettes. Total area was measured for three populations within each region. Length of population was measured along the forest edge or road side, and depth of invasion into the forest was measured using four transects running perpendicular to the length that stopped where the last *A. petiolata* plant was observed. One random point was chosen on each transect to measure percentage of adults and rosettes. For this, I used a 1m² grid and the mid point value technique. The distance to the furthest *A. petiolata* plant within the population was also measured (Tmax). Analysis of variance showed there was not a significant difference in the total percent of *A. petiolata* ($P=0.3589$), percent adult plants ($P=0.22$), and percent rosettes ($P=0.1461$) among populations from the three ecoregions (Fig. 1). Also the analysis of variance for the spatial data for T max ($P=0.3104$) and total area ($P=0.3675$) did not show any significant difference (Fig. 2).

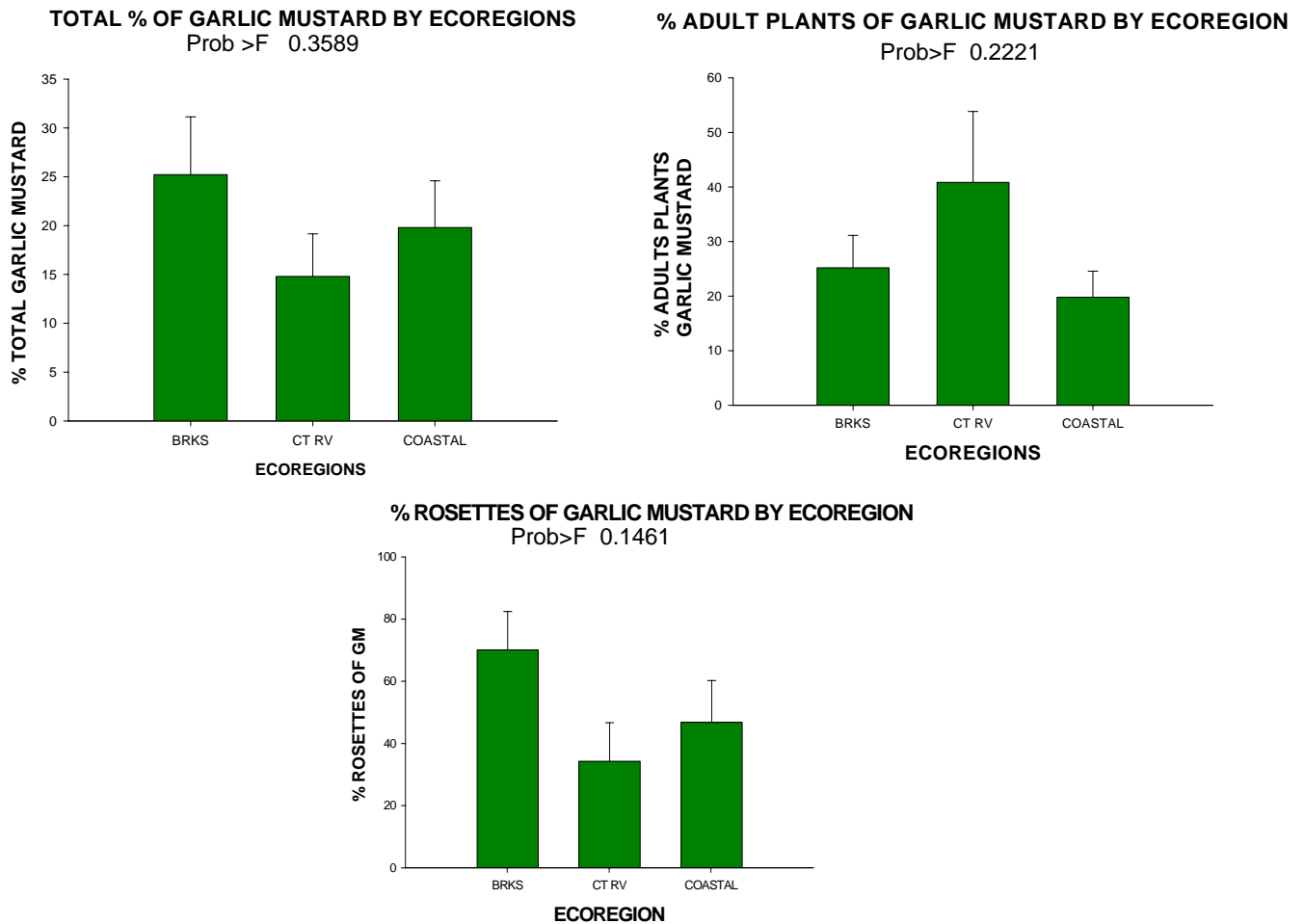
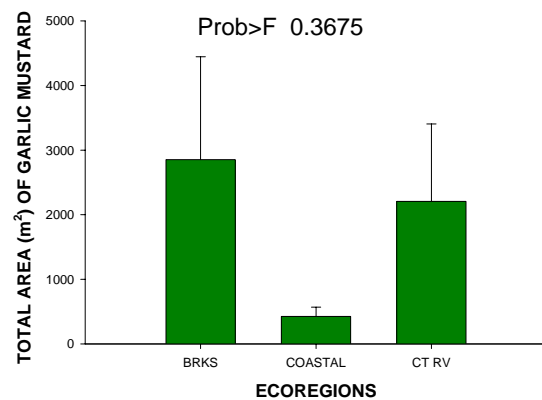


