THE HARVARD FOREST 2003-2004

Harvard University

Front Cover: The Harvard Forest and Petersham Ridge as viewed from across the Quabbin Valley.

Back Cover: Summer Research Students 2004.

Photography: David Foster, Ava Foster, Dave Orwig, Tracy Rogers, and Kristina Stinson.

ANNUAL REPORT OF THE HARVARD FOREST 2003–2004

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http://harvardforest.fas.harvard.edu

PERSONNEL AT THE HARVARD FOREST 2003-2004

Ron Adams	Woods Crew
Ian Baillie	Bullard Fellow
Michael Bank	Post-doctoral Fellow
Laura Barbash	Research Assistant
Audrey Barker Plotkin	Research Assistant
LeAnn Barnes	Laboratory Technician
Paul K. Barten	Bullard Fellow
Emery Boose	Information & Computer System Manager
Jeannette Bowlen	Accounting Assistant
John Burk	Archivist/Librarian
Posy Busby	Research Assistant
Jessica Butler	Research Assistant
Laurie Chiasson	Receptionist/Accounting Assistant
Elizabeth Colburn	Aquatic Ecologist
Willard Cole	Woods Crew
Tony D'Amato	Graduate Student
Brian DeGasperis	Research Assistant
Brian Donahue	Environmental Historian
Elaine Doughty	Research Assistant
Deena Duranleau	Graduate Student
Edythe Ellin	Director of Administration
Aaron Ellison	Senior Ecologist
Adrian Fabos	Facilities Manager
Edward Faison	Research Assistant
Barbara Flye	Librarian/Secretary
Richard T. T. Forman	Associate
Charles H. W. Foster	Associate
Christian Foster	Laboratory Technician
David Foster	Director
Kelli Graves	Secretarial Assistant
Lucas Griffith	Woods Crew
Julian Hadley	Ecophysiologist
Brian Hall	Research Assistant
Julie Hall	Research Assistant
Linda Hampson	Staff Assistant
Amber Jarvenpaa	Assistant Summer Cook
Eric Jefts	Woods Crew
Sultana Jefts	Research Assistant
Holly Jensen-Herrin	Research Assistant
Julia Jones	Bullard Fellow
John Klironomos	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
Matts Lindbladh	Bullard Fellow
David Lindenmayer	Bullard Fellow
Heidi Lux	Research Assistant
Dana MacDonald	Research Assistant
Brooks Mathewson	Graduate Student
Robert McDonald	Post-doctoral Fellow
Jacqueline Mohan	Post-doctoral Fellow
Glenn Motzkin	Plant Ecologist
John O'Keefe	Museum Coordinator
David Orwig	Forest Ecologist
Wyatt Oswald	Paeloecology Lab Coordinator
Julie Pallant	System and Web Administrator
Francis "Jack" Putz	Bullard Fellow
Dorothy Recos-Smith	Staff Assistant
Tracy Rogers	Summer Program Assistant
Juliana Romero	Laboratory Technician
Michael Scott	Woods Crew
Richard Schulhof	MFS Student
Judy Shaw	Woods Crew
Thomas Sinclair	Bullard Fellow
Pamela Snow	Schoolyard Coordinator
Rachel Spicer	Graduate Student
Bernhard Stadler	Bullard Fellow
Kristina Stinson	Research Associate
P. Barry Tomlinson	E.C. Jeffrey Professor of Biology, *Emeritus*
Jimmy Tran	Summer Program Assistant
Betsy Von Holle	Post-doctoral Fellow
John Wisnewski	Woods Crew
Steven Wofsy	Associate
Tim Zima	Summer Cook

Harvard University Affiliates

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

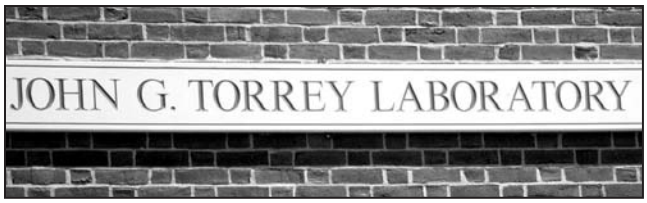
* Museum of Comparative Zoology
** Organismic and Evolutionary Biology
*** Earth and Planetary Sciences

INTRODUCTION TO THE HARVARD FOREST

Since its establishment in 1907 the Harvard Forest has served as Harvard University's laboratory and classroom for research and education on forest biology and ecology in the New England landscape. Through the years we have focused on forest management, the biology of trees, plant and landscape ecology, conservation and evolutionary biology, and ecosystem dynamics. Today, we continue to investigate historical and modern changes in natural ecosystems throughout the region and world resulting from human and natural disturbance, and to apply this information to conservation objectives. This activity is epitomized by the Harvard Forest Long Term Ecological Research (HF LTER) program, established in 1988 through funding by the National Science Foundation (NSF) and the National Institutes of Global Environmental Change (NIGEC) funded by the Department of Energy since 1990. Our Summer Research Program in Ecology offers hands-on research opportunities to more than 30 undergraduates annually and receives core funding from the National Science Foundation Research Experience for Undergraduates (REU) program.

Physically, the Harvard Forest exceeds 3,000 acres in the north-central Massachusetts towns of Petersham and Phillipston, and includes hardwood and conifer forests, ponds, streams, diverse wetlands, fields, and plantations. Additional land holdings include the 25-acre Pisgah Forest in southwestern New Hampshire (located in the 5,000-acre Pisgah State Park), a virgin forest of white pine and hemlock that 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 rooms for seminars and conferences. Nine additional houses provide accommodations for students, staff, and visiting researchers. Extensive long-term data sets, historical information, 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 Master's degree in Forest Science. 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 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 and educational objectives of the Harvard Forest. A management group meets regularly to discuss current activities and to plan future programs. 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, whereas major research support comes primarily from the National Science Foundation, Department of Energy, U.S. Department of Agriculture, NASA, Andrew W. Mellon Foundation, private foundations, and our Friends. Our summer Program for Student Research is supported by the National Science Foundation, the A. W. Mellon Foundation, and the R. T. Fisher Fund.

NEW STAFF

After a productive period as a Bullard Fellow, Elizabeth A. Colburn has joined the Forest as an Aquatic Ecologist focusing on the invertebrate biology and ecology of streams, ponds, and vernal pools. She received her B.A. from Occidental College, and an M.S. and Ph.D. from the University of Wisconsin at Madison. She served as Aquatic Ecologist for the Massachusetts Audubon Society from 1983 to 2001.

Kristina Stinson, who most recently was a post-doctoral fellow with Dr. Fahkri Bazzaz in OEB, has joined the staff as a Research Associate in the LTER program working with David Foster and Kathleen Donohue and focusing on invasive plant species. Kristina received her B.A. from Bennington College and her Ph.D. from Princeton University.

Two new post-doctoral fellows began work with David Foster and Glenn Motzkin on a research project examining the ecological impacts of forest harvesting in Massachusetts. Michael Bank, who is just completing his Ph.D. dissertation from the University of Maine, received his B.A. from SUNY and M.S. from Antioch New England Graduate School. Robert McDonald, recently received his Ph.D. from Duke University and his B.S. from the University of North Carolina at Chapel Hill.

Wyatt Oswald began working as the new Paleoecology Lab Coordinator last summer. He received his B.A. from Dartmouth and his M.S. and Ph.D. from the University of Washington in Seattle. Pamela Snow joined the staff as part of the LTER program to continue outreach and education efforts with K–12 students in local schools. Pam has a M.Ed, and a B.A. from the University of Massachusetts at Amherst and over a decade of experience as an environmental educator.

Heidi Lux sampling soils for nitrogen studies on Hemlock Hill in the Arnold Arboretum.

Laurie Chiasson is our new receptionist and accounting assistant. She has an associate's degree in computer science from Becker Junior College.

Heidi Lux, after five years working for the Marine Biological Labs-Ecosystems Center on the LTER soil warming experiment at the Harvard Forest, has joined the Hemlock Woolly Adelgid (HWA) research group led by David Orwig. She will primarily focus on the impact of the pest on Arnold Arboretum. Heidi received a B.F.A. from the Massachusetts College of Art, a B.S. from Oregon State University, and an M.S. from West Virginia University.

2004 Master's students, Brian DeGasperis, Ed Faison, Brooks Mathewson, and Posy Busby.

There will be four new Master's of Forestry Science (MFS) students who have begun work on their project during this summer. Posy Busby has a B.A. from Harvard College, Brian DeGasperis received a B.A. from the College of the Holy Cross, Edward Faison has a B.A. from Connecticut College and an M.S. from the University of Vermont, and Brooks Mathewson has a B.S. from Lehigh University and an A.L.M. from Harvard University.

TRANSITIONS AND ACCOLADES

Two long-time and key staff members at the Forest retired this year after many years of truly dedicated service. Dottie Recos Smith served as a secretary and administrative assistant to several directors and senior faculty during her 30 years of service. Among her many accomplishments, Dottie coordinated (and

typed!) a series of books and many papers for Barry Tomlinson. Dottie brought great energy and a wonderful sense of humor to her wide-ranging efforts. Her long-time co-worker, Barbara Flye, retired after 19 years serving as librarian and providing secretarial support to the staff, especially David Foster, John O'Keefe, and many Bullard Fellows. Barbara assisted David with the production of *Thoreau's Country* and her unfailing good humor, kind words, and enthusiasm for the Forest and its many visitors will be sorely missed.

Several other employees departed after working in various capacities. Kelli Graves departed after two years working as an administrative assistant as did paleoecology research assistant Dana McDonald. Dana had participated in numerous studies including fieldwork on the coastal study. Two facilities staff, Facilities Manager Adrian Fabos and Willard "Woody" Cole also left during the year. Woody, who worked for the Forest for eight years will be long remembered for his excellent efforts restoring the Fisher House.

RESEARCH ACTIVITIES

Biodiversity and Invasive Species

An emerging long-term goal at the Harvard Forest is to complete inventories of the biodiversity of key taxa on our land and in the local area. Much of this work is closely tied to ongoing experiments, to comparisons with historical data compiled by researchers decades ago, or to complementary studies of invasive and exotic species. Current inventories focus on birds, the vascular and bryophyte flora, ant species, and insects. Aaron Ellison has created a relational database using the Biota software for the data emerging from these and subsequent inventories. This database will be accessible to all researchers on the Harvard Forest Web site.

Flora of the Harvard Forest

For nearly a century, the Forest has been the focus of diverse ecological investigations, however, there have been few attempts to document the flora at specific time periods, and no attempt to evaluate changes over time. Hugh Raup used his extensive collections in the early 1930s to develop the first checklist of vascular plants of Petersham, Massachusetts. Subsequently, C. Earle Smith Jr. summarized what was known of the local flora based on the collections of Dr. I. M. Johnson and others in 1947 and specimens in the Harvard Forest and New England Botanical Club Herbaria. This spring, Glenn Motzkin and David Foster worked with Jerry Jenkins and REU student Bethany Burgee to undertake a complete assessment of the vascular and bryophyte flora at the Harvard Forest. This study will: 1) document the current flora, including detailed information on the distribution and abundance of locally and regionally uncommon species and invasive species; 2) enable a broad evaluation of changes in the flora over the past century and a detailed evaluation of changes over the past 50–60 years by comparing our results with those of H. Raup and E. Smith; and 3) serve as a baseline for documenting future changes.

Aaron Ellison supervising summer REU students David Diaz and Chelsea Kammerer-Burnham.

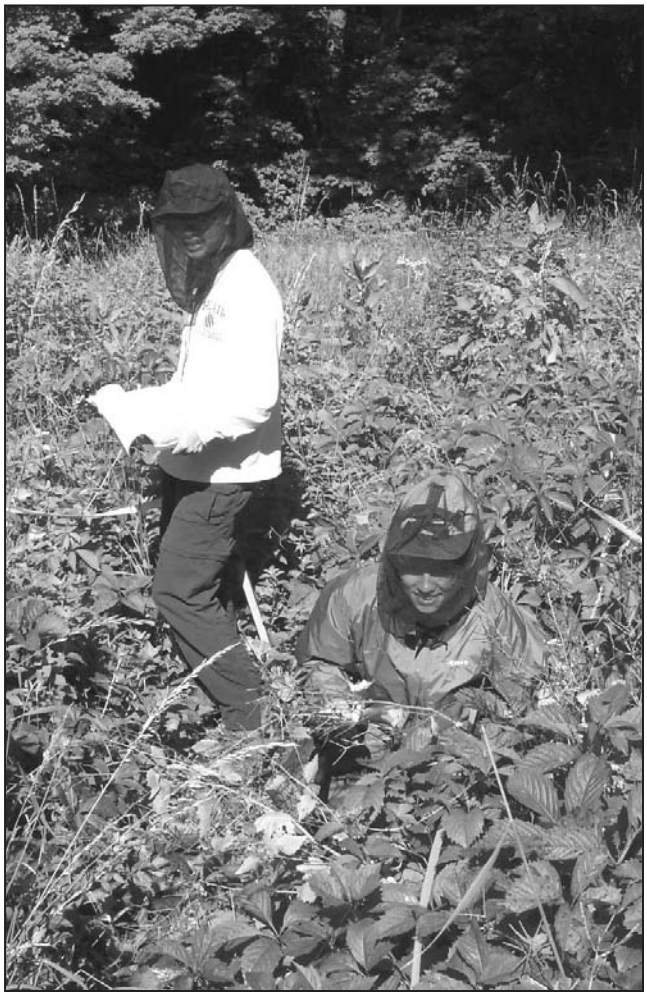
Ant and Insect Diversity

Aaron Ellison is working closely with REU students to inventory our ant biodiversity. Over 40 years ago, Walter Lyford suggested (in Harvard Forest Paper No. 7, 1963) that "the entire A horizon of some, if not most, virgin Brown Podzolic soils in New England consists of material returned by ants to the surface from the B horizon" and that ants could generate an A horizon 10–18 inches thick in 3,000 years. Since Lyford's work, however, there have been few subsequent studies of ants here. Surveys conducted with REU students Jonathan Chen and Matt Lau of sites in a range of successional stages and forest types increased by 3-fold (from 11 to 33) the number of ant species recorded at the Harvard Forest. In collabora-

tion with Nate Sanders and Paris Lambdin at the University of Tennessee, Aaron is inventorying insect biodiversity in hemlock stands and the changes in insect community structure following infestation by the hemlock woolly adelgid. A series of malaise traps, which passively collect flying insects, were installed in the experimental plots at the Simes Tract and a parallel set of traps were established in hemlock stands in the Great Smoky Mountains National Park. Bruce Archibald from Harvard's Museum of Comparative Zoology has initiated collections of insects around Harvard Pond.

Effects of Invasive Plants on Native New England Forest Communities

Few studies have empirically tested whether biological invasions negatively affect native plant communities, and how these impacts differ with the severity of the invasion. A group working with Kristina Stinson recently completed a study combining two years of vegetation sampling with experimental removal treatments to assess the community-level responses of the forest understory to invasion by the Eurasian biennial *Alliaria petiolata* (garlic mustard). They sampled areas ranging from low to high cover of garlic mustard, and experimentally removed 0%, 50%, or 100% of the mustard from some highly invaded plots. Diversity declined linearly with increasing densities of garlic mustard and increased only in response to full removal of mustard. In all cases, higher diversity was related to increased species equitability, rather than species richness, indicating that garlic mustard alters the composition, rather than total number of species in the community. Studies further demonstrated that native herbs, sedges, and tree seedlings declined with higher abundance or cover of the invasive. Similar results were found with the exotic shrub barberry *(Berberis thunbergii)* and suggest that managers can use full and partial removal strategies with different effectiveness, depending upon their priorities for promoting overall diversity, species richness, native species composition, and/or individual species. Collaborators for the studies included former postdoc Sylvan Kaufman, The Nature Conservancy (TNC) Director of Forest Conservation, Frank Lowenstein; REU student, Luke Durbin; and current MFS student, Brian DeGasperis.



Cynthia Chang and Kelsey Glennon measure seedling performance and seed production of the invasive plant, garlic mustard.

Invasive Species Population Responses to Habitat and Disturbance

Kristina is also investigating the role of disturbance history, source-sink metapopulation dynamics, and genetic adaptation in the invasion success of garlic mustard in forests. In these studies, she employs population-level experiments, metapopulation studies, and landscape-level historical analyses. A statewide roadside survey has mapped the distribution of garlic mustard along this major avenue of dispersal. Spatial analyses will test whether areas of past or present open canopy acted as corridors for the spread of invasive populations to present locations. These analyses will enable us to evaluate the generality of our population-level studies for predicting broad-scale factors controlling the distribution and abundance of exotic species.

