THE HARVARD FOREST 2004–2006

Harvard University

Front Cover: *Misty Morning on Prospect Hill*, John Burk
Back Cover: *Pasture at Harvard Forest*, Tracy Rogers
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ANNUAL REPORT OF THE HARVARD FOREST 2004–2006

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Clearing of a homestead by an early settler A.D. 1740. Harvard Forest Diorama.

PERSONNEL AT THE HARVARD FOREST 2004-2006

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Julia Jones	Oregon State University
Greg Jordan	University of Tasmania–Hobart
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INTRODUCTION TO THE HARVARD FOREST

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

Physically, the Harvard Forest is comprised of approximately 3,000 acres of land in the north-central town of Petersham, Massachusetts, that include mixed hardwood and conifer forests, ponds, streams, extensive spruce and maple swamps, fields, and plantations. Additional land holdings include the 25-acre Pisgah Forest in southwestern New Hampshire (located in the 13,500-acre Pisgah State Park), a virgin forest of white pine and hemlock that was 300 years old when it blew down in the 1938 hurricane; the 100-acre Matthews Plantation in Hamilton, Massachusetts, which is largely composed 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 laboratory space, computer and greenhouse facilities, and lecture rooms for seminars and conferences. Nine additional houses provide accommodations for staff, visiting researchers, and students. Extensive records, including long-term data sets, historical information, original field notes, maps, photographic collections, and electronic data are maintained in the Harvard Forest Archives.

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

The staff and visiting faculty of approximately fifty work collaboratively to achieve the research, educational, and management objectives of the Harvard Forest. A management group meets monthly to discuss current activities and to plan future programs. Regular meetings with the HF LTER science team, weekly research seminars and lab discussions, and an annual ecology symposium provide for an infusion of outside perspectives. The seven-member facilities crew undertakes 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, Andrew W. Mellon Foundation, and other granting sources. Our Summer Program for Student Research is supported by the National Science Foundation, the A. W. Mellon Foundation and the R. T. Fisher Fund.

TRANSITIONS AND ACCOLADES

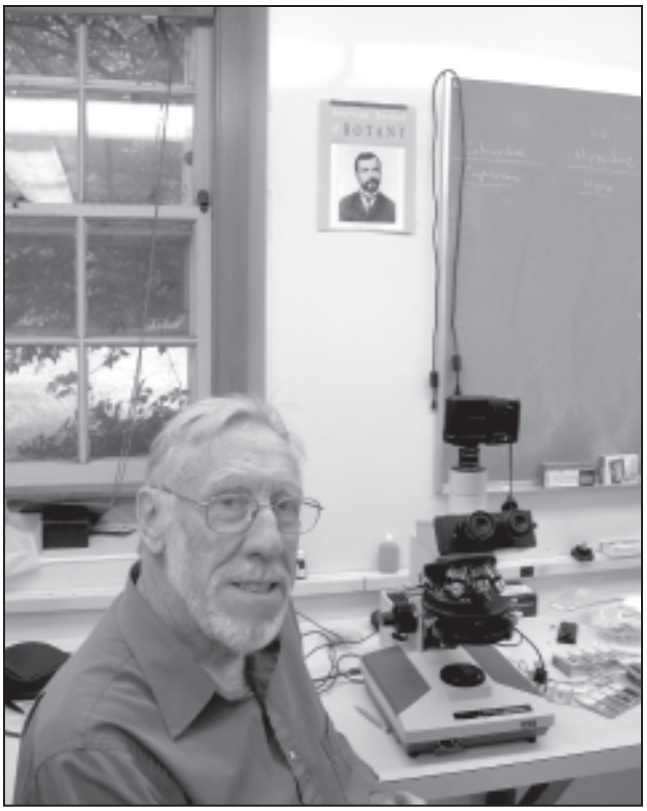
P. Barry Tomlinson was one of a select group of prominent botanists who were awarded the Centennial Medal of the Botanical Society of America to commemorate the one hundredth anniversary of the founding of the Society in 1906.

Two Forest post-doctoral fellows moved onto new positions. Robert McDonald is now beginning a one-year David H. Smith Conservation Research Fellowship at the Harvard University Graduate School of Design. The fellowship which is a program of the Society for Conservation Biology is devoted exclusively to applied conservation research problems. Rob will work with Richard Forman of the GSD and Dr. Peter Kareiva, from The Nature Conservancy.