Figure 1. Analysis of variance for total percent, adult plants and percent rosettes of *A. petiolata* by ecoregion. (Ortega)

TOTAL AREA OF GARLIC MUSTARD POPULATIONS BY ECOREGION



T MAX BY ECOREGION

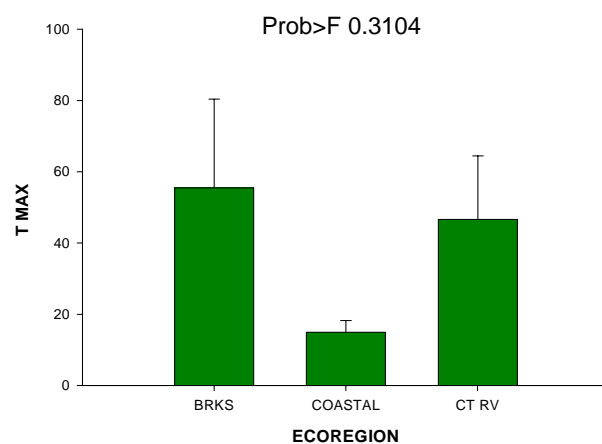


Figure 2. Analysis of variance for spatial data T max and total area of *A. petiolata* by ecoregion (Ortega)

Reconciling Soil Respiration Measurements with Eddy Covariance Estimates of Ecosystem Respiration

Rose Phillips

Consistency among measurements of soil respiration and other carbon fluxes is imperative for understanding ecosystem responses to climate change. At the Harvard Forest, measurements of midsummer soil respiration (R_s) in the northwest and southwest quadrants (dominant wind directions) of an eddy covariance tower's footprint exceed the tower's ecosystem respiration estimates. However, tower measurements may also be significantly influenced by unsampled areas of lower R_s . I sampled R_s six times over three weeks at a representative site in Canton soil ~50 m northwest of the tower, within the known footprint, and a previously unsampled site in Charlton soil on a south-facing Prospect Hill slope, ~450 m north-northwest of the tower. CO_2 concentrations were measured in 12 flux chambers per site and date with an infrared gas analyzer, and percent ground cover of exposed and nearly exposed (≤ 2 cm from soil surface) rocks was estimated at each site in three 50-m transects. The Charlton site had lower mean CO_2 efflux ($167 \text{ mg C m}^{-2} \text{ hr}^{-1}$) than the Canton site ($230 \text{ mg C m}^{-2} \text{ hr}^{-1}$), a marginally significant ($p=0.051$) difference using log-transformed fluxes. Rock cover was 4.2% and 6.0% at the Canton and Charlton sites, respectively. Although not statistically significant, the trend of higher rock content at the Charlton site may further contribute to its lower soil- CO_2 efflux. A previous study suggests nocturnal air drainage from Prospect Hill toward the tower, which implies significant contribution from the Charlton site to tower flux measurements. Hence, this spatial heterogeneity in R_s merits further investigation.

Is Physiology Color Blind? How Color Affects *Sarracenia purpurea*

Allison Rosenberg

Sarracenia purpurea, the northern pitcher plant, is a carnivorous plant found in ombrotrophic bogs along the East coast of North America. *S. purpurea*'s coloration varies considerably; the plant can be entirely red or green, with a range of intermediate phenotypes. Anthocyanin is the pigment responsible for the red color in *S. purpurea*, and tends to congregate along the veins of the pitcher.

S. purpurea's coloration is genetically controlled to some degree; entirely green plants are the result of a recessive mutation in a single gene. Most plants display some level of anthocyanins. The role of such distinctive coloration in *S. purpurea* is unknown. However, it is possible that anthocyanins influence plant function, plant relationship with the inquiline community, or the type or amount of prey trapped.

This project explored whether the presence and degree of variation in anthocyanins displayed affect *S. purpurea*'s ability to regulate temperature and photosynthesize. Pitcher temperatures were monitored in two experiments over the course of four days in a greenhouse; photosynthetic rates were measured two separate times.

Photosynthetic rates were unaffected by color. Pitcher temperature increased with higher photosynthetic photon flux (PPF), but there was no strong difference between red and green colored plants. Green pitchers filled with water appeared to have a greater buffering effect on water temperature at high PPF than red and empty green pitchers. Ultimately, temperature differences may affect nutrient supply from the food web to the plant, but these results show no benefit for any certain level of anthocyanin production.