At the population-level, Kristina has experiments testing for habitat-specific natural selection on physi-

Kathleen Donohue, Marlon Ortega, and Kristina Stinson analyze data.

ological, phenological, and allocational traits in open and closed-canopy conditions in sites with different land-use histories and varying degrees of invasion intensity. To date, we have found evidence that the maternal environment of a plant contributes to its germination and survival in a given habitat.

Landscape-Level Influences On Exotic Plant Invasion

Betsy Von Holle and students are engaged in numerous studies to assess the patterns and impacts of exotic plant invasion. With David Foster and Glenn Motzkin, Betsy is examining the effect of history, environment, and biotic factors on invasion by nonnative plants in Cape Cod National Seashore. Results suggest that nonnative species distributions and abundances in this landscape, which supports few exotics, are largely driven by soil nutrient conditions. Models that emerge from this study are being tested by applying them to the rest of the coastal landscape. In a smaller-scale study it was shown that nonnative species richness and abundance decreased with distance from typical natural disturbances (wind, salt spray) on the outer Cape, while native species richness and abundance peak with an intermediate level of disturbance. Betsy's group has documented that the invasive, nitrogen-fixing black locust tree *(Robinia pseudoacacia)* facilitates invasion by other nonnative plant species, most likely due to the nutrient-rich soils it generates. Currently, they are investigating the nutrient cycling characteristics of locust and native forests, initiating a restoration ecology experiment of a heathland, and conducting manipulative experiments to investigate the factors that promote invasion into heathlands

Ecology and Conservation of Uncommon Forest Communities

Structure, Dynamics, and Properties of Old-growth Forests in Western Massachusetts

The discovery of 18 old-growth forests in the Berkshire Hills and Taconic Mountains has provided Tony D'Amato (Ph.D. student) working with Dave Orwig an opportunity to document the composition, structure, dynamics, and processes of these rare ecosystems. Fieldwork in the Cold River Gorge, which contains one of the highest concentrations of old-growth forests and some of the oldest trees in the state, shows that old-growth stands occupy extremely steep northern or northwestern slopes (mean = 81.3%) and range in composition from hemlock-red spruce to sugar maple, beech, and yellow birch. All forests were uneven-aged, with hemlock ranging from 289 to 487 years old, beech between 150 and 225 years old, and yellow birch up to 328 years old. Contrasts in age-classes between plots, stands, and topographic positions suggest that the disturbance history has been dominated by small-scale processes such as windthrow and may vary with composition, topography, and physiographic setting. These initial

Anthony D'Amato in an old-growth red spruce forest on Mount Greylock.

results will be placed in a broader context through studies on the Mt. Greylock State Reservation and Mt. Washington State Forest.

Vegetation Dynamics of Ridgetop Pitch Pine and Red Pine Communities

Dave Orwig, Glenn Motzkin, and David Foster are conducting a study of the vegetation and long-term dynamics of ridgetop sites that support uncommon pitch pine or red pine communities. This past year, we focused on summits supporting dwarf pitch pine in the southern Taconics, as well as sites in western Massachusetts with native red pine. Dwarf pitch pines up to ~225 years old were documented, although the average age is substantially younger. All ridgetops visited with native red pine have evidence of past fire, and several sites have recent red pine morality from as yet unknown causes. Most native red pine sites support at least a few trees that are 140 to 180 years old. Red pine reaches more than 250 years on at least one site.

Part of the Forest Harvest Study crew looking at sites on the lands adjoining Quabbin reservoir: Mike Bank, Glenn Motzkin, and Brian DeGasperis.

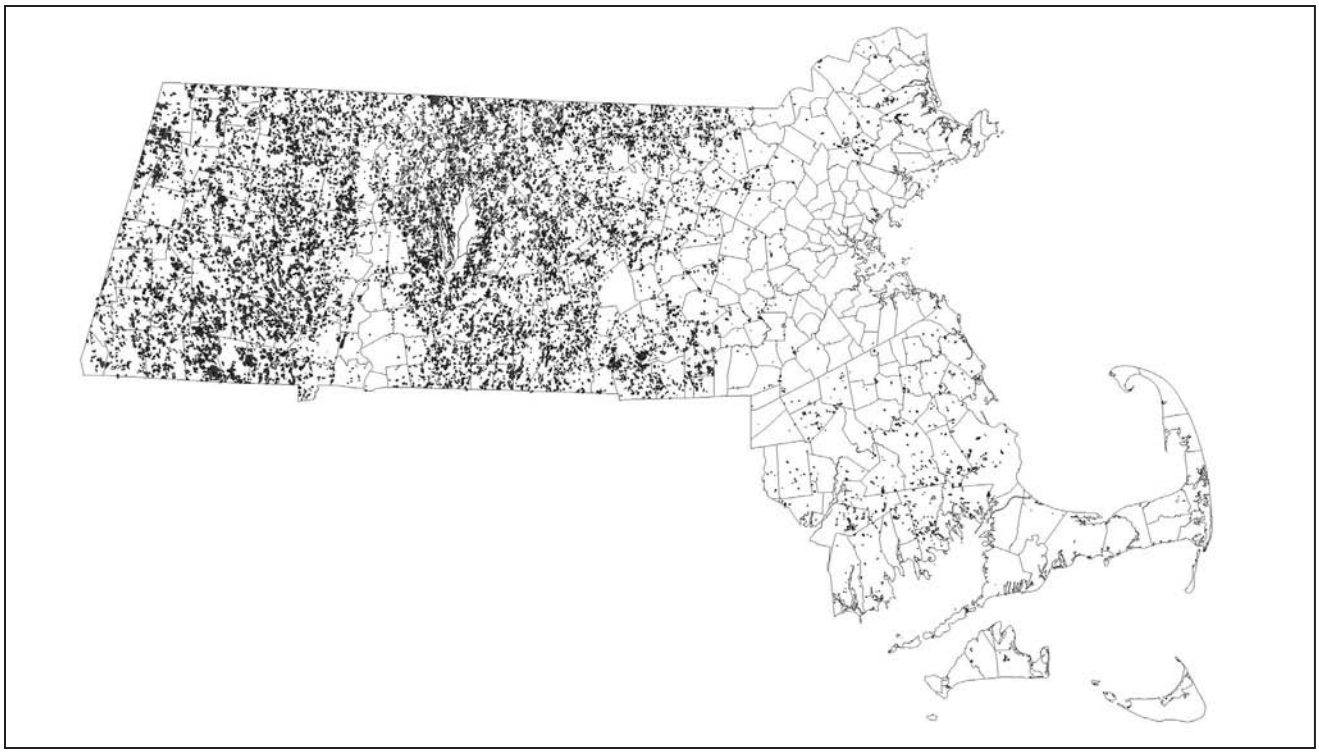
The Patterns and Ecological Consequences of Forest Harvesting in New England

Glenn Motzkin, David Foster, and Dave Kittredge have initiated a project evaluating the ecological, conservation, and resource implications of forest harvesting over the past two decades across Massachusetts. Two new post-doctoral associates, Mike Bank and Rob McDonald, are working closely with them and collaborators from The Nature Conservancy. Field studies are being assisted by MFS students Ed Faison and Brian DeGasperis and REU student Michelle Ziegler.

Bruce Spencer, chief forester at the Quabbin Reservoir, and Dave Kittredge.

With cooperation from the Massachusetts Department of Conservation and Recreation, John Burk completed gathering the Massachusetts harvesting data collected since 1984. Julie Hall checked over data, which will enable us to: (1) document forest harvesting patterns geographically and temporally; (2) analyze these spatial and temporal patterns with regard to physical, cultural, and environmental factors and important conservation values; (3) evaluate harvesting impacts on critical ecological characteristics, including invasive species distribution and plant species richness and composition; and (4) compare harvesting with natural disturbance regimes. Methodologies and results from this study will advance conservation planning across the eastern U.S., and will have broad relevance to global forest policy and conservation efforts. For instance, in a pilot study of the North Quabbin region, Dave Kittredge, Andrew Finley, and David Foster found a surprisingly high frequency of cutting: approximately 1.5% of the forest area was logged annually in a spatially random pattern that has left few large forest blocks undisturbed over the past 20 years.

Initial results from John Burk's efforts indicate



The pattern of timber harvests across Massachusetts from 1984–2003. These are the core data for our harvest study and will be the focus of intense field sampling over the next few years.

that from 1984 to 2003, 13,300 harvests were conducted statewide over approximately 455,000 acres. More than one billion board feet of timber were reported cut and nearly 800 harvests were 100 acres or larger. Private landowners conducted 76% of the harvests, while state agencies were responsible for about 15%. There was little cutting inside the heavily urbanized Route 495 belt in eastern Massachusetts. Dave Kittredge is using the harvesting data to explore relationships between commercial logging and community socioeconomic factors such as household income, real estate values, population density, and parcelization. Parcel data from randomly selected property tax assessments allow for analysis of the extent to which large, seemingly continuous blocks of forest are divided into increasingly small ownerships. REU student Kelly Grogan is assembling a dataset of parcel information from communities for this analysis.

Ecological, Conservation, and Cultural Impacts of an Invasive Forest Pest – The Hemlock Woolly Adelgid

New England's forests have experienced a series of severe impacts from introduced (nonnative) insect pests and diseases including the chestnut blight, Dutch elm disease, gypsy moth, and beech bark disease. With increased global exchange and communication and changing climatic conditions it is likely that the rate of these introductions will increase. Consequently, it is critical that we understand the factors that make forests susceptible to these invasions, the manner in which forest organisms and ecosystems respond to these disturbances, and the range of options that forest managers and landowners may have in these situations. The arrival of the hemlock woolly adelgid (HWA), an invasive pest form Asia that weakens and kills eastern hemlock, has provided us with an opportunity and imperative to address many of these issues. In 1994 the Harvard Forest initiated a research program investigating the hemlock woolly adelgid with the hiring of Dave Orwig as forest ecologist. Since that time Dave's program has continued and the entire effort has expanded to include many researchers at the Forest, across Harvard University and at collaborating institutions who are assessing the insect, its biology, and spread; hemlock, its physiology and response to HWA; the range of forest, aquatic and atmospheric responses to the decline and mortality of hemlock; the human responses to this situation; and the conservation

HWA damage in Williamsburg, Massachusetts.

implications of the adelgid and other pests and pathogens.

Multi-Scale Studies of Hemlock Ecosystems Impacted by the Hemlock Woolly Adelgid

Dave Orwig and his group continued ongoing studies across southern New England and initiated several new projects examining soil, tree, landscape pattern, and management responses to HWA. Sultana Jefts, and summer student Matthew Waterhouse extended studies of forest ecosystem responses to HWA in Connecticut and Massachusetts. Two sites logged in the last 4 years provide the opportunity to contrast the microenvironmental and ecosystem response to harvest versus adelgid. Both processes lead to microenvironmental changes such as increased light and soil temperature and decreased forest floor moisture content. In turn, these changes and changes in nutrient uptake by the stressed and dead trees alter soil nitrogen dynamics. Responses are much more rapid and greater in magnitude on logged sites.

Soils in heavily infested stands demonstrate high concentrations of available NO_3-N suggesting that increased nitrification rates may lead to NO_3-N leaching and denitrification. Uninfested and recently infested stands exhibit similar or greater NH_4-N availability than the heavily infested forests suggesting that much of the NH_4-N in those stands has been nitrified to NO_3-N. One site that had high nitrogen availability when all the hemlocks had died 10 years ago, now supports dense black birch and exhibits low nitrogen availability, presumably due to nutrient uptake by the birch. Investigations are also underway to examine the response of mycorrhizal fungi to the decline of hemlock and replacement by birch. Local high school student, LeAnn Barnes assisted for the second year with many of these labor-intensive laboratory and field activities.

Dave and summer assistants Don Niebyl and Megan Manner continued the regional study of hemlock stands in Massachusetts, documenting forest

Sultana Jefts.

David Orwig.

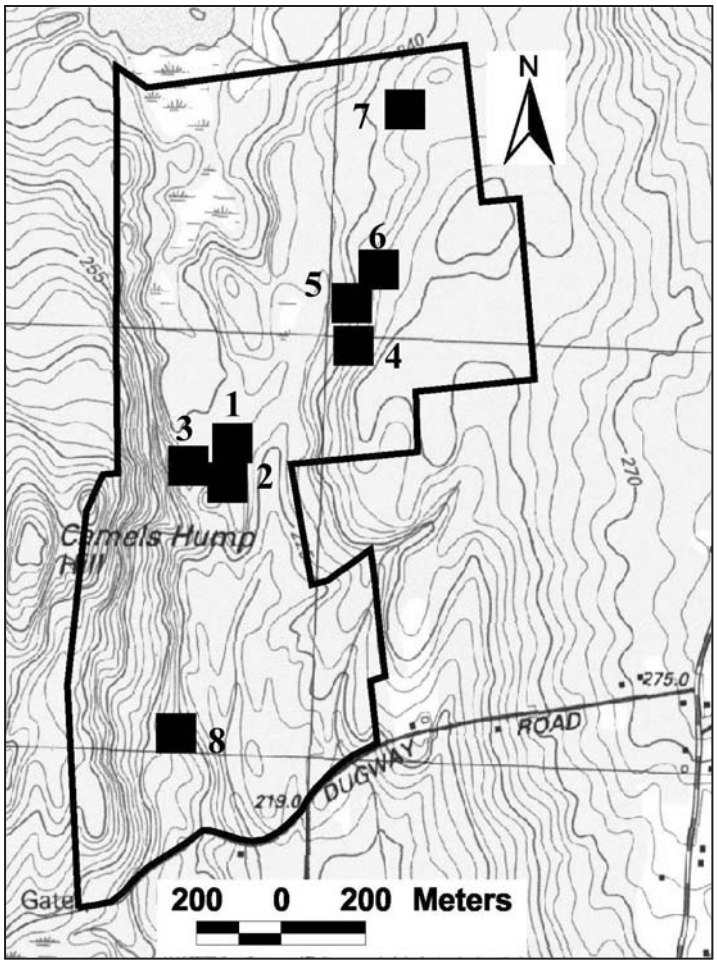
structure, composition, and crown vigor, site and edaphic characteristics, replacement species, and the distribution of the adelgid and canopy damage. HWA was present in ~40% of the 110 stands sampled, but overstory hemlock mortality levels remain low. Ten stands displayed greater than 20% hemlock mortality and two forests in southern Connecticut have losses exceeding 50%. Meanwhile, over half of the stands visited were logged in the last decade. The very cold winter of 2003 resulted in widespread decline in the adelgid. Replacement species present in the canopy of the hemlock forests surveyed include red oak, white pine, black birch, and maple species. Data from these studies will be the focus of Megan Manner's Master's thesis at Duke University.

Many landowners are choosing to harvest their hemlock stands pre-emptively due to the threat of HWA. Information from timber harvesters, state agencies, and Dave Orwig's studies indicate that logging is occurring with little ecological assessment and in the absence of scientific advice for owners, conservationists, land managers, or policy makers. Dave and Laura Barbash have extended previous work by Matt Kizlinski that compares harvesting and HWA impacts in terms of community and ecosystem dynamics. At 10 sites across central Massachusetts where hemlock has been harvested at varying intensities, they are assessing available soil nitrogen, soil mineralization and nitrification, and soil temperature throughout the growing season. They will also sample understory plant dynamics in relation to site conditions, microenvironmental change, and disturbance intensity. This work should lead to recommendations concerning ecologically appropriate management practices for hemlock stands.

We recently established plots in a small HWA infested watershed of the Quabbin Reservoir that is drained by Shay's Brook, a small stream, which has been intensively studied by Thom Kyker-Snowman (Massachusetts Department of Conservation and Recreation) and Paul Barten (University of Massachusetts). We will examine nitrogen availability and cycling and will compare these data with stream chemistry and flow to assess the impact of the loss of hemlock.