Michael Bank, a post-doctoral fellow at the Forest for a year has moved on to be Research Fellow at the Department of Environmental Health at the Harvard School of Public Health. His research focuses on amphibian declines and species loss. Mike worked as part of the research team investigating the effects of forest logging on vegetation patterns. Several research assistants also departed in the past year including: Sultana Jefts and Laura Pustell Barbash, both finished working at the Forest after two years as research assistants with the Hemlock Woolly Adelgid project headed by David Orwig; Julie Hall who worked on historical and spatial data analysis with Glenn Motzkin and David Foster; and Holly Jensen-Herrin who worked with Betsy Colburn on various aquatic projects in Massachusetts.

NEW STAFF

Travis Stolgitis was hired as a new member of the Woods Crew. Travis's specialty is carpentry and he has extensive experience in post-and-beam construction. Also, Eowyn Connolly-Brown, a junior at Athol High School, began working with the HWA research team led by David Orwig, assisting with lab and field work.



Professor P. Barry Tomlinson.

RESEARCH ACTIVITIES

Flora of Harvard Forest

For nearly a century, Harvard Forest has been the focus of a wide range of ecological investigations, with a strong emphasis on studies of vegetation, disturbance history, and stand dynamics. However, there have been no previous attempts to evaluate changes in the flora over time. In the early 1930s, Hugh Raup apparently developed the first checklist of vascular plants of Petersham, MA, based on his extensive collections. Subsequently, C. Earle Smith Jr. summarized the town's vascular flora in 1947, based on the collections of Dr. I. M. Johnson as well as other towns and a review of specimens in the Harvard Forest and New England Botanical Club herbaria.

Over the past two years, Glenn Motzkin has worked closely with Jerry Jenkins and Kirsten Ward to: 1) document the current flora including detailed information on the distribution and abundance of locally and regionally uncommon species and invasive species; 2) evaluate changes in the flora over the past century; 3) provide a strong baseline for documenting future changes in the flora. This year, Glenn and Jerry, working closely with Sue Williams, a bryologist from Rowe, Massachusetts, who has extensive experience with the bryophytes (mosses and liverworts) of the Northeast and summer researcher Laura Briscoe, are extending the flora project to include the bryophytes of Harvard Forest.

Pitcher-Plant Ecology

Research on pitcher-plant ecology continued its productive trajectory as NSF renewed support for PI Aaron Ellison's work on this model ecological system for another five years. Aaron and research assistant Jessica Butler focused the final year of their last grant on completing a two-year experiment on nitrogen uptake, storage, and translocation by the northern pitcher plant, *Sarracenia purpurea*. The analysis of

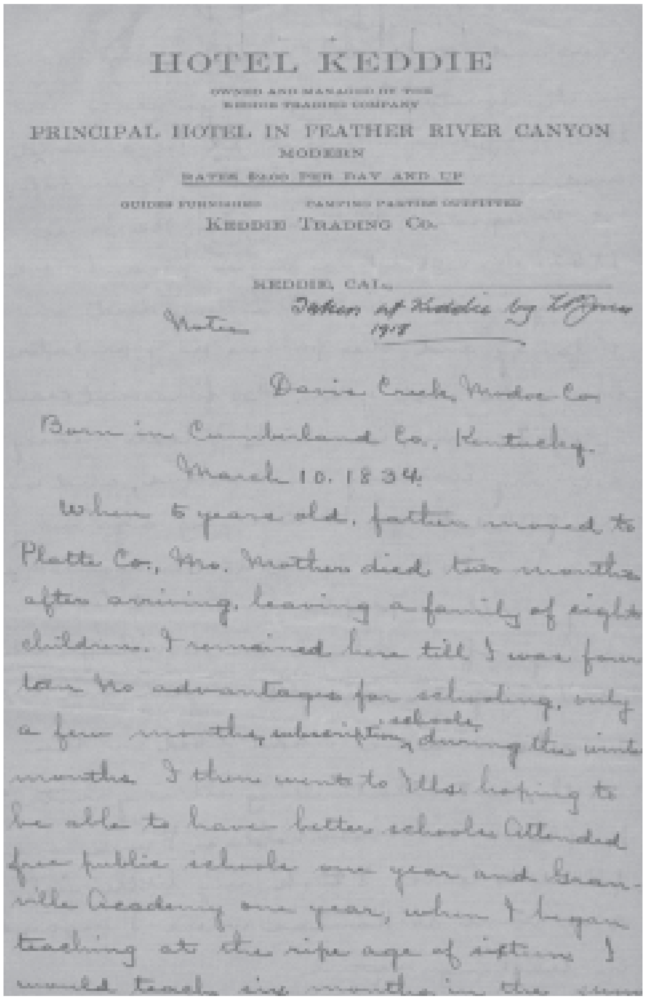
pitchers and/or roots fed either ^{15}N-enriched ammonium nitrate (to simulate acid rain) or pitchers fed ^{15}N-enriched fruit flies should allow us to finally construct a detailed nitrogen budget for this plant and cement its utility as a biological indicator for fine-scale assays of nitrogen deposition. As this report was being written, the tissue analyses of the ^{15}N-fed pitchers had just been completed by David Post's lab at Yale. Preliminary examination of the data suggests that microbial activity within the food web may dominate nitrogen cycling in this aquatic food web, in contrast to expectations based on many years of research focusing on the role of the fly larvae at the top of the pitcher's aquatic food web.