The Seed Bank Spatial Distribution of Hemlock Forests

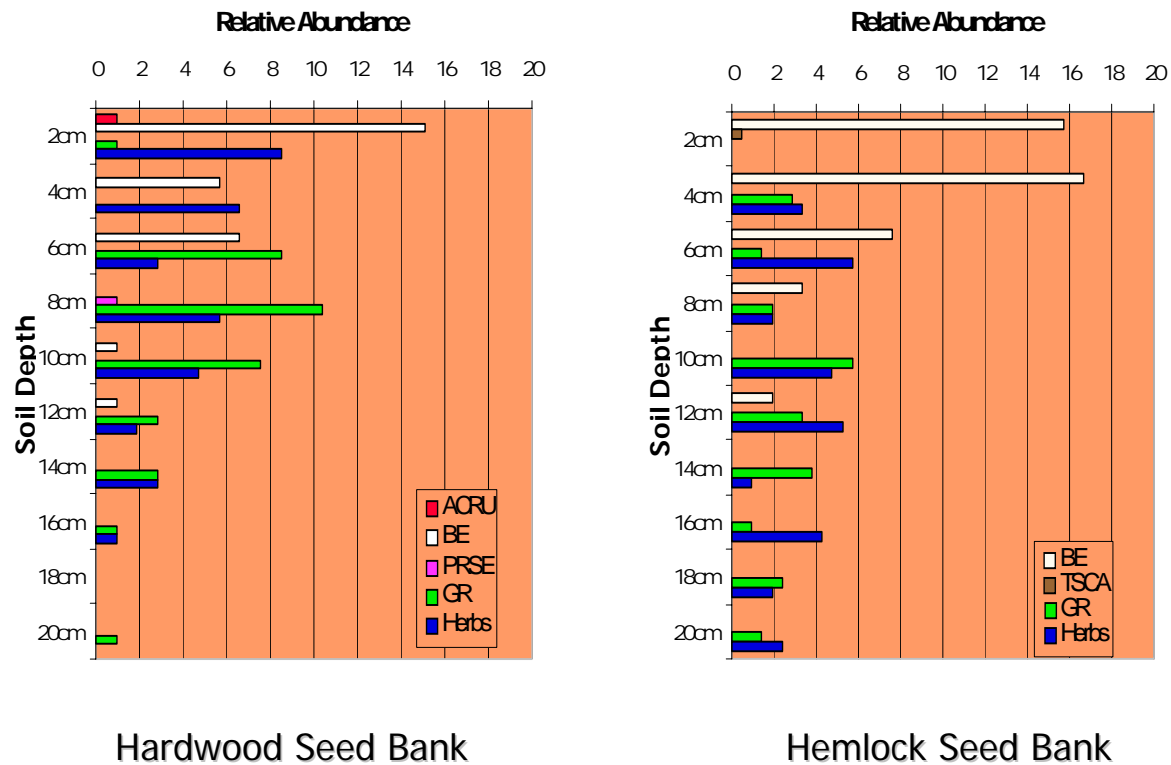
Kelley Sullivan

Hemlock forests provide an environment conducive to seeds forming a seed bank within the soil layers. Since the habitat consists of a dense shady canopy, shade-intolerant species are inhibited from germination. If their seeds have long viability then they have a tendency to accumulate. The seed bank was studied to determine the species distribution by soil depth and forest type.

Understory flora and seedlings germinating from soil samples in a greenhouse were identified and recorded from six hemlock and two hardwood plots (Fig. 1). In hemlock seed banks birch found in the top 12 cm soil layers accounted for 43% of the germinant followed by a more even distribution by depth of herbaceous species (30%) and grasses (24%). In hardwood seed banks grasses (35%), herbaceous species (34%), and birch (29%) dominated. The most abundant species in the hardwood understory were herbaceous species (88%) and in the hemlock understory was red maple (60%).

In hemlock forests, shade-intolerant species such as birch are long-lived seeds that over time are buried deeper into the soil forming seed banks. Shade-tolerant species such as red maple have short-lived seeds or germinate before forming seed banks. The difference in diversity between hardwood and hemlock plots is due to light levels. If disturbance events increase light levels, then seed bank distribution and composition could be affected. Therefore, researching the seed bank is crucial to understanding the differences in the regeneration process between a hemlock forest that slowly declined because of the hemlock woolly adelgid and one more rapidly altered by clear-cutting.