The Influence of HWA on Nutrient Cycling and Fluxes in Hemlock Forest Canopies

Bernhard Stadler (University of Bayreuth) continued his research on carbon and nitrogen cycling in the canopies of hemlock trees in HWA infested and uninfested stands. Rain that passes through the canopy will eventually reach the ground as throughfall that is likely to affect litter decomposition. Therefore, an experiment was initiated testing rain collected beneath infested and uninfested trees on the breakdown and decomposition of hemlock and birch litter and on nutrient export from the litter layer. An important aspect of these experiments is the inclusion of particulate organic matter (POM) in the analyses of nutrient fluxes. Although POM is rarely measured in studies on nutrient cycling it can be an important component, especially when insects are mediating flows of energy and nutrients. In addition, the abundance and activity of microorganisms growing on the leaf litter was examined. This trophic perspective of

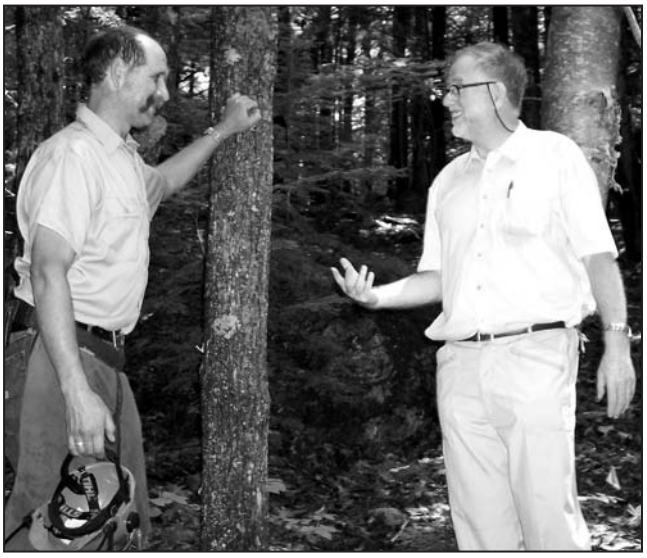


Map of the Simes Tract of Harvard Forest, showing locations of the hemlock manipulation plots (plots 1–6) and hardwood control plots (plots 7 and 8). Plots are 90m by 90m; treatments (girdling and logging) are planned for winter and summer 2005. Two hemlock plots will be left as controls that will eventually be impacted by the hemlock woolly adelgid.

nutrient cycling including HWA, microorganisms and POM, is expected to increase the understanding of the mechanisms associated with C and N cycling and the impacts of exotic insect pests on ecosystem processes and function.

Experimental Study of Hemlock Forest Response to Logging and the Hemlock Woolly Adelgid

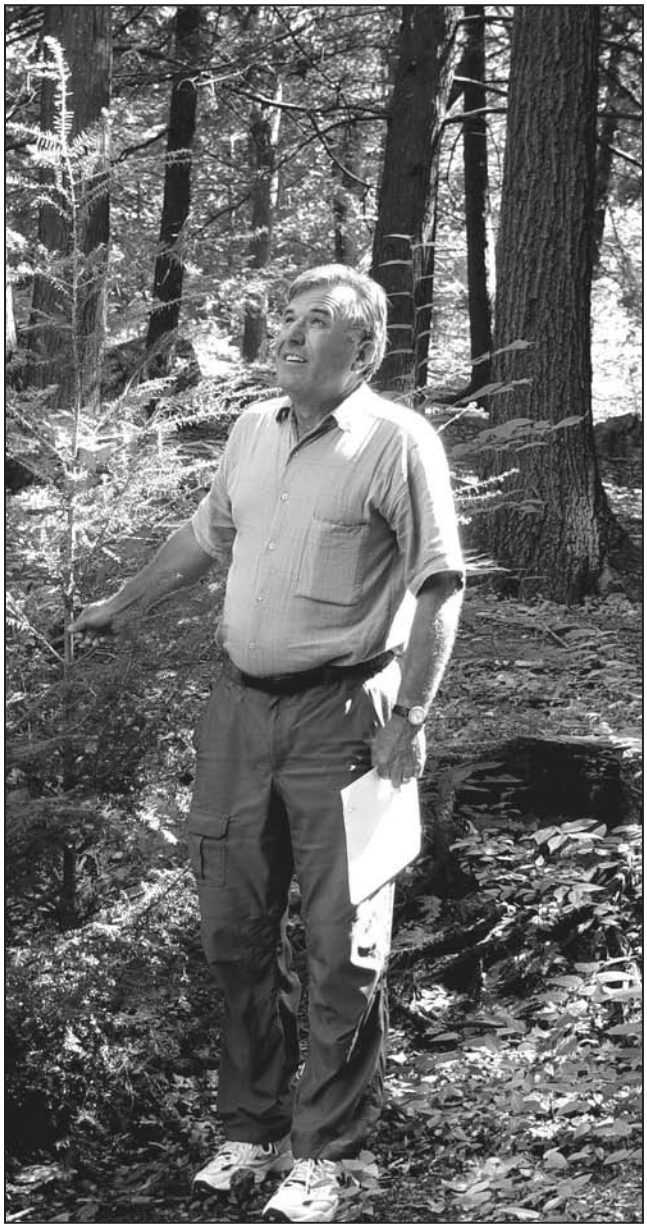
The current hemlock decline is a direct and indirect effect of the hemlock woolly adelgid. Insect damage is causing gradual mortality of hemlock, whereas concern about this damage is encouraging an indirect effect by landowners: widespread harvesting of hemlock after or in advance of mortality. Although both processes alter thousands of acres annually we have only a limited understanding of their effects on forest ecosystem function, productivity and dynamics. We anticipate that harvesting will yield different consequences than gradual mortality from the insect; to examine this we have designed an experiment consisting of eight large (0.8 ha) plots at the Simes Tract of the Forest. To simulate some of the effects of the adelgid (such as progressive mortality and retention of the wood on the site) we are girdling all hemlocks



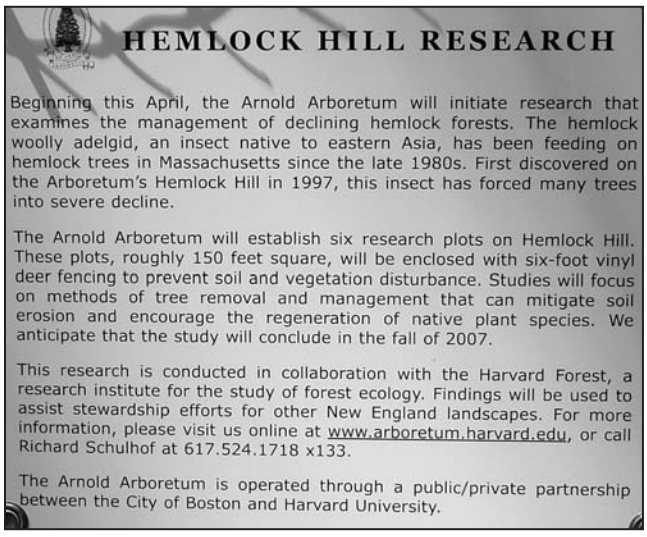
John Wisnewski discussing the hemlock girdling site with Ian Baillie.

in one treatment. In an adjacent area we are conducting a commercial harvest of hemlock. Other plots serve as controls, either with hemlock, which should eventually die from the adelgid or with hardwoods. Results from these treatments will be compared to the changes observed in Dave Orwig's regional study and can also be included in the integrated analyses of large experiments that form a core component of the Harvard Forest LTER program. In 2005, girdling and harvest treatments will be implemented on entire 90 by 90 m plots.

The adelgid has just arrived to the Simes tract and small populations were discovered in two plots by Scott Costa (University of Vermont) and REU student Diana Barszcz. All trees in all plots have been tagged, identified, measured, and mapped by Audrey Barker Plotkin, Jess Butler, REU students Peter Bettmann-Kerson and Kelley Sullivan, and high school junior Christian Foster. Within these plots, Audrey has sampled the understory vegetation; Kelley is characterizing the seed-bank; Peter is reconstructing stand dynamics and historical land-use; post-doc Marco Albani and REU student Mary Anderson are measuring canopy light environments and crown structure; Aaron Ellison and REU students Chelsea Kammerer-Burnham and David Díaz are inventorying insect biodiversity and the impacts of ants on N mineralization; Eric Davidson and Kathleen Savage (Woods Hole Research Center) continue to measure soil respiration; and Dave Orwig and his team are studying litter decomposition and nutrient fluxes. This summer we conducted a pilot girdling study in advance of the larger experiments planned for this winter (harvesting) and next summer (girdling). In the pilot study John Wisnewski and Lucas Griffith used chainsaws to cut two $1^1/_2$ inch deep incisions around the trunk of all hemlocks in one 30×30 m plot.



Peter del Tredici on Hemlock Hill at the Arnold Arboretum with a Chinese hemlock *(Tsuga chinensis)*, which is unaffected by the hemlock woolly adelgid.



HEMLOCK HILL RESEARCH

Beginning this April, the Arnold Arboretum will initiate research that examines the management of declining hemlock forests. The hemlock woolly adelgid, an insect native to eastern Asia, has been feeding on hemlock trees in Massachusetts since the late 1980s. First discovered on the Arboretum's Hemlock Hill in 1997, this insect has forced many trees into severe decline.

The Arnold Arboretum will establish six research plots on Hemlock Hill. These plots, roughly 150 feet square, will be enclosed with six-foot vinyl deer fencing to prevent soil and vegetation disturbance. Studies will focus on methods of tree removal and management that can mitigate soil erosion and encourage the regeneration of native plant species. We anticipate that the study will conclude in the fall of 2007.

This research is conducted in collaboration with the Harvard Forest, a research institute for the study of forest ecology. Findings will be used to assist stewardship efforts for other New England landscapes. For more information, please visit us online at www.arboretum.harvard.edu, or call Richard Schulhof at 617.524.1718 x133.

The Arnold Arboretum is operated through a public/private partnership between the City of Boston and Harvard University.

REU student Chris Petit, from Carleton College and Missy Holbrook's group, examined whether HWA infection alters the xylem properties of twigs and leaves. The work was motivated by the desire to understand how HWA kills hemlock trees. The hypothesis was that HWA infected branches would be more vulnerable to cavitation or show signs of xylem dysfunction. Instead, they found that HWA infected branches were thicker and the needles longer

Julian Hadley discussing the old hemlock forest on Prospect Hill with the Freshman Seminar.

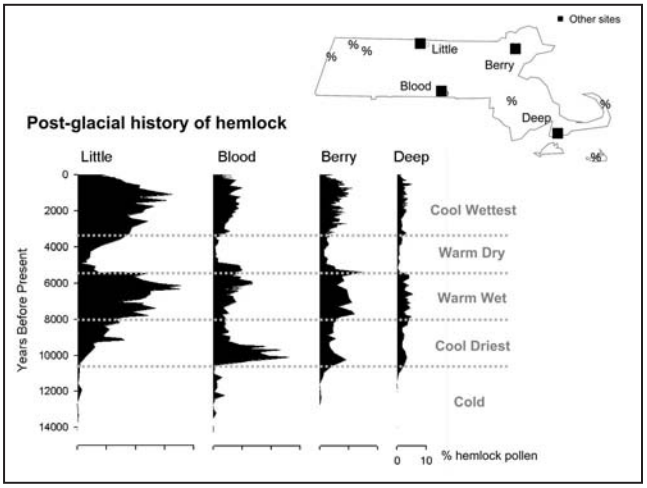
– suggesting that HWA stimulates greater phloem unloading close to sites of infection, leading to greater investments in xylem. As the adelgids feed on xylem parenchyma, this sort of insect:tree "manipulation" makes sense. This line of research continues this year, led by post-doctoral fellows Kristin Lewis and Sanna Sevanto, in collaboration with REU student Anne Marie Casper from Hampshire College.

Comparative Studies at the Arnold Arboretum

In cooperation with Peter del Tredici, Richard Schulhof, and Robert Cook, Dave Orwig and Heidi Lux began a study of hemlock dynamics at the Arnold Arboretum examining Hemlock Hill. This forest, long considered a remnant of the original forest in the heart of Boston was infested by HWA in the past 10 years. From 1998 to 2002, nearly 300 trees have died or were removed due to poor health and 70% of the remaining 1600+ trees are in poor condition. The Arboretum has developed plans for managing the area and all hemlocks have been tagged, measured for diameter, assigned a crown health rating, and mapped. Since this is a heavily used park many of the dead and dying trees will be removed to reduce risk. This unfortunate situation provides us with an opportunity to examine the impacts of hemlock death and removal in an urban environment with regard to nutrient cycling, microclimate, and vegetation, especially the spread of invasive plant species. This year we began collecting baseline soils and vegetation information in six plots. Hemlocks will be removed from four plots this winter and two plots will remain as controls. This urban project will provide a nice comparison to our other studies including the large experiment at the Simes tract *(above)*.

Carbon Dynamics of Hemlock Forests Before and After Infestation by the Aadelgid

In mid-April 2004 Julian Hadley and Paul Kuzeja resumed forest-atmosphere measurements in the old-growth hemlock stand in the Prospect Hill tract. Data summarized through June are consistent with previous (2001) results and show that maximum rates of carbon uptake are about one-third lower than maximum rates for the deciduous forests. An important additional measurement this year is water vapor flux (evapotranspiration or ET), which was lower than in the deciduous forest. The plan is to continue both measurements in the old-growth hemlock forest during the anticipated spread of hemlock woolly adelgid (HWA), which occurs at low abundance currently and has caused no significant damage. However, HWA population growth was slowed by the



Dynamics of Hemlock in the Massachusetts landscape since deglaciation. Although the abundance of hemlock varies across the state the broad pattern of change is similar at these four sites. The major decline at approximately 5000 years ago is associated with the outbreak of an insect pest and climate change.

The Paleoecology and coastal research crew with a sediment core from the Elizabeth Islands: David Foster, Sarah Truebe, Posy Busby, Glenn Motzkin, Elaine Doughty, and Wyatt Oswald.

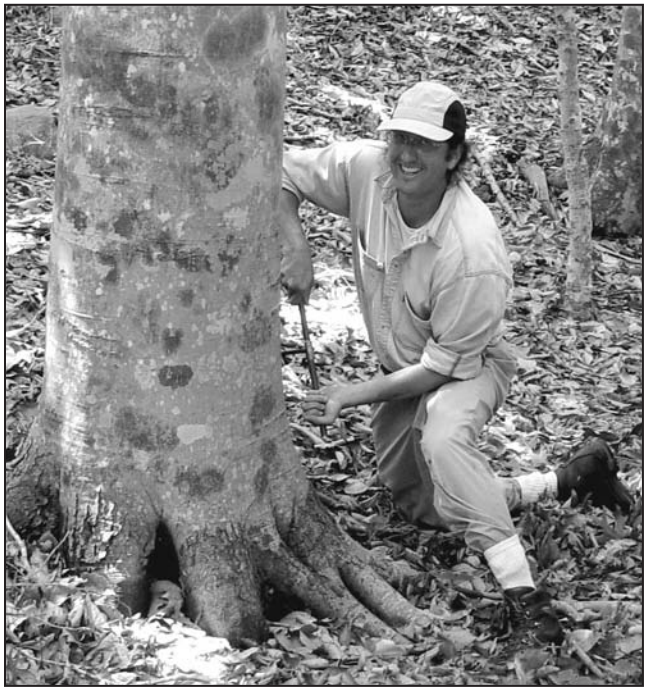
extremely low January temperatures (below –25˚C) and may expand rapidly when milder winters occur.

In a complementary effort Paul Moorcroft and Marco Albani are modeling the consequences of HWA infestation on carbon dynamics across New England. They have developed a GIS-based version of the Ecosystem Demography (ED) model that incorporates HWA and hemlock. Using this framework and data assembled by Dave Orwig and other researchers, they developed a HWA spread scenario and conducted simulations of the HWA impact on forest dynamics, biogeochemistry, and atmospheric fluxes. The ED simulations predict a substantial impact of the HWA infestation on the carbon dynamics, quickly turning these ecosystems from an average sink of about 0.1 Kg C m^2 yr^{-1} into a regional carbon source of -0.01 Kg C m^2 yr^{-1} by as early as 2005. While the local magnitude of the impact will vary depending on the abundance of hemlock and land use history, the simulations predict that the signature of the infestation will be observed for up to forty years.

Long-term Changes in Climate and Vegetation

To better understand the response of forest ecosystems to environmental change, our paleoecology group is studying post-glacial climate and vegetation history across New England. Current and former researchers, including Elaine Doughty, Ed Faison, Dana MacDonald, Sylvia Barry Musielewicz, Tim Parshall, Wyatt Oswald, and David Foster, have collected lake-sediment cores from more than two dozen sites in Connecticut, Massachusetts, and Vermont. Analyses by us and collaborators, Jim Huber, Barbara Hansen, and Natalie Drake, document the major changes in vegetation that have occurred in this region over the past ~15,000 years. A particular research focus, initiated by David Foster and Ed Faison, has been the post-glacial history of hemlock. By reconstructing the response of hemlock to environmental change, a mid-Holocene decline related to an insect pathogen, and land-use activities, this project provides a long-term context for our other studies on the ecological impact of the hemlock wooly adelgid.

Matts Lindbladh, a Bullard Fellow from the Swedish University of Agricultural Sciences, has developed a related study examining spruce dynamics in the late-glacial period. By applying a technique he developed for differentiating the pollen of spruce species, Matts has documented a previously



Glenn Motzkin coring a beech tree on the Elizabeth Islands.

REU student Ali Rosenberg and Jess Butler.

unknown shift from white spruce to black spruce ~13,000 years ago. This work has important implications for interpreting the environmental characteristics of a period of rapid climate change and Matts, Wyatt, and David are continuing these analyses.

Pitcher Plants.