The careful observations made in the summer of 2005 by Bullard Fellow Gidon Ne'eman and his wife Rina Ne'eman (on sabbatical from Anne Frank High School in Haifa) on pitcher-plant pollination appeared November 2006 in the *American Journal of Botany*. This summer, Jess Butler is monitoring plants that Gidi and Rina manipulated last year to determine how variation in nutrient availability and photosynthetic capacity in one year translate to changes in reproductive success in the subsequent year. NSERC post-doc Jim Karagatzides will be capitalizing on these data to determine "construction costs" (in terms of carbon) of various tissues of *Sarracenia* as we probe more deeply into the evolutionary costs of botanical carnivory. Rina's carefully collected set of pollen of all ten species of *Sarracenia* growing in the greenhouse were imaged and measured by Elaine Doughty and Wyatt Oswald in the Paleo Lab, and it appears that pollen of at least several species of *Sarracenia* can be distinguished based on only two measurements. This work may lead to additional palynological markers to identify patterns of herbaceous vegetation in many of the cores studied by the Paleo Lab.

The focus for the next five years is on spatial relationships among pitcher plants, ants (their primary prey), and two species of little-studied noctuid moths, *Exyra fax* and *Papaipema appassionata* (the latter is a species of special concern in Massachusetts). These three taxa – the ants, the plants, and the moths – make up the "terrestrial" food web of the *Sarracenia* system, and Aaron and Jess will be exploring how changes in plant quality resulting from patterns of moth herbivory translate into changes in population structure of the ants, which not only are prey for the plants but also forage at the plants for sweet nectar. Some of the preliminary data that led to this successful proposal were collected by 2003 Research Experience for Undergraduates (REU) student Dan Atwater; his data were published in *Northeastern Naturalist* in spring 2006.

Aaron is also working to place this work in a broader historical context. In the early twentieth century, the Delaware entomologist and naturalist Frank Morton Jones did extensive work on *Sarracenia* and its insect associates throughout the eastern United States, as well as on the California pitcher plant, *Darlingtonia californica*. Jones's archival papers from this research, along with his entomological and botanical collections were donated to the Peabody Museum at Yale. Aaron has the archival materials on long-term loan, and they are being digitized and compiled into a Web site by 2006 REU student Stephanie Day.

Several exciting aspects stand out from this material. First, Jones carried on extensive correspondence with major figures in nineteenth- and twentieth-century botany, including William Jepson and John MacFarlane, and compiled some of the key records of the collecting activities of Rebecca Austin *(see illustration on next page)*, a California naturalist who made some of the earliest and most detailed observations on the biology of *Darlingtonia*. Second, Jones's work on *Sarracenia* and its prey in the southeastern U.S.



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Born in Cumberland Co. Kentucky. March 10. 1834. When 5 years old, father moved to Platte Co, Mo. Mother died two months after arriving, leaving a family of eight children. I remained here till I was fourteen. No advantages for schooling, only a few months subscription schools during the winter months. I then went to Ills. hoping to be able to have better schools. Attended free public schools one year and Granville Academy one year, when I began teaching at the ripe age of sixteen. I would teach six months in the sum