Figure 1: The percent of each species by soil depth that emerged from the soil seed bank of hardwood and hemlock plots, 2004 (Sullivan)



Investigating Links Between Climate and the Mid-Holocene *Tsuga* Decline

Sarah Truebe

Lake sediment pollen records from Eastern North America show a mid-Holocene hemlock decline 5400 years before present (ybp). The hemlock decline has traditionally been interpreted as an insect or pathogen attack, perhaps not unlike the current Hemlock Woolly Adelgid infestation, but recent lake-level reconstructions have indicated that the hemlock decline may have occurred during a period of dry climate. To test whether the decline was associated with a climate change, I analyzed a sediment core from Benson Pond (Fig. 1a). The core contains a peat layer from 274-256cm suggestive of low lake levels, and I hypothesized that *Tsuga* pollen abundance would be low in the same interval. In order to demarcate the peat and other stratigraphic changes, I used a standard loss on ignition (LOI) method to measure organic content (Fig. 1b). LOI is thought to record fluctuations in lake level or lake productivity resulting from climatic changes. To ascertain the relationship between the peat and the *Tsuga* decline, I analyzed pollen for 14 levels from 100-360cm and found that *Tsuga* relative abundance declined sharply near 225cm (Fig. 1c). I compared *Tsuga* abundance with taxa that prefer warmer, drier environments and found that they increase during the decline. The decline coincides with another LOI peak from 230-175cm which may also indicate dry conditions. Though not correlated with the hemlock decline, the peat could very well be linked to an abrupt interval of cold and dry climate that occurred 8200 ybp. The manner in which these climate changes are recorded in the Benson Pond core may provide insight into interpretation of other lake sediment records and improves our understanding of the major Holocene climate and vegetation changes in New England.

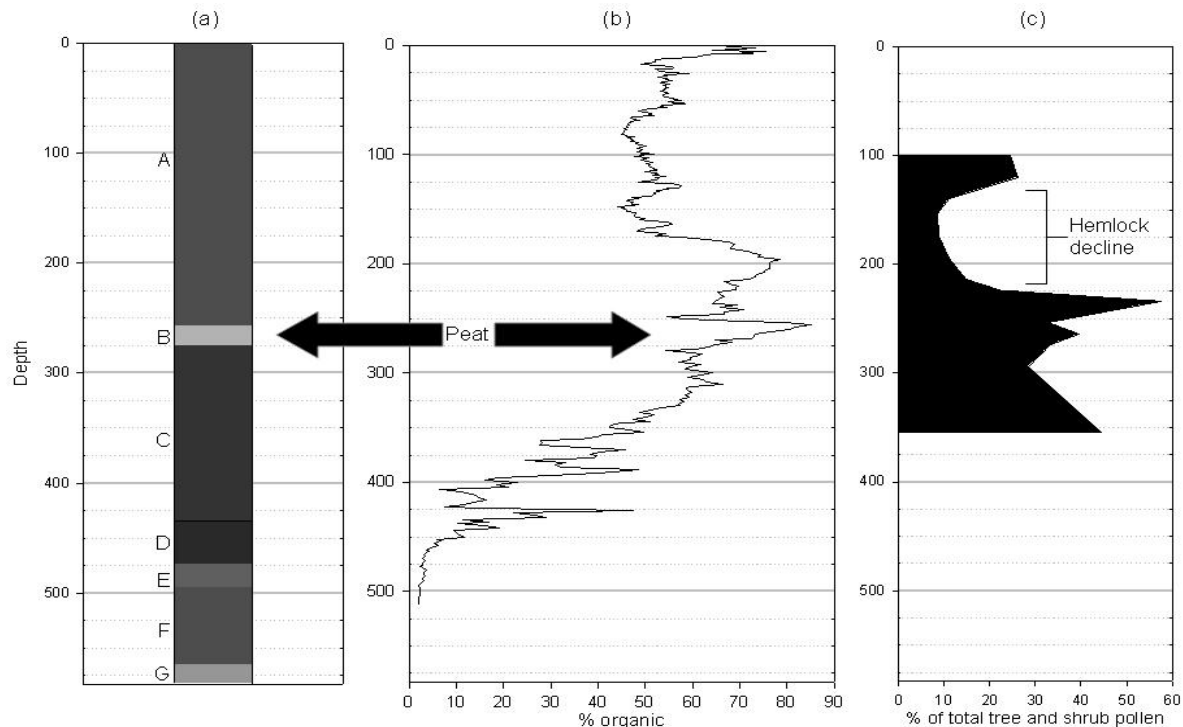


Figure 1: (a) Stratigraphic diagram of the Benson Pond core [A=brown sediment, B=dense sedge mat, C=organic brown sediment, D=striated bands of yellow, grey clay, E=grey clay with moss, F=grey clay with black striations, G=grey glacial clay]. (b) Organic content (percentage by weight) of Benson Pond. Note that the sedge peat layer shows up as a peak in organic content between 275 and 250cm. (c) *Tsuga* pollen as a percentage of upland (tree and shrub) pollen. The decline occurs rather precipitously ~225cm, or about 5400 years before present (dating from comparison with other pollen records, which record many of the same shifts in both *Tsuga* pollen and other taxa).