Research on the long-term history of the coastal ecosystems of New England and New York continues, including analyses of pollen and charcoal in a sediment core from Wildwood Lake, a site located in the central pine barrens of Long Island. To increase the network of coastal paleoecological records, a team of researchers, including David Foster, Wyatt Oswald, Glenn Motzkin, Posy Busby, Elaine Doughty, and REU student Sarah Truebe, collected sediment cores from three lakes on the Elizabeth Islands. Analyses of those records will inform coastal conservation efforts and management of the island's forests and grass-, heath-, and shrub-land ecosystems and should complete our initial paleoecological efforts in this region.

The Nitrogen Budget of Pitcher Plants

Aaron Ellison and Jess Butler continued to investigate how wetland communities assemble, disassemble, and reassemble in the face of chronic stresses. A series of experiments are documenting the sources, pathways, and sinks of nitrogen that pitcher plants require to grow and reproduce. The leaves of the northern pitcher plant, *Sarracenia purpurea*, a familiar carnivorous plant throughout North America, fill with rainwater into which ants, flies, moths, spiders, and occasional salamander larvae fall and drown. A small aquatic food web consisting of bacteria, protozoa, rotifers, mites, and larvae of mosquitoes and midges digests the arthropod prey and mineralize its nitrogen. In the last several decades, as inorganic nitrogen concentrations in rainfall have increased, pitcher plants in New England have been able to rely more on that nitrogen source and less on carnivory. Data collected by Aaron, Jess, and REU student Dan Atwater show that plants respond rapidly to additions of inorganic nitrogen, but respond little to additions of prey. These data complement data collected with University of Vermont colleagues Nick Gotelli, Sarah Wittman, and Amy Wakefield, that show that pitcher-plant stoichiometry is changed following the addition of inorganic nutrients but not prey. We hypothesize that the inorganic nitrogen in rain is used immediately, whereas nitrogen mineralized from prey is stored in rhizomes for growth and reproduction in subsequent years. Aaron and Jess, along with graduate student Jim Karagatzides (Queen's University, Ontario) and REU student Ali Rosenberg are conducting experiments using stable isotopes of nitrogen (^{15}N) and carbon (^{13}C) to test this hypothesis.

Studies in Aquatic Ecology and Forest Hydrology

Studies in aquatic ecology proceeded along several fronts, including salamander distributions in forest stands, the ecology of kettle ponds and lakes in Cape Cod National Seashore, salt-tolerance in nuisance midges on Cape Cod, the ecology of stream headwaters in hemlock and hardwood forests, studies and syntheses of vernal pool ecology, and education and outreach.

Salamanders

Graduate student Brooks Mathewson, working with Betsy Colburn and David Foster, surveyed the distribution and abundance of red efts (the terrestrial, juvenile stage of an aquatic salamander, the red-spotted newt) and redback salamanders (terrestrial salamanders common in northeastern woodlands) in hemlock and deciduous stands. He was investigating whether the loss of hemlock due to the hemlock woolly adelgid might affect populations of either species. Initial results show that red efts were significantly more common in hemlock than in deciduous forests, and that their abundance was negatively correlated with soil pH. Redbacks were more common in deciduoius stands when sampled by intensive searches of quadrants, but more common in hemlock under artificial cover boards. There were no identified environmental correlates of distribution using either method.

Cape Cod Waters

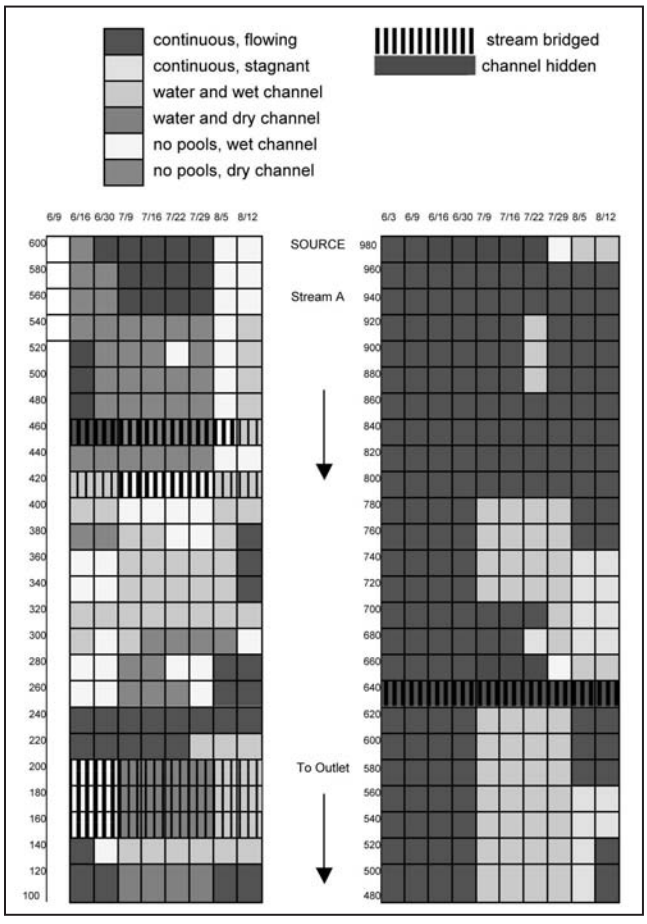
Holly Jensen-Herrin, Betsy Colburn, and assistants sampled kettle ponds, lakes, and vernal pools in the Cape Cod National Seashore. They are in the process of identifying animals in order to identify relationships between habitat characteristics of the water bodies and the composition and structure of the aquatic communities. The ultimate goal is to develop a long-term monitoring program for the National Seashore.

Nuisance Midges

Betsy Colburn analyzed results of her study of salt-tolerance in nuisance midges from East Harbor, Cape Cod National Seashore, for presentation at the joint meeting of the New England Biological Assessment of Wetlands Workgroup and the New England Association of Environmental Biologists, and at the North American Benthological Society. There is great interest in the study from the Park Service, residents of Massachusetts coastal communities where nuisance midge emerge in summer, and scientists. Results suggest that alteration of tidal flow by human activities may have allowed the development of high midge densities. Consequently, the high salinities achieved by restored tidal flow should theoretically, limit major midge emergences in future.

Forest Streams

Water flow, temperature, chemistry, and biology in small streams are highly dependent on the surrounding vegetation and current and past land use, and Betsy is investigating these relationships in old-growth forests and hemlock forests as affected by the hemlock woolly adelgid. Working with Betsy, Holly



Streamflow in the top 500 m of two headwater tributaries of Nelson Brook, Prospect Hill Tract of the Harvard Forest, in summer, 2003.

Jensen-Herrin is completing her Master's thesis at Antioch College on differences in the biological communities of headwater stream reaches with perennial and intermittent flow in an old-growth hemlock forest on Mt. Wachusett. They have comparable data from deciduous forest streams on the mountain. Several species, including some caddisfly larvae, are indicative of intermittent reaches.

REU student Kate Musgrove worked with Betsy examining the biota and water flow in Bigelow Brook and Nelson Brook on the Prospect Hill Tract. Kate produced a graphic illustration of changes in streamflow over time and Ethan Forbes, a fourth-grade teacher from Orange, Massachusetts, is extending this work. REU students Gavin Ferris and Bridget Collins are working with Betsy and Bill Sobczak,from Holy Cross College, to collect baseline data on stream habitat and biota from pairs of hemlock- and hardwood-dominated streams in north central Massachusetts, including the Prospect Hill and Slab City tracts, Mt. Wachusett, Erving and Wendell State Forests, and the Quabbin Reservation. The data will help us understand differences in community composition, trophic dynamics, and carbon flows associated with forest type.

The Hydrology of Forest Streams

Plans for long-term hydrological measurements on the Prospect Hill tract have been advanced by Emery Boose, Betsy Colburn, and Paul Barten. A survey of Harvard Forest researchers identified major questions that might be addressed by such measurements and solicited recommendations on methods and locations for studies. A draft plan for weirs and wells in the Nelson and Bigelow Brook watersheds was created based on the survey, field inspections, and GIS analyses. Installations should begin this fall. In the meantime, new sensors were added to the Fisher Meteorological Station to measure photosynthetically active radiation (PAR) and net radiation (short and long wave), essential parameters for hydrological modeling. Ground water measurements made by Walter Lyford in the early 1970s were also analyzed by REU student Debarat Perez-Rivera and his original wells were relocated in the Prospect Hill Tract.

Vernal Pools

Vernal pools are part of the gradient of aquatic systems being sampled on Cape Cod, and this year they are also the subject of a comprehensive book, *Vernal Pools*, written by Betsy and due out this summer from McDonald and Woodward, publishers.

Forest Exchanges and Interactions with the Atmosphere

The flux tower at Harvard Forest Environmental Measurement Site (HFEMS) run by Steve Wofsy and Bill Munger in the department of Earth and Planetary Sciences serves as the focal point for diverse studies. Here they measure the exchange of CO_2, H_2O, heat, and nitrogen oxides by eddy covariance and air pollutants, including CO, NO, NO_2, O_3, and PAN, and CFC concentrations. Among other things, these data provide a measure of the NET exchange of CO_2 from the forest. From the nighttime data alone ecosystem respiration is estimated. The gross exchange (or photosynthesis) is given by subtracting respiration from the net ecosystem exchange. To complement the CO_2 flux data field measurements extending upwind from the tower assess the seasonal and annual dynamics of carbon, including tree growth and mortality, coarse woody debris, and litter fall. Additional measurements were initiated in 1999 to assess the changes in the carbon cycle resulting from logging of adjacent forests. As part of her undergraduate thesis, Kathryn McKain is examining the spatial context of these measurements by re-surveying other sets of plots.

Tree Ring Analyses

Red oak and red maple are the primary contributors to carbon uptake in the forest surrounding the eddy-flux tower and we sampled both to compare tree-ring estimates of their growth. Red maples exhibit great radial growth plasticity. For example, on a given tree one side may experience a significant growth reduction for a decade while another side grows normally. Also individual trees may show nearly no growth for a decade or more. This plasticity suggests a survival strategy that allows red maple saplings to persist through years of poor growing conditions. A combination of abiotic and biotic factors reduced red maple growth. The largest growth declines occurred after gypsy moth defoliation in 1981, which also coincides with 6 years of August drought and two cold winters during the early 1980s. From 1930–1994 red maple

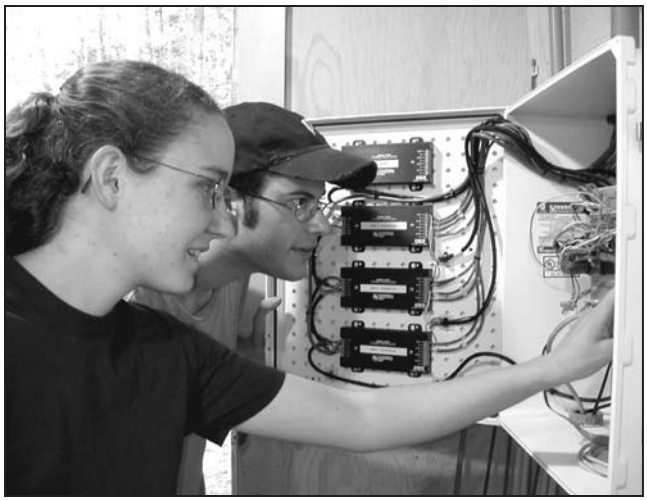
growth was strongly correlated to increased August precipitation and prior-October through January temperatures. In contrast red oak was only weakly correlated to August precipitation and prior October temperatures and significantly, but negatively correlated to February temperatures. Since oak was also negatively impacted by gypsy moth defoliation, its dominant canopy position and relative insensitivity to winter temperatures appear to give it a competitive advantage over maple. Consequently at the tree scale the contribution of red maple to forest carbon uptake is declining. However, due to their large numbers red maple still contributes significantly to stand level carbon uptake. Chronologies of 18 red oak populations covering central New England and New York will be used to place the Harvard Forest results into a long-term and regional perspective.

Carbon Dynamics in Hardwood Forests

Julian Hadley and Paul Kuzeja extended their measurements of carbon exchange in the oak, birch, and red maple forest on Little Prospect Hill (LPH) and compared their results with measurements from the Environmental Measurement Site (EMS). The two forests have similar composition but differ in age (less than 50 years old at LPH versus 70 to more than 100 years at EMS) and topographic and hydrologic positions (the EMS is in a low lying area). The sites show very similar annual patterns of carbon exchange and rates of summer storage. However, the forest on LPH had lower carbon storage during the growing season due to a shorter season of carbon storage but a lower net loss of carbon through ecosystem respiration in the winter. These differences approximately balance leading to approximately the same annual C storage (2.5 Mg C/ha) for November 2002 through October 2003.

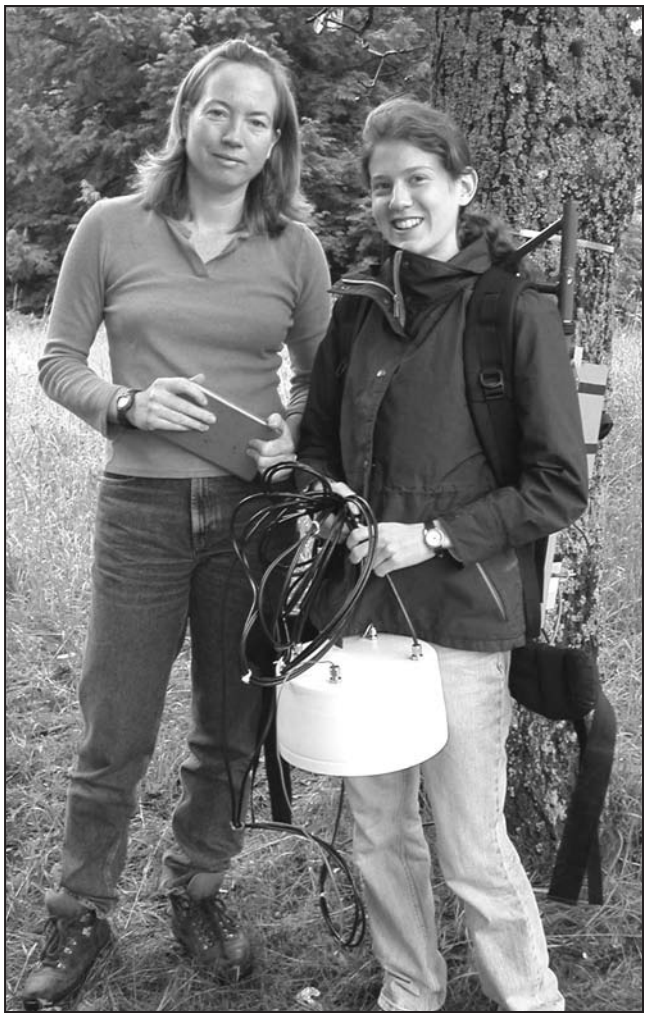
Experimental Assessment of the Impacts of Global Warming

In the soil warming experiments conducted by our LTER collaborators from the MBL Ecosystem Center the effects of climate change are being assessed by warming the forest soil in permanent plots by five degrees above ambient temperature. Studies of carbon and nitrogen dynamics at the Prospect Hill soil warming experiment, now in its 14th season, were continued and expanded as Serita Frey (University of New Hampshire) and graduate student Heather Smith sampled soil microbial communities. In addition, the first full year of data were collected from the Megaplot experiment in the Slab City tract that is addressing the question: Does the forest use the additional nitrogen made available from soil warming to process and store more carbon? If so, northern temperate forests could act as a net carbon sink and reduce the amount of "greenhouse gas" carbon in the atmosphere.



Liz Burrows and REU student Robert Hanifin.

After one year of warming, monthly soil CO_2 efflux increased an average of 31% and nitrogen mineralization increased an average of 38%. Understory biomass increased 46%, and foliar nitrogen increased significantly for birch (22%) and ash (9%). Jacqueline Mohan is testing the hypothesis that soil warming could affect forest regeneration, forest succession, and future net ecosystem productivity (NEP) by benefiting tree species differentially. Assessing 12 tree species, she found a 50% enhancement in the productivity of seedlings and saplings. The heating effect was negatively correlated with intrinsic growth rate, so that warming preferentially benefited slower-growing taxa. If this effect persists, carbon uptake by forests may be less than suggested by current estimates based on highly productive stands. REU student Robert Hanifin, is studying the implications of soil warming for the reproduction of the common herbs: Canada mayflower *(Maianthemum canadense)* and star flower *(Trientalis borealis)*. His initial findings suggest that with warming wildflowers shift their reproductive efforts away from sexual reproduction and toward the production of vegetative "clones."



Kathleen Savage and REU student Rose Phillips.

These results could have consequences for the genetic diversity of future forests.