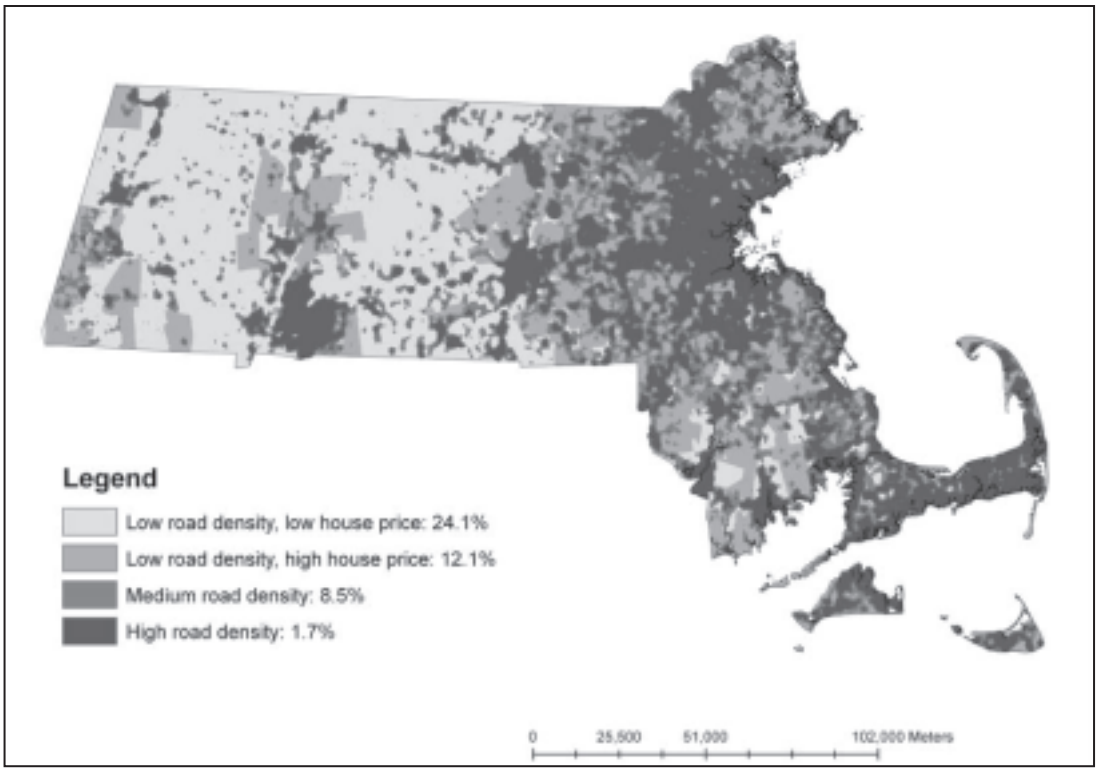
A page from the life story of nineteenth-century amateur botanist Rebecca Merritt Austin (1832–1919), as told by her daughter Mary Hail to Frank Morton Jones in 1918. Manuscript from the Frank Morton Jones Archives, Entomology Division, Peabody Museum of Natural History, Yale University.

predates the introduction of the red fire ant, *Solenopsis invicta*, providing a window into how changes in species composition of insects in bogs may have led to significant diet shifts of *Sarracenia*. Third, his detailed maps of localities will allow mapping of historic locations for *Sarracenia* and permit the assessment of the magnitude of region-wide declines in several species that are now federally endangered. Jones also did some of the only detailed work on bacterial populations within *Sarracenia* pitchers (published in 1927!). Post-doc Celeste Petersen in OEB is working on bringing bacterial studies of *Sarracenia* into the molecular age.

Jim Karagatzides's post-doctoral research with Dr. Aaron Ellison, funded by NSERC Canada, uses the carnivorous pitcher plant (*Sarracenia*) as a model system to examine three ecological themes. First, Jim evaluated cost-benefit models of plant carnivory by calculating the construction costs of plant structures. It is assumed that there is a benefit to plants constructing carnivorous structures, such as pitcher-shaped leaves to trap insects, but data to compare costs and benefits is insufficient. Comparisons will be made for multiple species of carnivorous plants in the Harvard Forest greenhouses collected from a range of environments across North America. A second component examines the stoichiometry of carnivorous plants in response to prey capture and other nutrient sources, e.g., root uptake, atmospheric deposition. A multinutrient approach is necessary because varying nitrogen inputs influence the nutrient ratios of plants. For example, acidic deposition adds nitrogen without the associated phosphorus and potassium inputs and could create nutrient imbalances relative to plants that receive increased insect inputs that provide multiple nutrients. The third component is a meta-analysis of nitrogen movement through food webs from studies using N-15 stable isotopes. This analysis will advance our understanding of the utility of N-15 stable isotopes to trace the movement of nitrogen through food webs and identify trophic levels.