(Truebe)

The Effects of Sunflecks and Ambient CO₂ on Water Use Efficiency of *Aralia nudicaulis* in both Steady-State and Dynamic Photosynthesis

Christina Walsh

This study used measurements of assimilation and conductance to determine a steady-state curve to predict water use efficiency and to compare those predictions to the measured water use efficiency (WUE, assimilation (A) over conductance (E)) in a dynamic situation in order to consider the effects of both sunflecks and ambient CO₂ on the dynamic and steady-state WUE of a population of ten *Aralia nudicaulis* chosen for their similarity in height, color, location, and herbivory in a formerly plowed forest stand.

Using a LiCor 6400 with ambient CO₂ levels at both 400ppm and 500ppm and an internal humidity maintained at 40% \pm 5%, I determined state-state WUE using a light curve at thirteen light levels ranging from 0 to 1000 mmolm⁻²sec⁻¹. To determine dynamic WUE, I used an induced sunfleck environment alternating between shade (25 mmolm⁻²sec⁻¹) and fleck (1000 mmolm⁻²sec⁻¹) with varying shade durations. The study focused on three plants from the chosen population.

In the steady-state situation, this population of *Aralia nudicaulis* had higher WUE in the 500ppm CO₂ level than the 400ppm level. In both CO₂ environments, WUE was lowest in darkness, highest at 200 mmolm⁻²sec⁻¹, and relatively constant at higher light levels. In 400ppm, the maximum water use efficiency was 0.105 μ molCO₂/mmolH₂O, whereas in 500ppm, the maximum was 0.117 μ molCO₂/mmolH₂O.

Furthermore, the steady state model was more accurate at predicting dynamic WUE at 500ppm (Fig. 1). At 400ppm, the average route mean square error for the three plants was 6.562 compared to 2.976 at 400ppm. The results proved to be statistically significant with a p-value of 0.004.

The results thus far indicate that this population has a higher and more predictable WUE at 500ppm and that WUE increases during sunflecks. Plans are currently underway for further study to determine the sunfleck and CO₂ environment with optimal WUE.

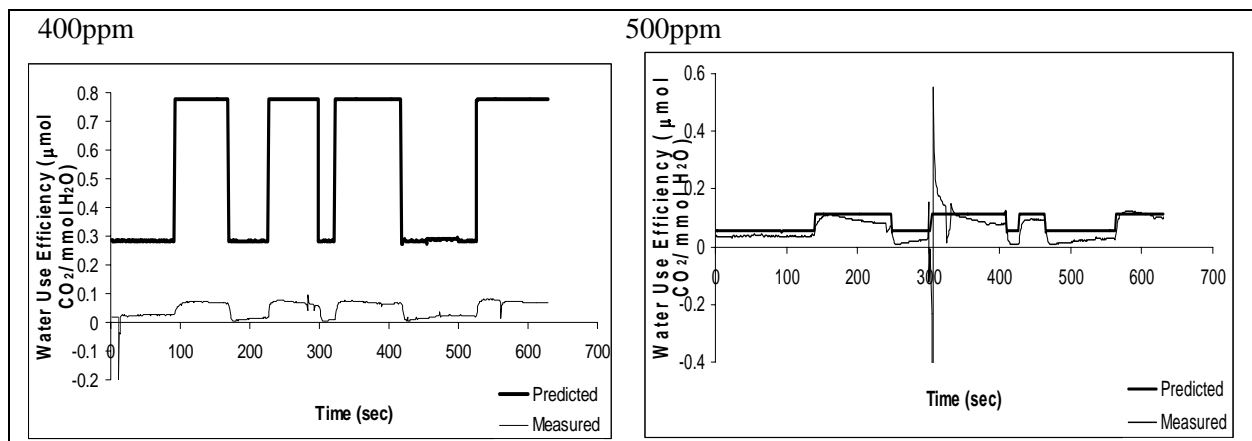


Figure 1. Predicted and measured WUE in a dynamic induced sunfleck situation at both 400 and 500ppm alternating between periods of shade (25 mmolm⁻²sec⁻¹) and fleck (1000 mmolm⁻²sec⁻¹) with shade durations lasting 15min, 6 min, 2 min, and 12 minutes. The average mean square error at 500 is 6.562 compared to 2.976 at 400ppm. These values are significantly different with a p-value of 0.004. (Walsh)

The Effects of Hemlock Woolly Adelgid (HWA) Infestation on Ectomycorrhizal Colonization of Hemlock Saplings

Matthew Waterhouse

Mycorrhizas are fungal root symbiotes which characteristically form in 95% of all plant genera. In this relationship, the mycorrhizal fungi receive 5-10% of the plant's fixed carbon, while supplying the plant with nutrients (P and N) and pathogen resistance. Hemlock are known to form both ecto and arbuscular mycorrhizal associations. While there is a known increase in soil nitrogen and decrease in needle vigor associated with HWA infestation, the effects ectomycorrhizal of colonization has not been documented.