Responses of Soil Respiration to Variations in Temperature and Precipitation

Throughfall Exclusion Experiment

Soil moisture affects microbial decay of soil organic matter, but interpreting the effects of summer drought is difficult because moisture and temperature often change simultaneously. A group led by Eric Davidson at the Woods Hole Research Center distinguished between these effects by simulating a prolonged drought. Roofs constructed over 5×5 m plots excluded water falling into the stands in contrast to adjacent control plots. Subsequently, the roofs were removed in order to assess the response of soil respiration to two years of summer droughts. Drought decreased annual soil respiration by 10–30% and annual net ecosystem exchange of C by 35–75% largely due to differences in water content in the litter layer and a decrease in primarily microbial respiration. We do not know if this soil C sink during drought is transient or long-lasting as the carbon stored during the simulated drought was only partly released through respiration during the following summer of natural throughfall. Nonetheless, differential decomposition of the litter layer caused by interannual variation of precipitation probably contributes significantly to observed interannual variation of net carbon uptake by the forest.

Nine Years of Soil Respiration Studies

In 2004, Eric's group began their tenth year measuring soil respiration at the Forest. These studies have demonstrated large differences among years in fluxes of CO_2 from the soil. The fluxes tend to be much lower during years with summer droughts, which is consistent with the results from the throughfall exclusion experiment. In 2003, a second year of data was collected from a system that measures soil respiration hourly with chambers that automatically move up and down and a system that circulates chamber air for CO_2 analysis. These high frequency data allow the study of responses to individual wetting events. Conclusion: even a small rainfall event that wet up only the litter layer, caused pulses of CO_2 flux.

Studies in Tree and Plant Biology

Biophysics of Plant Form and Function

Research in the lab of Missy Holbrook, professor in the Department of Organismic and Evolutionary Biology, focuses on the biophysics of plant form and function with an emphasis on the vascular system of trees. The Harvard Forest forms an outdoor laboratory for this work, one greatly aided by the new aerial lift ("Bucky"), which enables the study of large trees and their canopies. Activities this year were diverse, involving three REU students, graduate students from Chile and Brazil, and collaboration with Bullard Fellow Tom Sinclair. Post-doctoral fellow Brendan Choat worked with REU student Nora Lahr examining how vulnerability to cavitation varies along the length of tall sugar maple trees. Using an approach that allows us to measure the cav-

itation susceptibility of individual xylem vessels, Brendan and Nora made the first ever measurements of cavitation vulnerability in trunks and large branches. These data demonstrate that the main stem is better protected against cavitation than are terminal branches and roots, despite the fact that vessel diameters are largest in the main trunk.

A second study led by Maciej Zwieniecki, Sargent Fellow at the Arnold Arboretum, and Gina Cardinot from the Federal University of Rio de Janeiro, examined the relationship between cavitation of fine veins in leaves of red oaks and stomatal closure. Their work supports the idea that the measured declines in leaf hydraulic conductivity in oaks are due to xylem cavitation, rather than conduit collapse. Missy's lab also hosted graduate student Mylthon Jimenez, from the University of Concepcion, Chile, whose detailed measurements of the hydraulic properties of frond and rachis tissues of eight species of ferns make one of the most extensive studies of fern water relations.

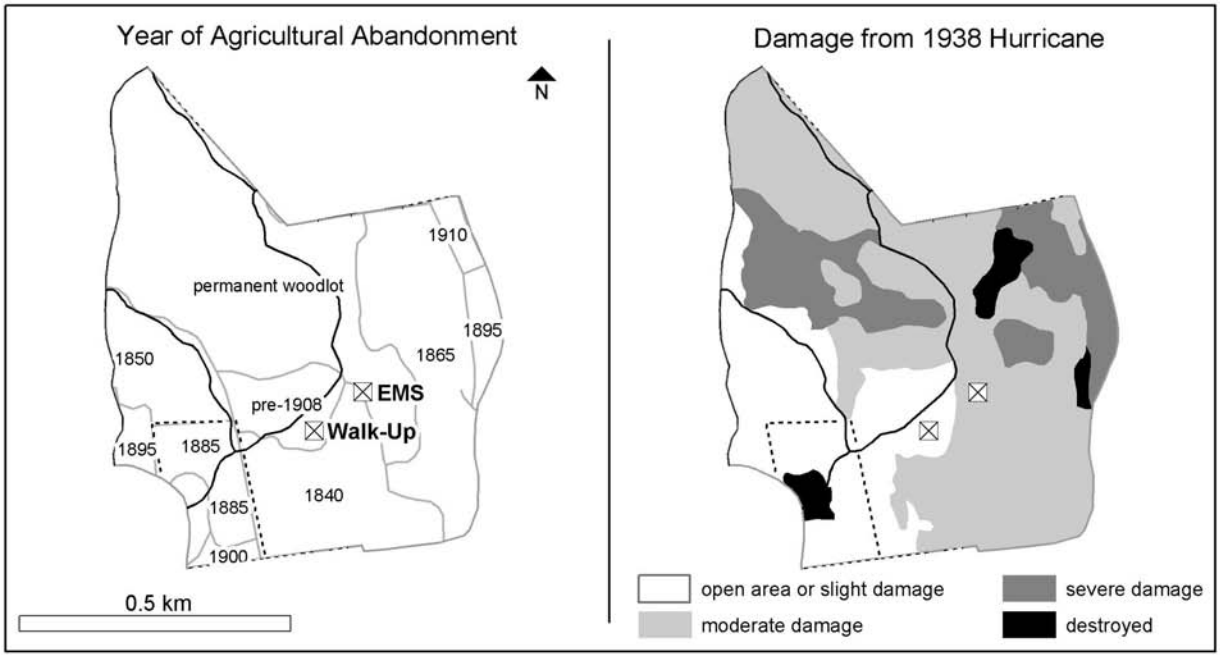
Rachel Spicer, Ph.D. student in Organismic and Evolutionary Biology, continues to work on the physiology of heartwood formation in large trees. Over the past year she has demonstrated that O_2 concentrations in the inner sapwood do not significantly depress sapwood parenchyma respiration rates, a finding consistent with the hypothesis that the death of xylem parenchyma forms part of a developmental program, rather than being the result of deteriorating conditions within stems. Rachel's current work explores the potential role of programmed cell death in heartwood formation.

Using material collected at Tom Swamp, Kajetan Zwieniecki is exploring the hydraulics of water lilies. She discovered that lilies partition water uptake through the long petiole from that absorbed through the abaxial leaf surface. Sanna Sevanto is using an approach that she developed during her Ph.D. studies in Finland to look at phloem transport in large trees, especially estimating the lateral hydraulic connectivity between xylem and phloem.

Geographic Information System Developments

Harvard Forest Tract Maps

Since 1908, researchers at Harvard Forest have mapped and conducted inventories of the forests approximately every 10 to 20 years. Environmental



Propsect Hill Compartment 7 – an example of some of the informative maps recently made available in GIS format.These datalayers provide important historical context to research sites in the Harvard Forest's three major tracts such as the EMS and Walk-up Towers.

features including soils, elevation, damage from the 1938 hurricane, and silvicultural treatments were also documented. This past year Julie and Brian Hall digitized these data to make them available for downloading from the Harvard Forest Web site. This georeferenced data will provide convenient and valuable historic and environmental context for the numerous research projects conducted on our major tracts.

1830 Map Series

Given the history of deforestation and reforestation in New England the 1830 map of Massachusetts' woodlands has been an important research tool as it provides insight into the histories of individual study locations and the state as a whole. Since 1830 was near the peak of deforestation, we have hypothesized that many of the sites that were wooded at that time have remained wooded until the present. In turn these forests may differ in vegetation structure and composition and ecosystem processes from adjoining sites that were deforested and then reforested. This year Brian Hall, Glenn Motzkin, and David Foster have begun an analysis of this map to describe more fully where the 1830 woodlands were, what factors controlled their spatial distribution, and what legacies this history imparts to modern forests conditions. These results will allow us to model forest locations in towns without 1830 maps and to evaluate the reliability of the map in specific areas. Mid-nineteenth century historical documents including census data, diaries, and agricultural journals will be examined to understand the structure, composition, and use of these woodlands. In a related study, we will conduct field surveys comparing the forest vegetation and soil characteristics between sites that were shown as wooded versus open on the 1830 map; this will enable us to determine the legacies of nineteenth century land use on modern forests.

HARVARD FOREST ECOLOGY SYMPOSIUM 2004 (*denotes summer students)

M. Albani and P. Moorcroft. *Modeling the Impact of Hemlock Loss on New England Forests with the Ecosystem Demography Model.*

I. C. Baillie. *A Comparison of Methods for the Characterisation of the Edaphic Environments of Some CTFS-Asia Plots in Tropical Rain Forests.*

A. Barker Plotkin, A. Ellison, J. Butler, D. R. Foster, and D. Orwig. *Establishment of the Hemlock Removal Manipulation Study.*

A. Barker Plotkin, K. Wilson,* and D. R. Foster. *Harvard Forest Hurricane Experiment: The Next Generation.*

M. Battle. *Measurement of the O_2-CO_2 Stoichiometry of Terrestrial Ecosystems.*

E. Boose, E. Colburn, and P. Barten. *Hydrological Stations.*

E. Boose. *Information Management.*

B. H. Braswell, S. C. Hagen, E. Linder, S. V. Ollinger, and A. Richardson. *A Statistical Analysis of Tower-Based Estimates of Gross Primary Production.*

J. Burk, J. Hall, B. Hall, D. Kittredge, D. R. Foster, and G. Motzkin. *Forest Harvesting in Massachusetts.*

J. L. Butler, D. Atwater*, and A. M. Ellison. *Northern Pitcher Plants a Sink for Red Spotted Newts.*

D . Causey. *Seasonal Dynamics and Higher-Order Community Structures of Birds and Their Parasites at Harvard Forest.*

E. Colburn and H. Jensen-Herrin. *Aquatic Macroinvertebrates as Indicators for Biomonitoring Long-Term Change in Lakes and Ponds in the Cape Cod National Seashore.*

E. Colburn. *Salt-Tolerant Midges: Important Considerations for Restoration of a Coastal Wetland in the Cape Cod National Seashore.*

M. H. Conte and J. C. Weber. *Molecular and Isotopic Studies of Biogenic Aerosols and Source Vegetation at the Howland Forest Ameriflux Site.*

S. D. Costa, J. Brown*, D.A. Orwig and B.L. Parker. *A Sampling Plan for Hemlock Woolly Adelgid.*

P. Crill and R. Varner. *High Frequency Measurements of CO_2 Efflux from Forest Soil.*

A. W. D'Amato and D. A. Orwig. *The Structure and Composition of Old-Growth Forests in the Berkshire Hills of Western Massachusetts.*

E. A. Davidson, K. Savage, D. Hollinger, and A. Richardson. *The Ratio of Soil: Ecosystem Respiration Varies Seasonally at Howland and Harvard Forests.*

A. M. Ellison, J. Chen*, and M. Lau*, and N. J. Gotelli. *Ant Diversity at the Harvard Forest: Preliminary Data from the Prospect Hill and Simes Tracts, with Additional Observations from the Chronic N Addition Plots.*

E. K. Faison, D. R. Foster, W. W. Oswald, B. C. S. Hansen, and E. Doughty. *The Post-Glacial History of Hemlock in Massachusetts.*

D. R. Fitzjarrald, R. K. Sakai, M. Czikowsky, A. Tsoyref, and R.M. Staebler. *Forest-Atmosphere Exchange Processes: Report on Activities 2003–2004.*

S. D. Frey, M. Knorr, J. L. Parrent, and R. T. Simpson. *Chronic Nitrogen Enrichment Affects the Structure and Function of the Soil Microbial Community.*

E. Gaige, B. Dail, E. Davidson, D. Hollinger, H. Sievering, M. LeClerc, and J. Aber. *A Nitrogen Experiment in a Maine Spruce-Hemlock Forest: Results From a Wet NH_4NO_3 Canopy Fertilization.*

M. Glessner, B. Dail, E. Davidson, J. Chorover. *Factors Affecting Saturability of Nitrate Immobilization in Northern Forest Soils.*

J. Hadley and P. Kuzeja. *Ecosystem Carbon Exchange on Little Prospect Hill.*

B. Hall, G. Motzkin, and D. R. Foster. *Massachusetts' Woodlands in the Mid-19th Century: Where Were They, What Did They Look Like, and What Are Their Long-Term Legacies.*

S. S. Jefts and D. A. Orwig. *Assessing N Availability Through Multiple Resin Extractions Following the Onset of the Hemlock Woolly Adelgid.*

J. P. Jenkins, L. Plourde, S. V. Ollinger, M. E. Martin, M-L. Smith, A. D. Richardson, D. Y. Hollinger, and B. A. Braswell. *Scaling Forest Canopy Carbon Flux From Sites to Landscapes Using Airborne Remote Sensing and Canopy Nitrogen Chemistry.*

H. Jensen-Herrin, D. Williams, and E. A. Colburn. *Salamanders and Benthic Invertebrates in the Headwaters of Bolton Brook, Mount Wachusett, Massachusetts.*

D. B. Kittredge. *Timber Harvest in a Fragmenting Landscape Dominated by a Diversity of Ownerships*.

D. Köster and R. Pienitz. *Environmental History of Two New England Ponds: Natural Dynamics Versus Human Impacts*.

C. Lai, J. Ehleringer, A. Schauer, D. Hollinger, K. T. Paw U, J. W. Munger, and S. Wofsy. *Photosynthetic 13C Discrimination in North American Temperate Forest Biomes*.

K. C. Lewis and F. A. Bazzaz. *Does Evolutionary Change in Resource Allocation by Alliaria petiolata Drive Invasiveness?*

M. Lindbladh, E. Faison, D. R. Foster, and W. W. Oswald. *The Rise and Fall (and Rise and Fall) of Spruce in Massachusetts*.

H. Lux, E. Burrows, J. M. Melillo, P. A. Steudler, F. P. Bowles, S. Morrisseau, and A. Chan. *Soil Warming at Barre Woods: Megaplot Responses after One Year of Warming*.

A. H. Magill, J. D. Aber, W. Currie, K. J. Nadelhoffer, M. E. Martin, W. H. McDowell, J. M. Melillo, and P. Steudler. *Ecosystem Response to 15 Years of Chronic Nitrogen Additions*.

B. Mathewson, E. Colburn, and D. R. Foster. *Salamanders in Eastern Hemlock Stands – The Forgotten Forest Fauna*.

P. Medeiros, M. H. Conte, J. C. Weber, and B. R. T. Simoneit. *Sugar Biomarkers as Source Indicators of Biogenic Organic Carbon in Aerosols Collected at the Howland Experimental Forest, Maine*.

J. M. Melillo, P. A. Steudler, H. B. Lux, E. H. Burrows, J. D. Aber, F. P. Bowles, E. Farnsworth, and A. Chan. *Soil Warming on Prospect Hill: The First Decade and Beyond (1991–2003)*.

Q. Min. *Impacts of Aerosols and Clouds on Forest-Atmosphere Exchange*.

Q. Min and B. Lin. *Satellite Observations of Forest-Atmosphere Exchanges*.

J. E. Mohan, F. A. Bazzaz, E. Burrows, H. Lux, and J. M. Melillo. *Soil Warming Hastens Successional Dynamics in a Temperate Forest Ecosystem*.

G. Motzkin, D.R. Foster, D. Kittredge, J. Burk, B. Hall, and J. Hall. *Twenty Years of Forest Harvesting Across Massachusetts: Influences on Stand Composition and Invasive Plant Species*.

G. Motzkin, D. A. Orwig, and D.R. Foster. *Vegetation and Disturbance History of Ridgetop Pitch Pine and Red Pine Communities in Southern New England*.

J. O'Keefe. *Woody Species Phenology, Prospect Hill Tract, Harvard Forest – 2003*.

S. Ollinger, M-L. Smith, J. Jenkins, L. Plourde, M. Martin, D. Hollinger, and J. Aber. *Scaling Forest Productivity Through Space and Time Using Hyperspectral Remote Sensing and Ecosystem Modeling*.

D. Orwig, P. del Tredici, H. Lux, R. Schulhof, and D. R. Foster. *Hemlock Woolly Adelgid at the Arnold Arboretum: Threats and Opportunities*.

D. Orwig and N. Povak.* *Landscape Level Analyses of Hemlock Woolly Adelgid Outbreaks in Massachusetts*.

D. Orwig, L. Pustell, S. Jefts, and D. R. Foster. *Community and Ecosystem Effects of HWA-Induced Logging*.

D. Orwig, S. Jefts, L. Pustell, and D. R. Foster. *Ecosystem Analyses of Hemlock Woolly Adelgid Outbreaks in Southern New England*.

W. W. Oswald, D. R. Foster, and G. Motzkin. *Late Holocene Vegetation Patterns of the Coastal Region of Southern New England and New York*.