PATTERNS OF FOREST HARVESTING, HISTORICAL LAND-USE, AND INVASIVE SPECIES IN MASSACHUSETTS

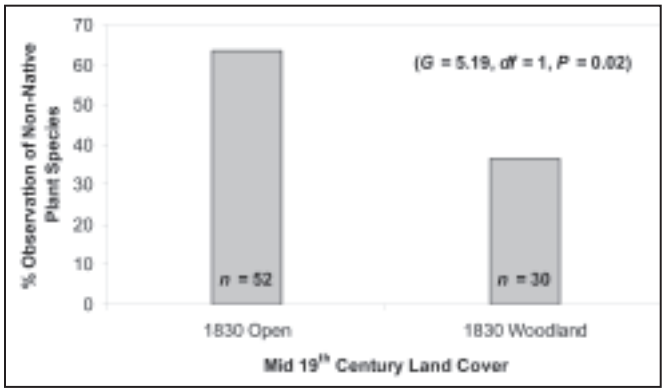
Rob McDonald, David Foster, and Glenn Motzkin completed a study evaluating the influence of forest harvesting, past land-use, and site conditions on the distribution and abundance of invasive plant species in Massachusetts. Based on two seasons of field data, they determined that invasive plant species are widespread in the woodlands of central and western Massachusetts, but typically occur in low abundance. The most common invasive species preferentially occur on relatively rich soils and sites formerly cleared for agriculture. Extensive wooded areas have few invasive species whereas woodlands in highly developed or fragmented landscapes typically support more invasives. The occurrence and intensity of forest harvesting over the past twenty years was not a strong predictor of the occurrence of several common invasive species. Methodologies and results from this study will advance conservation planning across the eastern United States, and will have broad relevance for forest management and policy efforts.



Throughout Massachusetts, 24.1 percent of forests with a low road density (less than 2.5 km of road per km^2) and a low house price (below $162,000 dollars) were harvested between 1984 and 2003. In areas of the state where either of these two variables are greater, forest harvesting is much less prevalent.

The project evaluating the broad ecological, conservation, and resource implications of forest harvesting across Massachusetts, initiated by Glenn Motzkin, David Foster, and Dave Kittredge, has achieved its major objectives. Previous work by Andrew Finley and John Burk had assembled a spatially explicit database of all forest harvesting in the state since 1984.

Robert McDonald took the lead in quantifying the spatial pattern of forest harvesting in Massachusetts. Mean harvesting intensity varies from 28.3 m^3 ha^{-1} in the Taconics to 50.3 m^3 ha^{-1} in the coastal plain, with higher harvesting intensities generally occurring in the eastern portion of the state. Around 0.5 percent of forests in the coastal plain are logged each year, while 1.4 percent of forests are logged each year in the Worcester Plateau. There are two main factors limiting forest harvesting in the eastern portion of the state: smaller parcel size, due to greater landscape fragmentation, and higher land prices, which reduces the incentives to landowners to harvest their forest and increases the incentives to landowners to develop their land. This work was published in *Forest Ecology and Manuscript* in May 2006.



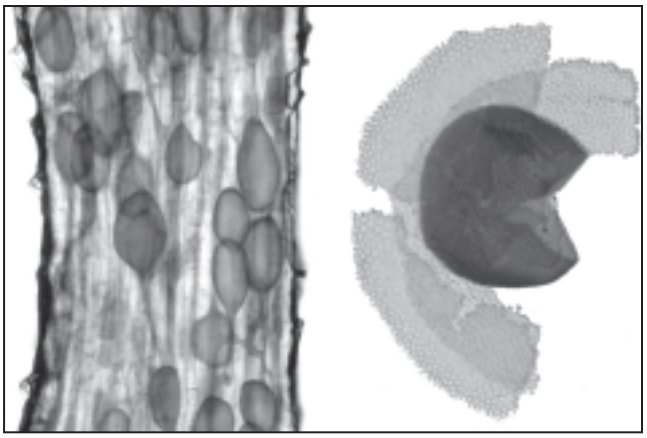
Sites that were cleared for agriculture in the nineteenth century are twice as likely to have an invasive species present.

DISTRIBUTION, POPULATION DYNAMICS, AND IMPACTS OF INVASIVE PLANT SPECIES

Population-to-landscape level observations, historical studies, and controlled experiments are being conducted to investigate invasive plants as both responders to and drivers of forest change. Although invasive plant species are widespread, remarkably little is known about their ecological impacts, the landscape to regional patterns of distribution and abundance of these taxa, or the factors controlling their rates and patterns of spread. Recent results provide new evidence for direct and indirect impacts of the invasive plant, garlic mustard, on native plants and their fungal mutualists. Geographic variation has also been demonstrated in the distribution and abundance of this plant across ecoregions in Massachusetts, and local variation in the demographic performance of invading populations in different forest habitats.

The enemy of my friend: An invasive plant disrupts mutualistic associations between native tree seedlings and mycorrhizal fungi.