To address this question, I determined percent ectomycorrhizal colonization of hemlock saplings in infested and uninfested sites. Two control sites were located in central Massachusetts near the Harvard Forest and three infested sites were located in southern Connecticut. Hemlock saplings were taken from each of the sites and analyzed for percent ectomycorrhizal colonization by a grid intercept method using a dissecting microscope.

The percent ectomycorrhizal colonization decreased with increasing HWA infestation (Fig. 1). The percentage of root tips in infested saplings ($23.7 \pm 1.9\%$ N=40) was significantly less than that of the uninfested saplings ($37.4 \pm 1.8\%$ N=46). This decrease in root tips and ectomycorrhizal colonization may indicate that soil nitrogen is no longer limiting and the trees are not allocating as much resources to belowground production. In uninfested saplings there was a positive correlation between root tip composition and ectomycorrhizal colonization suggesting mycorrhizal influence over root morphology. The overall decrease in ectomycorrhizal colonization with HWA infestation could have many other ecological implications, including changes in soil nutrient availability and cycling.

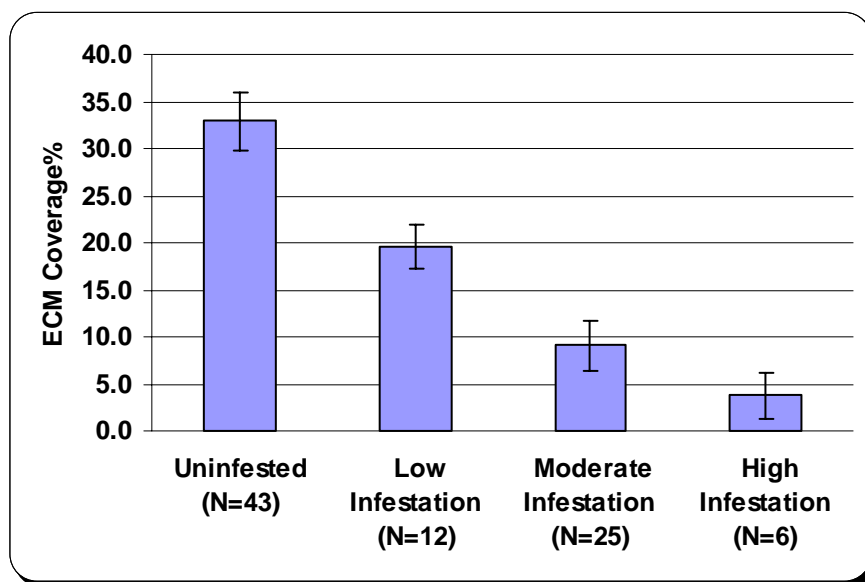


Figure 1. Percent Ectomycorrhizal Colonization Sorted by HWA Infestation Level. (Waterhouse)

Oak Regeneration in the Connecticut River Valley and Central Uplands of Massachusetts

Michelle Ziegler

The decline of oaks in eastern North America is of major concern to ecologists. Dramatic changes in plant species composition and wildlife habitat may be expected from a continuous decline in oak seedling establishment. My study on oak regeneration is part of the larger Forest Harvesting Project, which is a study of the effects of harvesting, land-use, and environmental variation on plant species composition. I hypothesized that sites with more oak in the pre-harvest stand would have more oak regeneration, and that more intense harvests would have higher oak seedling densities. Our team sampled more than 60 sites where harvesting occurred in Massachusetts. I used 29 of these data points for my analysis on oak regeneration. At ten points throughout each forest stand, we used a point sampling method to describe and quantify the seedlings, trees, and stumps present. I analyzed the effects of tree and stump basal area on seedling density and found that a high pre-harvest composition of oaks results in a high percent of post-harvest oak seedlings. Sites with more intense harvesting do not have higher oak seedling densities.

As intensity of harvest increases, shade tolerant seedlings, such as red maple, are more abundant (Fig. 1). There is no apparent trend in variation in the percentage of oak seedlings between the two regions studied. Results suggest that factors other than harvest intensity influence oak regeneration. These may include land-use history, local environmental characteristics, and relationships amongst seedlings, saplings, and herbaceous species.