N. Pederson, E. Hammond Pyle, A. Barker Plotkin, G. Jacoby, and S. Wofsy. *Contribution of Red Maple to Carbon Uptake in the Eddy-flux Tower Plot Forest*.

N. Phillips, M. Daley, M. Friedl, and G. Salvucci. *Vegetation Control of Ecohydrologic Processes*.

E. Hammond Pyle, C. M. Jones, S. Urbanski, K. McKain*, Z. Liscow*, V. Y. Chow, L. Hutyra, J. Budney, J. W. Munger, and S. Wofsy. *Carbon Dynamics at Harvard Forest: Results from the EMS Tower and Ecological Plots*.

F. Rockwell. *Red Maple Re-Visited*.

L. E. Rustad, I. J. Fernandez, S. McNulty, A. Magill, J. D. Aber, and the NERC N Network. *A Cross-Site Study on the Effects of Experimental N Additions on Fine Root Biomass, N Concentration and Total Soil Respiration*.

K. Savage, E. A. Davidson, and D. Hollinger. *Coherence Analysis of High Frequency Soil Respiration, Temperature and Moisture Measurements*.

N. Scott, E. Davidson, D. Hollinger, C. Rodrigues, J. Lee, H. Hughes, J. Walsh, and P. Malerba. *Changes in Carbon Storage and Net Carbon Exchange After a Shelterwood Harvest at Howland Forest, Maine*.

T. Sipe, J. Clowers*, A. Sanchez Sierra*, and J. Vuong*. *Temporal and Spatial Variation of Neargound Atmospheric CO_2 in a Permanent Woodlot Site in Prospect Hill*.

H. Smith, S. D. Frey, M. Knorr, H. Lux, and J. Melillo. *Microbial Responses to Soil Warming*.

W. Sobczak and E. Colburn. *Forecasting Stream Ecosystem Responses to a Regional Landscape Disturbance: Indirect Ecological Consequences of the Removal of Eastern Hemlock from New England Forests.*

R. Spicer and N. M. Holbrook. *Heartwood Formation in Forest Trees: Parenchyma Cell Death as a Driver of Sapwood Senescence*.

P. A. Steudler, A. K. Chan, J. D. Aber, J. Gulledge, C. Cavanaugh, and J.M. Melillo. *Long-Term Trends in Soil CH_4 Consumption at the Harvard Forest Chronic Nitrogen Addition Experiment: Implications for the Future Growth in Atmospheric CH_4.*

K. A. Stinson and F.A. Bazzaz. *Elevated CO_2 Allows Smaller Plants to "Catch Up" to Dominants in Competing Stands of Common Ragweed (Ambrosia artemisiifolia).*

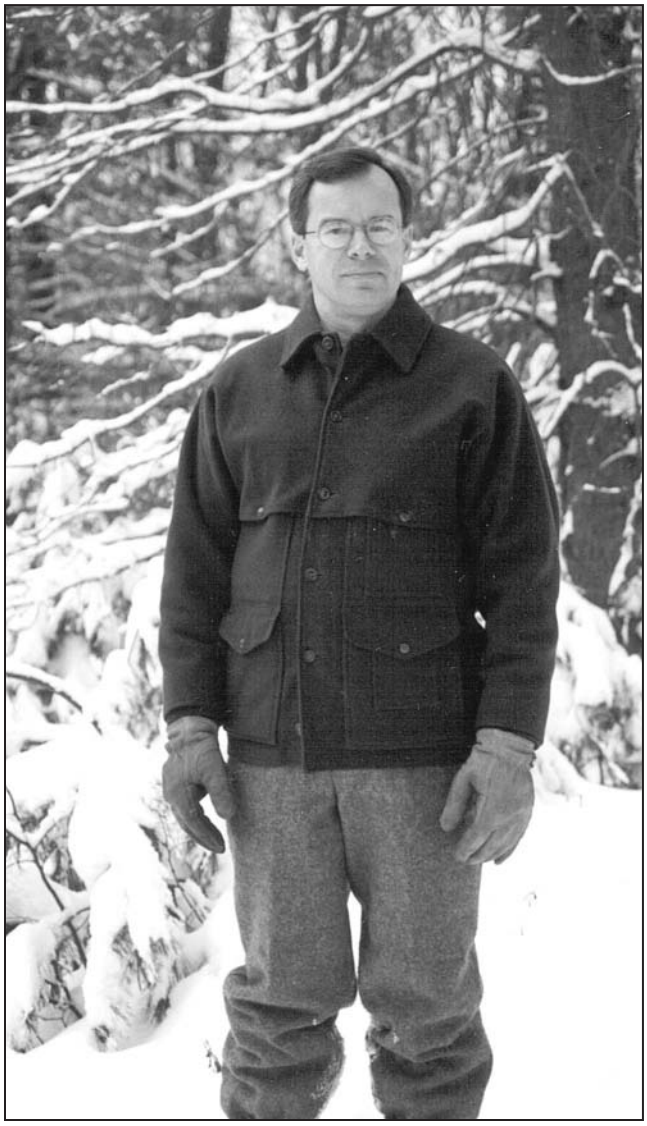
K. A. Stinson. *The Impact of Garlic Mustard* (Alliaria petiolata) *on Native New England Forest Communities and the Importance of Habitat for Controlling its Spread.*

B. Von Holle, D. R. Foster, and G. Motzkin. *Historic and Current Influences on Habitat Invasibility in a Mosaic Landscape: Cape Cod National Seashore.*

K. Wilson*, A. Barker Plotkin, and D. R. Foster. *Hurricane Damage Exerts Long-Term Effects on Forest Development.*

X. Xiao, Q. Zhang, B. Braswell, S. Urbanski, S. Boles, S. Wofsy, B. Moore, III, and D. Ojima. *Satellite-Based Modeling of Gross Primary Production in a Deciduous Broadleaf Forest.*

BULLARD FELLOWS



Paul Barten.

Ian Baillie (Cranfield University, U.K.) continued his studies on the soils of tropical forests and the role of edaphic factors in maintaining the high diversity of these forests. He worked primarily in the Harvard Herbaria, in collaboration with the Smithsonian Center for Tropical Forest Studies (CTFS) – Arnold Arboretum group. However, he also lived and worked at the Forest and made several field trips to large-scale, long-term forest sites in the CTFS pantropical network. Ian gave a seminar at Peradeniya University in Sri Lanka, and a presentation at the Smithsonian Tropical Research Institution in Panama.

Paul Barten (University of Massachusetts at Amherst) contributed to a National Research Council study of Atlantic salmon *(Salmo salar)* in Maine focusing his contribution on the influence of land use on aquatic habitat and fish populations. Barten and Avril de la Crétaz completed a literature review and synthesis on land-use effects on streamflow and water quality in the Northeastern United States. Barten and colleagues at UMass, the Trust for Public Lands, and the U.S. Forest Service completed an EPA-funded project designed to protect drinking water supplies through forest conservation and pollution control. Barten is also using land-use history, weather and streamflow data, and prediction equations from watershed experiments to estimate changes in streamflow in relation to historical changes in forest cover from 1700 to 2000.

Antonio Lara (Universidad Austral de Chile, Valdivia Chile), completed writing projects on: a national policy for forest conservation in Chile; patterns of *Nothofagus pumilio* at treeline; tree growth of *Nothofagus oblique-N. alpina* forests; and the effects of fast-growing plantations on water yield and the economic value of native forests. Antonio gave conferences on climate reconstruction and forest ecosystem services at the Universities of Montana, Western

Julia Jones.

Ontario, Arizona, and Massachusetts at Amherst; the David Rockefeller Center for Latin American Studies, Harvard University; Palacio Ariztia, Cámara de Diputados (Congress), Santiago, Chile; and Earthwatch International. He lectured on Patagonian forests in David Foster's Forest Ecology course and worked with Julia Jones and David to develop a proposal for comparative ecological studies in New England, Oregon and Patagonia. Antonio also worked with David and Missy Holbrook on an exchange program of students and faculty between Harvard and Universidad Austral de Chile. He also worked with Pascal Poussard and Daniel Schrag (Department of Earth and Planetary Sciences) to produce an oxygen isotope chronology from *Fitzroya* tree-rings. He spent a month at the Institute of Ecosystem Studies (IES) in Millbrook, New York.

Working with Wyatt Oswald, David Foster, and Edward Faison, Matts Lindbladh investigated spruce dynamics in Massachusetts during the late glacial, a period from 15,000 to 11,000 years ago when spruce dominated the region. Three complete pollen diagrams from Massachusetts were analyzed, including the Black Gum Swamp located near Shaler Hall. Matts used his new method of separating pollen of the three species of spruce that occur in New England: white, black, and red spruce *(Picea glauca, mariana and rubens).* In total, 1198 spruce grains were examined. Matts also worked on a paper about the importance of retained snags on clear-cuts for the diversity of saproxylic (wood dependant) beetles in southern Sweden and assisted with fieldwork in western Massachusetts. He explored the exciting bird fauna of New England, working on an article on that very subject to be submitted to The Swedish Ornithology Society's journal — *Vår Fågelvärld*. He also ran 353 miles in the Petersham countryside.

Francis E. "Jack" Putz (University of Florida) spent much of his time in Petersham writing about Amazonian forest history and rednecks as ecosystem managers. His redneck essay, in *Wild Earth Magazine,* elicited responses from supporters and detractors, most of whom are either NASCAR fans or National Public Radio subscribers, respectively. Meanwhile, his wife, Claudia Romero, with help from Barry Tomlinson, made progress on her dissertation on bark ecology, his daughter, Juliana, successfully matriculated from the 9th grade at Mahar Regional High School, and his son Antonio matured as a slugger for the Petersham baseball team. During his fellowship, Jack was appointed as the Prince Bernhard

Francis E. "Jack" Putz.

Chair of International Conservation at Utrecht University. Jack's campaign to protect representative stands of hemlocks from the hemlock woolly adelgid was presented in the Massachusetts Audubon Society's *Sanctuary Magazine* and in *Massachusetts Wildlife* but attracted no obvious supporters among the rich and powerful.

Thomas Sinclair worked in Missy Holbrook's laboratory, investigating the response of plants to changes in volumetric soil water content. A theoretical derivation was developed that describes in a relatively simple manner the sensitivity of plant water uptake to changes in soil hydraulic conductivity. An experiment was undertaken to explore whether the changes in plant transpiration rates with drying that have been widely reported for annual species is appropriate for perennial, woody species. With appropriate adjustments to account for water storage, the basic response of the woody species to soil drying was the same as reported for annual species. Finally, a laboratory procedure was set up to measure the hydraulic conductivity of the rhizosphere (soil+roots) as soils dry. These results point to a clear limitation of hydraulic conductivity on sustained water uptake as soils dry.

Bernhard Stadler (University of Bayreuth) returned to extend his research on carbon and nitro-

gen cycling in hemlock canopies. In addition, he completed papers addressing insect-ecosystem relationships by examining the effects of ants and aphid honeydew on litter decomposition. He also started a book entitled *Mutualisms: Ants and Their Partners* for Cambridge University Press. Mutualisms (reciprocal beneficial interactions between organisms) are interesting because these interactions extend to higher levels of organization, such as communities, and may ultimately affect ecosystem processes.

EDUCATIONAL ACTIVITIES

In the fall David Foster taught Forest Ecology to a diverse group of undergraduate and graduate students. The course includes fieldtrips to western Massachusetts and the Harvard Forest. This year it considered the history, ecology, and management of Yellowstone National Park and the national parks in Patagonia (Chile and Argentina) as case studies for the insights to ecology and conservation that come from historical research. Bullard Fellow Antonio Lara presented key lectures in that course. In the spring John O'Keefe, Dave Orwig, and Glenn Motzkin joined David in leading the Harvard Forest Freshman Seminar. The seminar meets over four weekends and provides an overview of Harvard Forest research and an introduction to the landscape and history of New England. It finishes with the students undertaking an independent study. David served as advisor to undergraduate Sara Clark on her thesis concerning the Bush Administration's Healthy Forest Initiative. He also serves on the doctoral committees of Takeshi Ise and Heather Lynch in Organismic and Evolutionary Biology and Doerte Keoster at Laval University.

In July, for the third consecutive year, Barry Tomlinson was an instructor in the Kenan College Professor's course in tropical botany of the National Tropical Botanical Garden in Kauai, Hawaii, and had a reunion in February in Miami with the previous year's students. While in Miami, he participated in the University of Miami's Advanced Course in Tropical Ecology, offering a workshop on tree architecture.

A series of classes from the Department of Organismic and Evolutionary led successful field trips to the Harvard Forest: OEB 124 *Biology of Plants* (Prof. Elena Kramer and Missy Holbrook); Biology Sciences 55 *Ecology: Populations, Communities, and Ecosystems* (Prof. Paul Moorcroft); Biology 98r *Introduction to Research* (Prof. David Haig and others); and the Freshman Seminars *Applied Microfluids: Structure, Function, and Evolution of Trees* (Prof. Missy Holbrook and Peter del Tredici) and *Darwin's Finches* (Prof. Kathleen Donohue). In addition, OEB 157 *Global Change Biology* (Profs. Paul Moorcroft and Jim McCarthy) spent a Saturday fieldtrip at the Forest touring experiments with Julian Hadley and examining major research projects.

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 work closely with researchers, while many conduct their own independent studies. The program includes 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 is made to the Institute of Ecosystem Studies (Millbrook, N.Y.) to participate in a Forum on Careers in Ecology. Students present major results of their work at the Annual Summer Student Research Symposium in mid-August.

REU students Matthew Waterhouse and Kelley Sullivan.

Summer Students 2004

Mary Anderson	Haverford College
Diana Barszcz	UMASS-Amherst
Peter Bettman-Kerson	Hampshire College
Bethany Burgee	Smith College
Anne Marie Casper	Hampshire College
Cynthia Chang	University of Maryland
Sara Clark	Harvard College
Jennifer Clowers	Franklin & Marshall College
Bridget Collins	College of the Holy Cross
David Diaz	Harvard University
Gavin Ferris	Clarion University of Pennsylvania
Kelsey Glennon	Salisbury University
Daniel Gonzalez-Kreisberg	Harvard College
Kelly Grogan	Dartmouth College
Robert Hanifin	Dickinson College
Sheilah Lillie	Humboldt State University
Chelsea Kammerer-Burnham	Clark University
Erin Largay	Connecticut College
Megan Manner	Duke University
Kathryn McKain	Mount Holyoke College
Kirsten McKnight	Brigham Young University
Thaddeus Miller	Bethel College
Christopher Miwa	Michigan Technological Institute
Thomas Mulcahy	Johnson State College
Jacquelyn Netzer	Franklin & Marshall College
Donald Niebyl	Virginia Tech University
Marlon Ortega	University of Nebraska
Barbara Ozimec	University of Guelph, Canada
Rose Phillips	Mount Holyoke College
Allison Rosenberg	Haverford College
Kelley Sullivan	Harvard University
Sarah Truebe	Stanford University
Christina Walsh	Franklin & Marshall College
Matthew Waterhouse	University of Maine, Farmington
Michelle Ziegler	University of North Carolina

Assistant Program Coordinators
Tracy Rogers
Jimmy Tran

Posy Busby and REU student Michelle Ziegler.

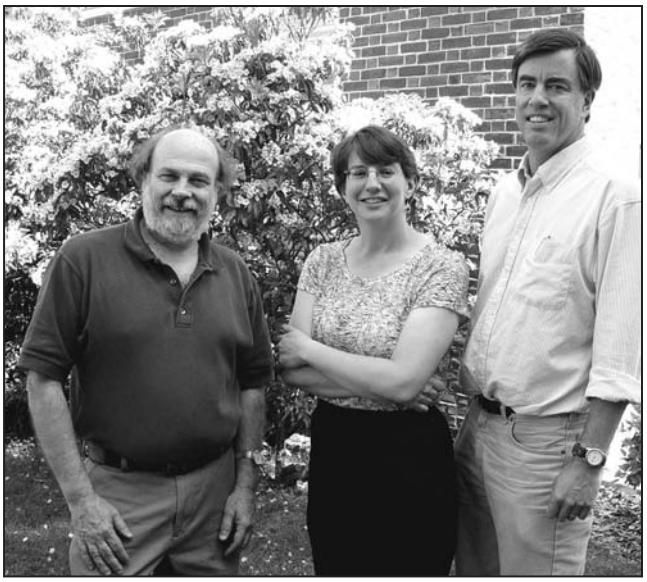
David Kittredge and REU student Kelly Grogan.

Kristin Lewis, REU student Anne Marie Casper, and Colin Orians.