Very few studies have empirically investigated how invading plants may alter ecological interactions among resident species in the invaded range. Kristina Stinson and collaborators John Klironomos (University of Guelph) and Ben Wolfe (OEB) demonstrated that *Alliaria petiolata* (garlic mustard), a European invader of North American forests, suppresses the growth of key native canopy tree seedlings by disrupting their longstanding mutualistic associations with arbuscular mycorrhizal fungi (AMF). Seedlings of the dominant native hardwood tree species of northeastern North America (sugar maple, red maple, and white ash) had lower growth and fungal colonization of roots in soil invaded by garlic mustard than in uninvaded soils. These reductions were similar to those observed on sterilized soils. All three species also demonstrated lower root colonization by AMF in soils conditioned by garlic mustard than in unconditioned soils or soils conditioned by other native plants. The suppressing effects of garlic mustard appear to result from water-soluble chemicals exuded from the plant, as aqueous extracts from garlic mustard were just as effective as the living plants at reducing the root colonization and germination of AMF spores. Garlic mustard also suppressed



Left: A Microscope view of a plant root colonized by arbuscular mycorrhizal fungi (AMF) spores; *right:* crushed spore of an AMF in the genus *Acaulaspora.*

AMF colonization of roots in several additional species typical of forest successional gradients. However, tree seedlings were most strongly dependent on the mutualism and demonstrated the strongest negative growth responses. Thus, the antifungal effect of this invader disproportionately reduces the performance of native tree seedlings over other plant species.

Landscape and habitat variation in demographic attributes of invasive plant species

Kristina, Kathleen Donohue, and summer undergraduates researched the role of landscape and habitat factors on demographic attributes of the invasive plant *Alliaria petiolata* (garlic mustard) in northeastern forests. The Prospect Hill tract at Harvard Forest was surveyed and they found that six invasive species, including garlic mustard, are most abundant in sites with agricultural land-use history. Also, local populations of garlic mustard were monitored in sun, intermediate, and forest habitats at Harvard Forest over a period of three years. Using census data from four life-stages in 90 $1m^2$ quadrants, they constructed demographic population matrices and found that population growth rate was greatest in sun populations and lowest in intermediate habitats.

Survivorship between life-stages depended mainly on yearly fluctuation and less on type of habitat. The reasons for the higher growth rate of sun populations were higher seed production and a higher survivorship from first- to second-year plants.

A forest understory in Massachusetts heavily invaded by garlic mustard.

Regional variation in forest invasion by garlic mustard

At a broader scale, Kristina, Brian DeGasperis, and REU student Kevin Burls recently conducted a regional comparison of landscape-level distribution of garlic mustard *(Alliaria petiolata)* in forested sites in Massachusetts. Using the Massachusetts Geographical Information System (MassGIS) layers to determine the locations of forest cover and subsequently generate random sampling points, they surveyed fifty sites in two contrasting ecoregions, the Connecticut River Valley and the Berkshire Valley for the following: presence/absence of garlic mustard in forest edge and forest understory habitats, incursion rates (distance of population invasion into forested habitat), and percent cover of this species. The Berkshire Valley had ~ 60 percent occurrence of garlic mustard, compared to only ~15 percent in the Connecticut River Valley. Preliminary results demonstrate that the two ecoregions differed in the percent cover of first-year plants and in total percent cover of garlic mustard. Further analyses are underway to determine the degree to which these locations differ in abundance and incursion rates, and the relative contributions of environmental, historical, and physiographic variation to the success of forest invasion.

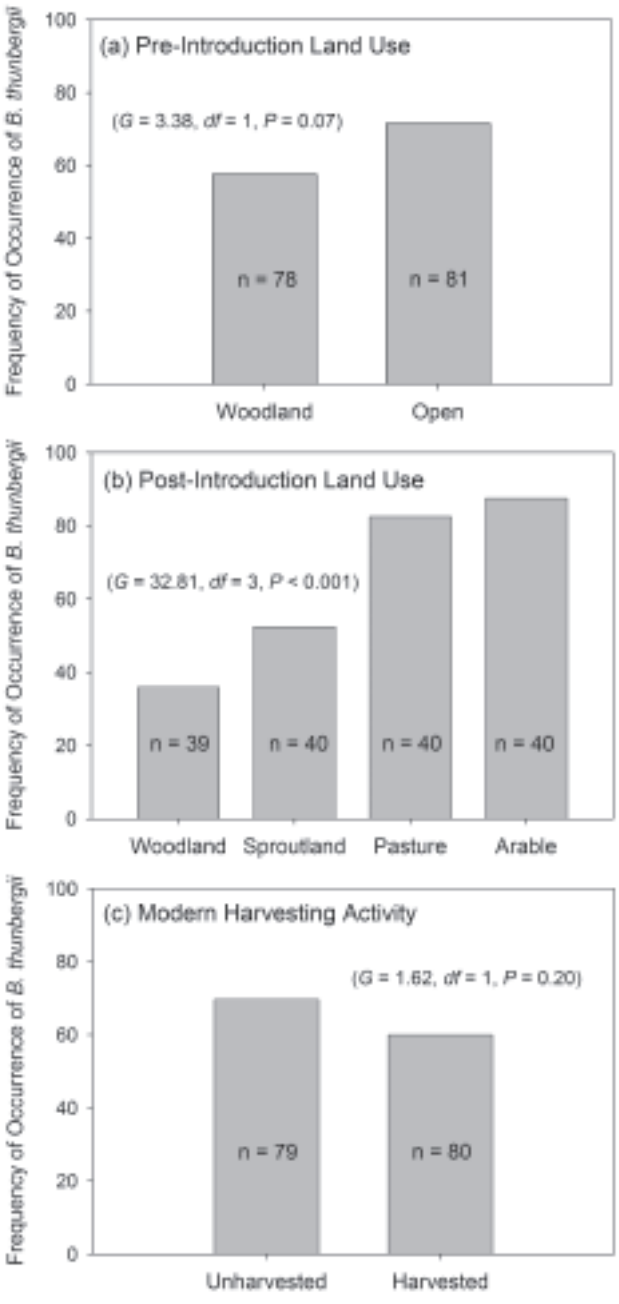
Influences of historical land use and forest harvesting on Japanese barberry invasion