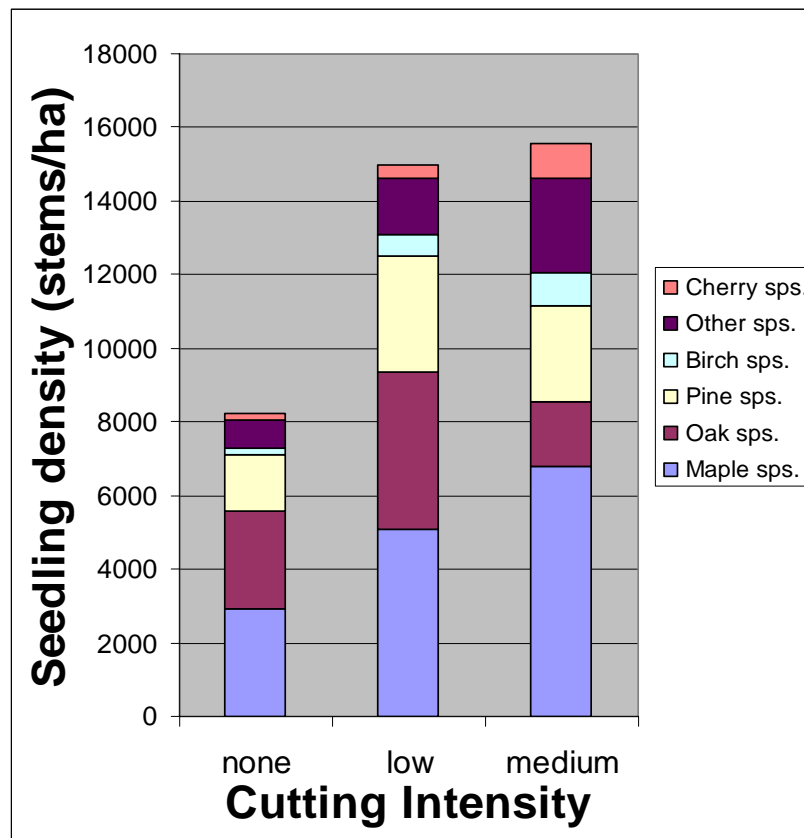


Figure 1. (Ziegler)

**2004 STUDENT SUMMER PROGRAM
SEMINARS AND WORKSHOPS**

Date	Program	Speaker(s)
June 7	Workshop 1. How to do a Literature Search and The Anatomy of a Scientific Paper	John Burk Bill Sobczak
June 9	Seminar 1. History of New England Land Use Change	David Foster
June 14	Workshop 2. How to Design an Experiment	Aaron Ellison
June 16	Workshop 3. Choosing and Applying to Graduate School	Dave Kittredge, Rachel Spicer, Megan Manner, Kristina Stinson and Posy Busby
June 21	Seminar 2. Forest and the Global Carbon Cycle	Steve Wofsy
June 23	Workshop 4. Harvard Forest Tree and Plant ID	John O'Keefe, Glenn Motzkin, Ed Faison and Heidi Lux
June 28	Student Presentations	Tracy Rogers and Jimmy Tran
June 30	Student Presentations	Tracy Rogers and Jimmy Tran
July 6	Seminar 3. Old-Growth Forests in Southern New England	Anthony D'Amato
July 8	Reading Group 1. Invasive Species	Julian Hadley, Rob McDonald and Brian DeGasperis
July 12 & 13	Institute of Ecosystems Studies in Millbrook, New York	
July 15	Seminar 4. Invasive Species	Kristina Stinson and Kathleen Donohue
July 20	Reading Group 2. Biogeochemistry	Sultana Jefts, Heidi Lux and Paul Kuzeja
July 21	Optional Seminar: History of Quabbin Reservoir	John Burk
July 22	Seminar 5. Biogeochemistry	John Aber
July 27	Workshop 5. Giving a Scientific Presentation	David Orwig
July 28	Workshop 6. Scientific Writing & Preparing an Abstract	Aaron Ellison
July 29	Optional Seminar: Ecology of Mount St. Helens	Fred Swanson
August 2	Seminar 6. Stream Invertebrates	Bill Sobczak and Betsy Colburn
August 19	Summer Research Symposium	

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PERSONNEL AT THE HARVARD FOREST 2004