Building the LTER Schoolyard Program

Pam Snow joined the Harvard Forest in September to solidify and expand the LTER schoolyard program in local schools. Pam spent the fall developing research protocols suitable for use in K–12 schools based on three HF LTER studies. These were introduced to environmental educators and classroom teachers and were piloted this year. Teachers Ethan Forbes and Ann Murray of Butterfield School in Orange undertook a stream study in the Millers River watershed and analyzed the data collected by their fifth-graders through the year. Teacher Susan Radtke of Wildwood School in Amherst piloted a Hemlock Woolly Adelgid study with her fourth-grade class related to David Orwig's research. In the "Hemlock Trees and the Pesky Pest, The Woolly Adelgid" project, students identified and counted eggs sacs of the HWA at a site near their school. Over time students can help track the spread of this invasive hemlock pest. Melaney Burgos of Fort River school in Amherst piloted a phenology study related to one conducted by John O'Keefe. This project "Buds, Leaves, and Global Warming," involves monitoring tree buds in the spring twice weekly leading up to budburst and culminating with leaf drop in the fall. Over time these data can reveal changes in the growing season and climate.

In the spring we received an Ed En Venture supplement to the LTER grant in order to expand the schoolyard efforts. This grant will allow us to provide training and support to 20 teachers who will implement the ecology projects described above. We have joined with the Millers River Environmental Center in Athol and the Hitchcock Center for the Environment in Amherst to provide teachers with support to initiate field research with their students. This summer we hosted a three-day Summer Institute for Teachers to begin this exciting project. Teachers can obtain materials on each project from the HF Web site and information has been distributed to local schools to inform teachers of this field-based science education. We are also developing teacher notebooks that include protocols, data sheets, scientific reference sheets, background information, teaching resources, supplemental activities, and HF research abstracts for each project.



John O'Keefe, Edythe Ellin, and David Foster.

ACTIVITIES OF THE FISHER MUSEUM

The Fisher Museum plays an important role in the educational mission of the Harvard Forest by providing a public outlet for research in forest biology, conservation, and management. The Museum also provides a unique setting for conferences and workshops sponsored by the Forest and outside organizations. Dr. John O'Keefe has primary responsibility for the development of activities and coordination of the use of the Museum.

The Museum volunteers completed another very successful weekend schedule made even more enjoyable by the installation of air conditioning in the Museum in July 2003. In November the group shared fellowship, food, and ideas at our thirteenth Volunteer Recognition Dinner. Mary Ann Walker once again received special thanks for her continuing, enthusiastic work as volunteer coordinator. Bob Clark, who joined the volunteer group this year, received special recognition for being the most active volunteer. During the winter the group was deeply saddened by the deaths of Roger Corey and Marianna Berry. Both were in the founding group of volunteers, were strongly committed to the Museum, and were consistently among the most active members. They will be sorely missed.

During the year the Museum provided programs for 29 elementary and secondary schools, 37 college and university classes, and 27 community and professional groups. During the summer the Museum hosted three groups of inner city youth in our con-

tinuing collaboration with the University of Massachusetts Extension's "Learn About Forests" program. Each group spent the day exploring, learning, and working on the Schwartz lot and then enjoyed a cookout behind Shaler Hall.

Meetings, Conferences, Seminars

In September, the Museum and Forest hosted a two-week workshop for tropical forest ecologists sponsored by the Smithsonian and the Arnold Arboretum. The participants, all of whom work at sites with long-term tropical forest plots, learned consistent methods for data collection, management, and analysis. In March, we hosted a meeting of representatives from seven LTER sites funded through a National Science Foundation Bio-Complexity grant (Agricultural Landscapes in Transition) to Charles Redman (Arizona State University), David Foster and others to study the conservation consequences of long-term changes in land-use. The Fifteenth Annual Harvard Forest Long Term Ecological Research Symposium and National Institute for Global Environmental Change meeting was held in the Museum on March 29.

Other group meetings at the Harvard Forest included the Land Trust Alliance Quabbin to Cardigan planning group, Massachusetts Department of Conservation and Recreation Logging Workshop, Massachusetts Executive Office of Environmental Affairs Land Trust Retreat, Massachusetts State Forestry Committee, Massachusetts Forestry Association, Massachusetts Forestry Forum, Massachusetts Forest Steward's Training, Massachusetts Agriculture in the Classroom, Massachusetts Envirothon Retreat, Massachusetts Society to Promote Agriculture, Mount Grace Land Conservation Trust, New England Forestry Foundation, Mount Wachusett Community College, Northeast Resource Conservation and Development Foresters, North Quabbin Regional Landscape Partnership, the Nature Conservancy, and Vegetation Control Service. The Forest also hosted a faculty retreat for the Harvard University Graduate School of Design.

Speakers in the Harvard Forest Seminar series included:

Ian Baillie	Cranford University, England
John Baker	Clark University
Michael Bank	University of Maine
Paul Barten	UMASS - Amherst
Brian Beckage	University of Vermont
David Bowman	Northern Territory University, Australia
Douglas Causey	Harvard Museum of Comparative Zoology
Valerie Eviner	Institute of Ecosystem Studies
Ivan Fernandez	University of Maine
Kathryn Flinn	Cornell University
Serita Frey	University of New Hampshire
Daniel Gavin	Universities of Illinois and Vermont
Jessica Gurevitch	State University of New York
N. Michele Holbrook	Harvard University
David R. Houston	USDA Forest Service
Alice Ingerson	Applied History for Land Conservation
Julia Jones	Oregon State University
John Klironomos	University of Guelph
Antonio Lara	Universidad Austral (Chile)
Matts Lindbladh	Swedish University of Agricultural Sciences
David Lindenmayer	Australian National University
James Levitt	Director, Program on Conservation Innovation
Jacqueline Mohan	Harvard University
Francis E. "Jack" Putz	University of Florida
Claudia Romero	University of Florida
Robert Ryan	UMASS–Amherst
Eric Sanderson	Wildlife Conservation Society
Thomas R. Sinclair	U.S. Department of Agriculture
Steven Stoll	Yale University
Fred Swanson	USDA Forest Service, Pacific Northwest
Mark Vellend, Peter Marks, and Kathryn Flinn	Cornell University

David Foster and Aaron Ellison.

FOREST MANAGEMENT AND INFRASTRUCTURE

Several important projects were completed through the combined efforts of the Woods Crew and outside contractors. Due to growth in our summer program, we completed updates to Fisher House and significant renovations to Raup House, which was converted from a large single-family home to community housing for up to 13 students. We finished significant renovations to one apartment in the Community House and modest improvements in heating in the Summer Apartment in Higginson House. Finally, the Crew is assisting with preparations necessary for the first major renovation to Shaler Hall since it was built in 1938. This past year, four offices were renovated and the electrical systems were upgraded. In the coming year, most of the first and second floors of Shaler Hall will be renovated including new lighting, ceiling, floors, and painting. Finally, the Crew removed the stand of aging red pine in front of Shaler Hall and are using the timber to build the new garage. This large front area has been planted with an interesting variety of native plants, shrubs, and trees.

With a grant from the National Science Foundation, Aaron Ellison has been overseeing the complete renovation of the Torrey Lab greenhouses and the small greenhouse south of Shaler Hall. The Torrey upgrades include large, mobile benches, supplemental lighting, automatic vent controls, shading and cooling systems, and automatic watering systems. These systems are linked to a small weather station adjacent to the greenhouse, and are computer controlled. The Shaler greenhouse was replaced with a new, slightly larger unit, which has mobile benches and radiant heat that is highly efficient and will yield significant savings. In addition two lath shade houses were constructed next to the common garden below Lyford House. These can easily accommodate tree seedlings and saplings and provide much needed space for summer research.

LIBRARY AND ARCHIVES

During the year important changes were made to the library based on recommendations by the Library Committee, consisting of Emery Boose, John Burk, Edythe Ellin, and Glenn Motzkin. All journals and books were inventoried and reshelved, and foreign language journals were moved to temporary storage. Harvard librarians from the Arnold Arboretum, Botany, and Cabot Libraries visited the Forest and provided valuable advice on collection management and development, use of physical space, and electronic cataloging. Plans were initiated to catalog the Harvard Forest collection using the Library of Congress system and to add holdings to HOLLIS, the University's online catalog. Judy Warnemen, director of the Botany Libraries, and Sheila Connor, archivist at the Arnold Arboretum, began implementing this effort. In conjunction with the library work, the sample archive was reorganized and transferred to a garage bay. Over forty boxes of material from the John Aber's group were transferred to storage at the U.S. Forest Service in Durham, N.H.

INFORMATION MANAGEMENT AND TECHNOLOGY ADVANCEMENT

Wireless access to the network was added for the Common Room and adjacent areas in Shaler Hall with assistance from FAS Network Operations. As the number of laptop users increases, we expect that wireless access will become increasingly important and will be extended to other locations across the Forest. Over the past year work continued on our Data Archive, which contains online data and metadata (documentation) for current and recent research projects. Dataset documentation includes both "discovery-level" and "entity-level" metadata. The former enables the discovery of appropriate datasets from a catalog, and includes project title, personnel

(investigators and contact person), temporal coverage (start and end dates), geographical coverage (location description, latitude, longitude, elevation), taxonomic coverage (species, genera, etc. studied), keywords, abstract, methods, and related datasets. The latter enables the reading and correct interpretation of individual data entities (files), and includes such technical details as file name and location (URL), file type and structure, and variable names and types. Discovery-level metadata for all online datasets has been converted to Ecological Metadata Language (EML) – the new standard for ecological metadata – while conversion of entity-metadata to EML will continue over the next year.

Jess Butler and Sultana Jefts.

ACTIVITIES OF THE HARVARD FOREST STAFF

Audrey Barker Plotkin coordinated the annual Harvard Forest Ecology Symposium and Weekly Seminar. Along with summer student Kristin Wilson, she presented a poster at the LTER All-Scientists Meeting. Emery Boose served on the NSF site review panel for the Jornada LTER program in southern New Mexico. He attended the LTER Information Managers Executive Committee (IMExec) meeting and Web Services workshop in San Diego, as well as meetings of the LTER Network Information System Advisory Committee (NISAC) at the National Center for Supercomputing Applications (Champaign, Illinois) and the San Diego Supercomputer Center.

John Burk contributed to articles in *Massachusetts Wildlife*, *Natural New England*, *Worcester County Online*, the *Lake Sunapee Conservation* newsletter, the *Harvard University Resource*, and a brochure produced by the North Quabbin Woods group. He led several local nature walks and participated in a visitor management forum for Maine's Baxter State Park. Betsy Colburn contributed to discussions on the Harvard Forest publication *Wildlands and Woodlands*, continued to work with Emery Boose and Paul Barten on planning for weirs on streams at Harvard Forest, provided input into the new Web site, participated in the LTER All-Scientists' Meeting in Seattle, and contributed to proposals for new laboratory equipment for Torrey Lab. Betsy made presentations on headwater stream research to the Mount Wachusett Advisory Committee, and on midge research at two professional meetings; she collaborated with Pam Snow, on curriculum materials for teachers; and she worked with a fourth-grade teacher from Orange on stream monitoring. Betsy and David Foster served as advisors for the Master's thesis of Brooks Mathewson.

Audrey Barker Plotkin.

Aaron Ellison spent much of the year completing *A Primer of Ecological Statistics*, which was published by Sinauer in May. This text, co-authored with University of Vermont Professor Nicholas Gotelli covers fundamental topics in probability theory, experimental design, and statistical analysis for ecologists and environmental scientists. Aaron wrapped up 15 years of research in the Central American wetlands with a synthetic monograph describing these ecosystems. He also spent a week at Kellogg Biological Station as one of their three annual "Eminent Ecologists." There, Aaron presented two seminars on his research on pitcher plants and assembly of ecological communities, and spent a delightful week interacting with graduate students, visiting pitcher plant bogs and

Ed Faison.

agricultural fields, and collecting ants. Aaron presented seminars on ecological statistics at the University of Massachusetts and at an NSF/ESA workshop in Jackson Hole, Wyoming. He continued his stints as Associate Editor-in-Chief for *Ecology* and *Ecological Monographs* and as Associate Editor for *American Journal of Botany*. Closer to home, Aaron continued his terms on the Royalston Conservation Commission and on the Land Protection Committee of the Mt. Grace Land Trust.

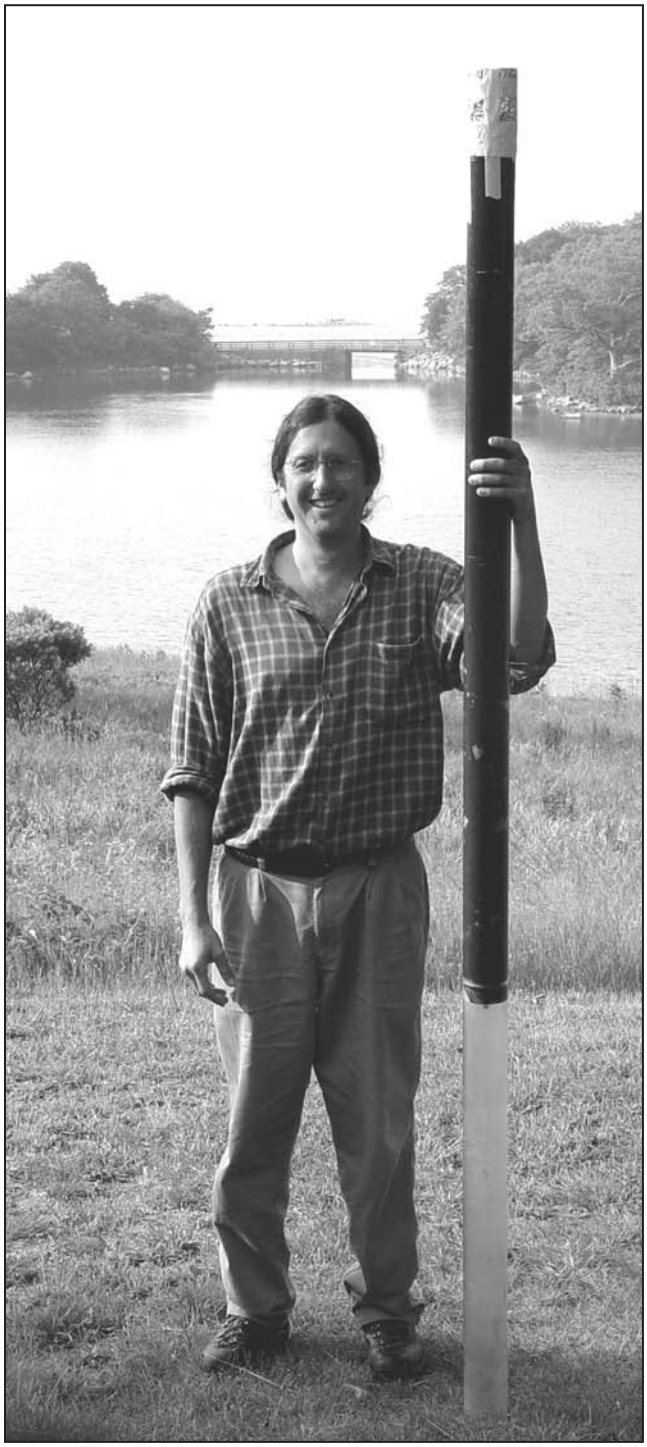
Ed Faison continued his research on hemlock and openlands in the Paleo Lab and co-led a field walk with Dave Orwig on the long-term dynamics of the Hemlock woodlot for the Smithsonian Research Group. In the spring he presented results at an informal paleoecology meeting at Brown University. In June, Ed transitioned into the MFS program and has been developing a landscape-scale moose-browse study while serving on the field crew of the Forest Harvesting Project.

David Foster continued in his role as editor for *Ecosystems*, *Northeastern Naturalist*, and *Physical Geography*, board member at the Highstead Arboretum, and advisor to the Doyle Center of The Trustees of Reservations. At Harvard he is principal investigator of the LTER program, the director of the graduate program in forest biology, board member of the Center for Health and the Global Environment and National Institutes for Global Environmental Change (NIGEC), and faculty advisor at the Rockefeller Center of Latin American Studies. He served as an advisor to Old Sturbridge Village living museum and gave interviews regarding the publication of *Forests in Time* to the BBC and various National Public Radio stations. David attended the LTER All Scientist Meeting and he gave the 2003 Lynn W. Day Distinguished Lectureship in Forest and Conservation History at the Forest History Society and Duke University. In July he coordinated the Harvard Forest LTER site review, which was led by Richard Waring and Henry Gholz. David and Charles Redman, Arizona State University, coordinated a Biocomplexity Workshop at the Forest and David represented the Harvard Forest LTER at a Coordinating Committee meeting in Santa Barbara. In April he participated in A NEON planning workshop hosted by the University of Virginia.