Attempts to determine the characteristics of habitats that render them invasible to non-native species have met with limited success. One possible explanation for this shortcoming may be that by focusing on modern conditions, most studies fail to consider invasibility in the context of a historically dynamic landscape in which both the abundance of a species and the invasibility of a site may change. Despite the recognized importance of historical factors in controlling

many native species distributions, few studies have incorporated historical landscape changes into models of invasive species distribution and abundance. As part of his MFS research Brian DeGasperis explored the possibility that the current distribution of invasive species may reflect legacies of historical land use despite nearly a century of forest succession and subsequent disturbances. This work is based in part on the recognition that since the mid-nineteenth century southern New England has been transformed from a predominately agricultural landscape to a largely forested condition. Thus, species in our forests today may have spread and become established in fields or young forests of the past. Forests were surveyed for the occurrence and abundance of Japanese barberry, *Berberis thunbergii*, a problematic nonnative shrub in northeastern forests, relative to two distinct periods of historical land use (1830 and 1927), forest harvesting (1984–present), and environmental and edaphic characteristics. Barberry occurred more frequently and was more abundant in sites historically cleared for agriculture than in continually wooded sites.

This relationship was strongest for areas in agriculture in the early twentieth century when barberry was widespread in the region. While land-use history is confounded with soil fertility and distance to putative seed sources, Brian's data suggest that the strong relationship between modern distribution and prior land use is a consequence of colonization of abandoned agricultural lands and persistence through subsequent reforestation. In contrast, recent forest disturbances, such as harvesting, did not influence the occurrence or abundance of barberry at the landscape scale. These results indicate that invasibility of a site must be considered in the context of changing landscape conditions. In particular, interpretations of both native community composition and modern

Legacies of an agricultural past: a wood land stonewall delineating a dense thicket of Japanese barberry.



Frequency of occurrence of Japanese barberry in modern forests relative to: (a) land use prior to barberry's introduction to Massachusetts; (b) post-introduction land use; and (c) modern harvesting activity. The distribution of barberry is strongly influenced by historical agriculture, but not by recent selective logging.

plant invasions must consider the importance of historical landscape changes and the timing of species introduction along with current environmental and edaphic conditions.

CO_2 ENRICHMENT ALTERS REPRODUCTION, COMPETITIVE INTERACTIONS, AND GENETIC

Structure of Common Ragweed Populations

Plants growing in dense stands may not equally acquire or utilize carbon gains from elevated CO_2. As a result, the size and reproductive differences between dominant and subordinate plants may be altered under rising CO_2 conditions. Kristina Stinson is completing studies on the impacts of global change on the competitive interactions and relative reproductive output of individuals and genotypes of the allergenic weed, *Ambrosia artemisiifolia* (common ragweed).

Effects of high CO_2 on reproductive dominance

It is hypothesized that shaded, subordinate individuals of ragweed would achieve greater growth and reproduction in proportion to stand totals than light-saturated dominants under elevated CO_2. They grew experimental stands of ragweed at either 360 µL L^{-1} or 720 µL L^{-1} CO_2 levels and measured the growth and reproductive responses of competing individuals. To test whether elevated CO_2 diminished or exaggerated size and reproductive inequalities within stands, stand-level coefficients of variation (CV) were compared in final shoot, root, and reproductive organ biomasses. Smaller plants produced more reproductive biomass per unit of growth in the enriched-CO_2 treatment. The elevated CO_2 treatment stimulated growth and reduced inequalities in all plant organs, especially reproductive allocation. Positive relationships between the CV and total stand productivity deteriorated under elevated CO_2, indicating that growth enhancements to smaller plants diminished the relative biomass advantages to larger plants in increasingly crowded conditions. It was concluded that CO_2-induced growth gains of subordinate *A. artemisiifolia* plants stimulate stand-level reproduction and equalize the reproductive output of small and large plants. Thus, more individuals are likely to produce greater amounts of seeds and pollen in future populations of this allergenic weed.