Ronald Adams	Woods Crew	Matts Lindblah	Bullard Fellow
Ian Baillie	Bullard Fellow	Heidi Lux	Research Assistant
Michael Bank	Post-doctoral Fellow	Brooks Mathewson	Research Assistant
Laura Barbash	Research Assistant	Robert McDonald	Post-doctoral Fellow
Audrey Barker Plotkin	Research Assistant	Jacqueline Mohan	Post-doctoral Fellow
Leann Barnes	Laboratory Technician	Glenn Motzkin	Plant Ecologist
Paul Barten	Bullard Fellow	John O'Keefe	Museum Coordinator
Emery Boose	Information & Computer System Manager	David Orwig	Forest Ecologist
Jeannette Bowlen	Accountant	Wyatt Oswald	Paleoecology Lab Coordinator
John Burk	Archivist & Librarian	Julie Pallant	System and Web Administrator
Posy Busby	Research Assistant	Francis "Jack" Putz	Bullard Fellow
Jessica Butler	Research Assistant	Juliana Romero	Laboratory Technician
Laurie Chiasson	Receptionist/Accounting Assistant	Michael Scott	Woods Crew
Elizabeth Colburn	Acquatic ecologist	Richard Schulhof	Research Assistant
Brian DeGasperis	Research Assistant	Judy Shaw	Woods Crew
Elaine Doughty	Research Assistant	Pamela Snow	Environmental Educator
Ashley Eaton	Landscaper	Bernhard Stadler	Bullard Fellow
Edythe Ellin	Director of Administration	Kristina Stinson	Research Associate
Aaron Ellison	Senior Ecologist	P. Barry Tomlinson	E.C. Jeffrey Professor of Biology, <i>Emeritus</i>
Adrian Fabos	Facilities Manager	Betsy Von Holle	Post-doctoral Fellow
Ed Faison	Research Assistant	John Wisnewski	Woods Crew
Richard Forman	Landscape Ecologist	Steven Wofsy	Associate
Charles H. W. Foster	Associate	Tim Zima	Summer Cook
Christian Foster	Laboratory Technician		
David Foster	Director		
Lucas Griffith	Woods Crew		
Julian Hadley	Ecophysiologicalist		
Brian Hall	Research Assistant		
Julie Hall	Research Assistant		
Linda Hampson	Staff Assistant		
Amber Jarvenpaa	Assistant Summer Cook		
Sultana Jefts	Research Assistant		
Holly Jensen-Herrin	Research Assistant		
Julie Jones	Bullard Fellow		
David Kittredge	Forest Policy Analyst		
Paul Kuzeja	Research Assistant		
Oscar Lacwasan	Woods Crew		
Antonio Lara	Bullard Fellow		
James Levitt	Director, Program on Conservation Innovation		

Harvard University Affiliates

Douglas Causey	MCZ*
Peter del Tredici	Arnold Arboretum
Kathleen Donohue	OEB**
N. Michelle Holbrook	OEB
Paul Moorcroft	OEB
William Munger	EPS***
Maciej Zwieniecki	Arnold Arboretum

- * Museum of Comparative Zoology
- ** Organismic & Evolutionary Biology
- *** Earth & Planetary Sciences



The Institute of Ecosystem Studies

A FORUM ON OPPORTUNITIES IN ECOLOGY

Tuesday, July 13, 2004
9:30 a.m. - 3:30 p.m.
at the IES Auditorium

This forum provides undergraduate and graduate students the opportunity to hear firsthand about a wide range of career paths in ecology, including:

- Academia
- Media
- Education
- Consulting
- Applied Ecology
- Industry
- Government
- Research
- Policy
- Activism
- Environmental Law
- Conservation

In the morning session (9:30 a.m. - 12:30 p.m.), speakers representing each field will discuss the rewards and motivations involved in their work.

In the afternoon session (1:30 p.m. - 3:30 p.m.), speakers will join small groups for informal discussions about issues of concern to the student participants.

The forum is open to all students at no charge. Interested individuals should register for the afternoon program by calling *Heather L. Dahl, REU Program Coordinator* at (845) 677-7600 x326. No registration is necessary for the morning session.

There will be a break from 12:30 p.m. - 1:30 p.m.: please bring your own lunch and beverage.

Institute of Ecosystem Studies
Route 44A (181 Sharon Turnpike)
Millbrook, New York 12545
www.ecostudies.org

Backyard Bocci Ball



Ali Rosenberg Blueberry Picking at Tom Swamp



Celebrating in Boston on 4th of July



Peter Bettman-Kerson and Gavin Ferris
showing off some legs



Ant Patrol
David Diaz and Chelsea Kammerer-Burnham



Campfire Cooking at IES Conference



Blueberry Picking near Quabbin Reservoir



Hiking Monadnock



Marlon Ortega and Cynthia Chang
trendsetting with HF headnets



Learning Map and Compass at Orientation



Ready..... set..... go!



REU Students!!!!

2004 SUMMER RESEARCH PROGRAM



Mary Anderson



Diana Barszcz



Peter Bettman-Kerson



Anne Marie Casper



Cynthia Chang



Jennifer Clowers



Bridget Collins



David Diaz



Gavin Ferris



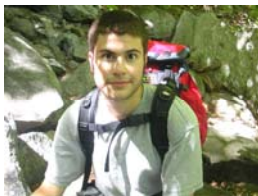
Kelsey Glennon



Daniel Gonzalez-Kreisberg



Kelly Grogan



Robert Hanifin



Chelsea Kammerer-Burnham



Megan Manner



Kathryn McKain



Kirsten McKnight



Chris Miwa



Thomas Mulchay



Jacquelyn Netzer



Donald Niebyl



Marlon Ortega



Rose Phillips



Ali Rosenberg



Kelley Sullivan



Sarah Truebe



Christina Walsh



Matt Waterhouse



Michelle Ziegler



Tracy Rogers



Jimmy Tran