Brian Hall attended three conferences: the New England Arc Users Conference in Newport R.I. where he presented a poster entitled: "Massachusetts's Forest Cover in 1830," the New England Arc Users Meet at UMASS Amherst, and the LTER Agricultural Transitions Data Analysis Workshop in Ann Arbor, Michigan. Sultana Jefts attended the LTER All Scientist Meeting in Seattle and co-coordinated the hazardous waste disposal and pickup for Harvard Forest. Sultana assisted coordinating the 2004 REU summer orientation and organizing and implementing the new reading group associated with speakers for the summer seminar series.

Dave Kittredge presented results of his international review of forest owner cooperative organizations at a meeting hosted by the Ford Foundation and on a nationally televised satellite videoconference. At the Student Forum of the national convention of the Society of American Foresters, Dave made a presentation on the *Illusion of Preservation* topic published several years ago as a Harvard Forest Paper. Dave also

presented results on a study conducted with former REU student Andrew Finley on forest owner cooperation potential in Massachusetts. Dave participated in the development of the *Wildlands and Woodlands* report and took part in the Harvard Forest meeting of the NSF Biocomplexity project "Transformation of Agrarian Landscapes."



Glenn Motzkin.

Glenn Motzkin continues to serve as an Ecology Advisor for The Trustees of Reservations, and an Associate Member of the Massachusetts Natural Heritage and Endangered Species Program Advisory Committee. Glenn attended the LTER All-Scientists meeting in Seattle and Glenn and Jack Putz participated in a field tour led by Bill Patterson and Dave Crary on Managing Fuels in Northeastern Barrens. Glenn served on the thesis committee of Gretel Clarke from UMASS, and led field trips to Montague Plain for the Conway School of Landscape Design and, along with Tim Simmons of the Massachusetts Natural Heritage and Endangered Species Program, for the Town of Montague. Glenn led field trips to Mt. Tom and Montague Plain during a visit to Harvard Forest by Peter Marks, Jesse Bellemare, Katie Flynn, and Mark Vellend from Cornell University.

John O'Keefe gave talks on Harvard Forest research and the history of northeastern forests at the U.S. Fish and Wildlife Service in Hadley, the Great Falls Discovery Center in Turners Falls, and the Westborough Community Land Trust Annual Meeting. He presented a poster at the NSF LTER All-Scientist Meeting in Seattle and attended the Agricultural Transitions/Biocomplexity workshop at Harvard Forest. John serves on the boards of the Mount Grace Land Conservation Trust, where he is Vice-president, Massachusetts Forestry Association, and Millers River Environmental Center, and on the executive committee of the North Quabbin Regional Landscape Partnership. He also continues to serve on the Secretary of Environmental Affairs' Advisory Group on Environmental Education.

Dave Orwig presented old-growth talks at the Forest Summit Lecture Series at Holyoke Community College and at the Wachusett Mountain Advisory Council Meeting. He gave an invited talk at the University of Maine and was a keynote speaker for the New England Wildflower Society's Symposium on "Insects and the changing New England landscape." He led field trips at Harvard Forest for the Center for Tropical Forest Studies and Hampshire College. Dave served as practicum advisor to Sarah Parker and David Kay at Antioch College and continues to serve as the Ph.D. dissertation advisor to Anthony D'Amato at the University of Massachusetts.

Pamela Snow attended an LTER Education Committee grant-planning meeting in Wheeling, West Virginia. Barry Tomlinson spent the winter at "The Kampong" of the National Tropical Botanical

Fife Brook, one of Tony D'Amato's old-growth forest sites.

Garden in Coconut Grove, Miami, using the laboratory of Jack B. Fisher at the Fairchild Tropical Botanical Garden. In December a brief visit was made to Montpellier, France to discuss research on tree architecture with an old colleague, Professor Francis Hallé.

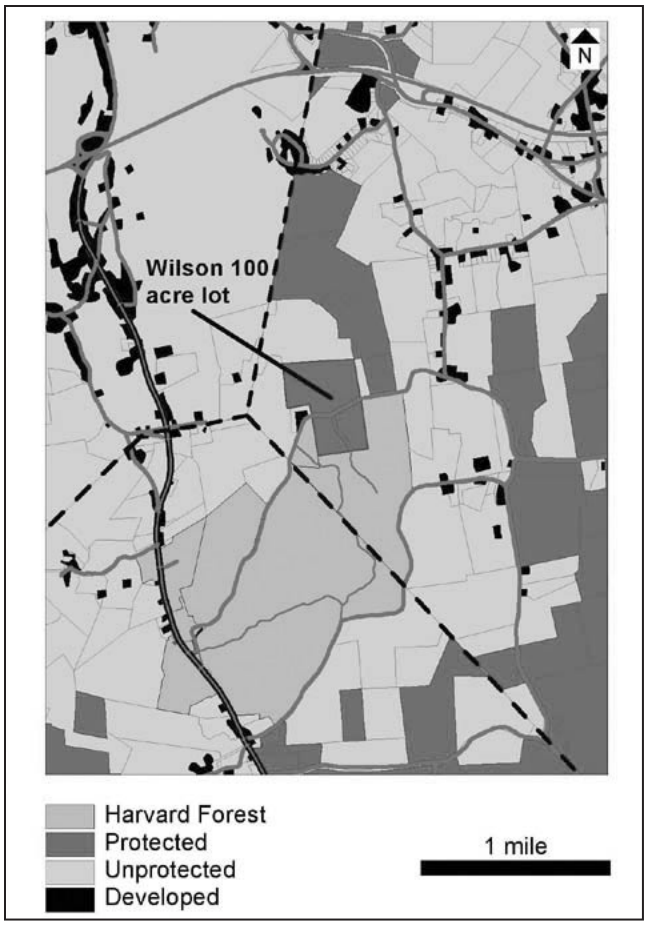
LAND PROTECTION EFFORTS

For decades rural central Massachusetts, which supports a remarkable 90% forest cover and low population density, has been bypassed by significant development. Recently, as prices and housing densities have risen across New England and transportation has improved, this situation has begun to change and our region has experienced increasing development. This threat to natural landscapes has become a major focus of regional and statewide conservation groups (e.g., Mount Grace Land Conservation Trust, The Trustees of Reservations, Massachusetts Audubon Society, The Nature Conservancy), state agencies (DEM, DFW, MDC), and the federal government (Forest Legacy Program).

For its first eighty years the Harvard Forest was able to ignore the greatest threat to its continued operation, namely the exposure of its land to abutting public roads (many of which appear today as woodland dirt roads) and the development of private property. Unfortunately, the greatest exposure to development occurs around the Prospect Hill tract, which also supports our most intensive research and densest array of scientific equipment. This threat was underscored last year when a single small parcel on the Forest's northern border was sold unexpectedly, the existing dirt road was improved and a new house and yard were carved out of continuous forest.

A new threat appeared this year. The Wilson lot is 100 acres in Phillipston abutting the new house and jutting into the northern boundary of the Prospect Hill tract. In the spring of 2003, Don Wilson approached Mount Grace Land Conservation Trust (MGLCT) and the Forest concerning a sale for conservation and research purposes as an alternative to development. Harvard Forest and MGLCT agreed to collaborate on the project with MGLCT initially purchasing the property, placing a conservation easement on it, and subsequently selling the restricted land to us. In early May 2004, purchase of the Wilson property was finalized by MGLCT with an agreement to transfer the property to Harvard Forest with a conservation easement.

Currently, MGLCT and Harvard Forest are collaborating on an application to the U.S. Forest Service Forest Legacy Program to purchase conservation easements on the Wilson property, and more than a dozen other properties abutting our land, and continuing in a corridor south through Petersham. Success in this project will protect an important part of the Harvard Forest and will significantly enhance the corridor of protected forest and wildlife habitat in our region. Raising funds for land protection is a new venture for the Harvard Forest that is prompted by the urgency to protect the integrity of our lands, research, and educational program. To date we have received donations and pledges totaling over half the cost of the Wilson project, a tremendous response from our friends, and we continue to seek funds from a variety of sources. We greatly appreciate the contributions of friends, alumni, neighbors, regional groups, and foundations toward making this first and crucial step possible.

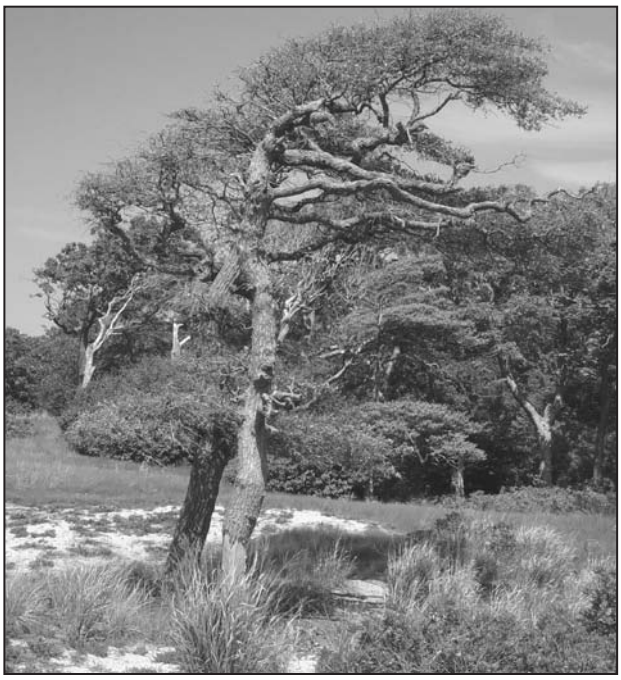


Harvard Forest's Prospect Hill tract showing the location of the Wilson lot and other surrounding unprotected and protected parcels.

VISITING RESEARCH SCIENTISTS AT THE HARVARD FOREST 2003-2004

A large number of Harvard University and outside scientists use Harvard Forest facilities and research sites. Many of these scientists are involved in the Harvard Forest LTER or NIGEC programs.

John Aber	Univ. of New Hampshire
Jacqueline Aitkenhead	Univ. of New Hampshire
Marco Albani	Harvard University
Bruce Archibald	Harvard University
Mark Ashton	Yale University
Fakhri Bazzaz	Harvard University
Richard Bowden	Allegheny College
Frank Bowles	Ecosystems Center – MBL
Robert Brooks	USDA Forest Service
David Bryant	Harvard University
John Budney	Harvard University
Elizabeth Burrows	Ecosystems Center – MBL
Elizabeth Chilton	University of Massachusetts
Brendan Choat	Harvard University
V. Y. Chow	Harvard University
Scott Costa	University of Vermont
Patrick Crill	Stockholm University
William Currie	University of Michigan
Bryan Dail	University of Maine
Eric Davidson	Woods Hole Research Center
Brian Donahue	Brandeis University
Jim Ehleringer	University of Utah
Serita Frey	Univ. of New Hampshire
David Fizjarrald	SUNY, Albany
Julia Gaudinski	UCLA, Irvine
Nicholas Gotelli	University of Vermont
Elaine Gottleib	Harvard University
Michelle Hofton	University of Maryland
David Hollinger	USDA.Forest Service
Lucy Hutyra	Harvard University
Christine Jones	Harvard University
Döerte Köester	Université Laval
Chun-Ta Lai	University of Utah
Xuhui Lee	Yale University
Kristin Lewis	Harvard University
Alison Magill	Univ. of New Hampshire
Lynn Margulis	University of Massachusetts
Mary Martin	Univ. of New Hampshire
Jerry Melillo	Ecosystems Center – MBL
Randy Mercurio	American Museum of Natural History
Patricia Micks	Ecosystems Center – MBL
Qilong Min	SUNY, Albany
Mitch Mulholland	University of Massachusetts
Knute Nadelhoffer	University of Michigan
Tommi Nyman	Harvard University
Scott Ollinger	Univ. of New Hampshire
Colin Orians	Tufts University
Neil Pederson	Columbia University
Nathan Phillips	Boston University
Jennifer Pontius	USDA Forest Service
Elizabeth Pyle	Harvard University
Renee Richer	Harvard University
Steven Roberge	Yale University
Fulton Rockwell	Yale University
Lindsay Rustad	USDA Forest Service
Kathleen Savage	Woods Hole Research Center
Sanna Sevanto	Harvard University
Andrew Simons	Carleton University
Tim Sipe	Franklin & Marshall College
William Sobczak	Holy Cross College
Rolf Staebler	SUNY, Albany
Paul Steudler	Ecosystems Center – MBL
Margaret Torn	Lawrence Berkeley Labs
Susan Trumbore	University of California
Akane Uesugi	University of Michigan
Shawn Urbanski	Harvard University
Hui-Ju Wu	Yale University
Maciej Zwieniecki	Harvard University



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ACKNOWLEDGMENT OF SUPPORT

Activities described in this Annual Report are supported by funds provided by the following sources, to which we are indebted:

Friends of the Harvard Forest
Andrew W. Mellon Foundation
Commonwealth of Massachusetts
    Department of Environmental Management
    Division of Fisheries and Wildlife
    Natural Heritage & Endangered Species Program
Department of Energy, National Institute for Global Environmental Change
Greenleaf Foundation
Harvard University
    Center on the Environment
    David Rockefeller Center
    The Clark Fund
    The Cooke Fund
Massachusetts Environmental Trust
Mrs. Elisabeth Dudley
National Park Foundation
National Park Service
National Science Foundation
    Digital Government Program
    Ecosystem Studies
    International Programs
    Information Technology Research
    Long-term Ecological Studies
    Ecology Program
    Research Experience for Undergraduates
Southern Taconics Research and Conservation Center
Sweetwater Trust
The Nature Conservancy

GIFTS

Many thanks to retiring Athol map dealer Casimir Pinigis for recent donations of over 1,100 USGS topographic maps covering all of southern New England, New Hampshire, and Vermont and for help with numerous map orders over the years. Thanks to Jim Baird for continued support with ornithological journals. Thanks also to Holly Jensen-Herrin for donating a collection of historic topographic maps of central and eastern Massachusetts.

NEW FUNDING

Aaron Ellison, Kathleen Donohue, David Foster, and N. Michelle Holbrook – FSML: Infrastructure for Whole-Plant Biology at the Harvard Forest; NSF DBI 03-30605: $132,148. REU supplement also awarded for $7,674.

Aaron Ellison – Effects of Nutrient Stress on a Coevolved Food Web; NSF REU Supplement DEB-02355128: $7,347.

David Foster and Dave Orwig – Forest Response to the Decline of a Dominant Species: Ecosystem to Regional Analyses of the Impact of the Hemlock Wooly Adelgid on Northeastern Forests; NSF LTER REU Supplement DEB-0236897: $12,000.

David Foster and N. Michelle Holbrook – A Mobile Canopy Access Platform for Environmental and Physiological Research at Harvard Forest; NSF REU Supplement DBI-0200868: $7,424.

David Foster, Glenn Motzkin, and Elizabeth Chilton – Archaeological, Historical, and Ecological Studies Related to the Conservation of Coastal Landscapes; NSF LTER III Supplement DEB-0080592: $ 49,956.

David Foster, Betsy Colburn, Dave Orwig, and Aaron Ellison – Comparative Cross-Site Studies of the Impact of Exotic Pests on Forest and Stream Ecosystems; NSF LTER III Supplement DEB-0080592: $15,000.

David Foster and Julian Hadley – New Eddy Covariance System in Harvard Forest's Old-Growth Hemlock Forest; NSF LTER III Supplement DEB-0080592: $25,000.

David Foster, Pamela Snow, and John O'Keefe – Harvard Forest LTER in the Schoolyard K–12 Education Program; NSF LTER III Supplement DEB-0080592: $15,000.

David Foster, Jacqueline Aitkenhead, and Richard Bowden – Detritus Input and Removal Treatments (DIRT): a Collaborative Project with the Síkf_kút ILTER Site, Hungray; NSF LTER III Supplement DEB-0080592: $14,292.

David Foster and David Orwig – Landscape Patterns of Hemlock Woolly Adelgid Damage in New England Forests; NSF LTER III REU Supplement DEB-0080592: $12,000.

David Foster, David Orwig, Aaron Ellison, Michelle Holbrook, Paul Steudler, Betsy Colburn, and Paul Barten – Nutrient Analysis Equipment for Community, Ecosystem, Hydrological and Physiological Research at Harvard Forest; NSF LTER III Supplement DBI-0400759: $59, 640.

David Foster, John O'Keefe, Pamela Snow, Betsy Colburn and David Orwig – Environmental Education: Forest Ecology Research in the Schoolyard: Collaboration with North Quabbin and Pioneer Valley Communities; NSF LTER III Supplement DEB-0080592: $74,608.

David Foster and Glenn Motzkin – The Ecological Influence of Forest Harvesting Across Massachusetts; USDA Forest Service Forestry Innovation Grants Program Award No. 04-DG-1124425-181: $50,109.

David Foster and Betsy Von Holle – The role of soils and land use in determining the distribution of invasive species; Highstead Arboretum: $11,200.

David R. Foster
Director

Petersham, Massachusetts
August 2004