Architectural and physiological response to high CO_2

Using data from the experiment described above, REU students Jen Petzold and Jimmy Tran compared the relative growth, photosynthetic capacity, and architecture of subordinate and dominant plants in each treatment, and assessed size inequalities using the stand-level coefficient of variation (CV). In elevated CO_2, plants grew larger, but subordinate plants shifted more mass to upper stem allocation than dominants. Dominant plants demonstrated reduced leaf-level photosynthetic gains in elevated CO_2 compared to subordinate plants. Reduced CVs in plant size reflected smaller proportional growth gains by dominants over subordinates in elevated versus ambient stands. Jen and Jimmy concluded that differences in the architectural and physiological responses of subordinate and dominant ragweed plants reduce competition and allow subordinate plants to catch up to dominants in elevated CO_2 conditions.

Functional relationship models for the biomass and reproductive allocation of ragweed genotypes at ambient and elevated CO_2.

Using functional relationship models, Kristina and collaborators at University College, Dublin, Ireland, John Connolly and Caroline Brophy, are investigating the effect of CO_2 on the hierarchical structure of genotypes within these stands with respect to biomass and reproductive allocation. Twelve genotypes of ragweed from known maternal lines were selected and grown competitively in the experimental stands described above. Each genotype was replicated twice within each stand. To date, they have found novel evidence that the structure of populations changed under elevated CO_2 – those genotypes that perform less well under ambient CO_2 conditions benefit proportionately more than others under elevated CO_2, i.e., subordinate genotypes 'catch-up' to dominants. This was true for both biomass and reproductive allocation. Moreover, genotypes with a smaller reproductive allocation at ambient CO_2 were no longer subordinate under elevated CO_2 as all genotypes tended to a common reproductive allocation. This is the first study to demonstrate a genetic basis for dominance hierarchies within developing stands, and to show how elevated CO_2 can alter these hierarchies to affect the outcome of competition.

Culvert built in the fall of 2006 on Bigelow Brook.

HYDROLOGICAL STUDIES

The combination of long-term hydrological, meteorological, and eddy flux measurements at the Harvard Forest provides a rare opportunity to study the hydrological cycle of small forested watersheds. A pilot project conducted by Emery Boose, Julian Hadley, and summer undergraduate Safina Singh in summer 2005, estimated water budgets for Prospect Hill by integrating precipitation data from the Fisher meteorological station, evapotranspiration data from the Hemlock and Little Prospect Hill eddy flux towers, stream discharge data from the Nelson and Bigelow gages, and ground water data from wells installed in the 1970s by Walter Lyford. In both watersheds results showed the expected seasonal decline in system water storage from late spring through early summer in both the Nelson and Upper Bigelow watersheds, as well as a significant increase in the relative loss of water to evapotranspiration after leaf-out in early June. Nelson watershed, with its much higher percentage of wetland area (60 percent vs. 10 percent), retained significantly more water during this period. In both watersheds the change in water storage calculated from precipitation, evapotranspiration, and stream discharge closely matched the estimated change in ground water storage.

Recent developments in wireless networking and sensor technology will make it possible to collect, analyze, and display such measurements online in near-real time. However management of such data streams presents a number of interesting technical challenges, including how to do real-time documentation and quality control of the data. These prob-

lems are being studied as part of a long-term collaboration between ecologists at the Harvard Forest: Aaron Ellison, Emery Boose, and Julian Hadley, and computer scientists at UMass-Amherst, Leon Osterweil, Lori Ann Clarke, Alexander Wise, using a real-time water budget system for Prospect Hill as a model case.

ECOLOGY AND CONSERVATION OF KETTLE PONDS AND VERNAL POOLS

Efforts to complete long-term studies of vernal pools in Massachusetts have continued. Betsy Colburn analyzed five years of data from fourteen vernal pools on Cape Cod and prepared a manuscript examining patterns in community change in relation to year-to-year variations in precipitation and pool hydrology. Betsy also continued processing of samples collected from vernal pools across the state, as

Emery Boose on a new weir.

part of an ongoing comprehensive analysis of invertebrate community composition in relation to geography, hydrology, and historic land use.

As part of the development of long-term monitoring methods for kettle ponds and vernal pools in the Cape Cod National Seashore, Betsy carried out a

The big weir on Nelson Brook.

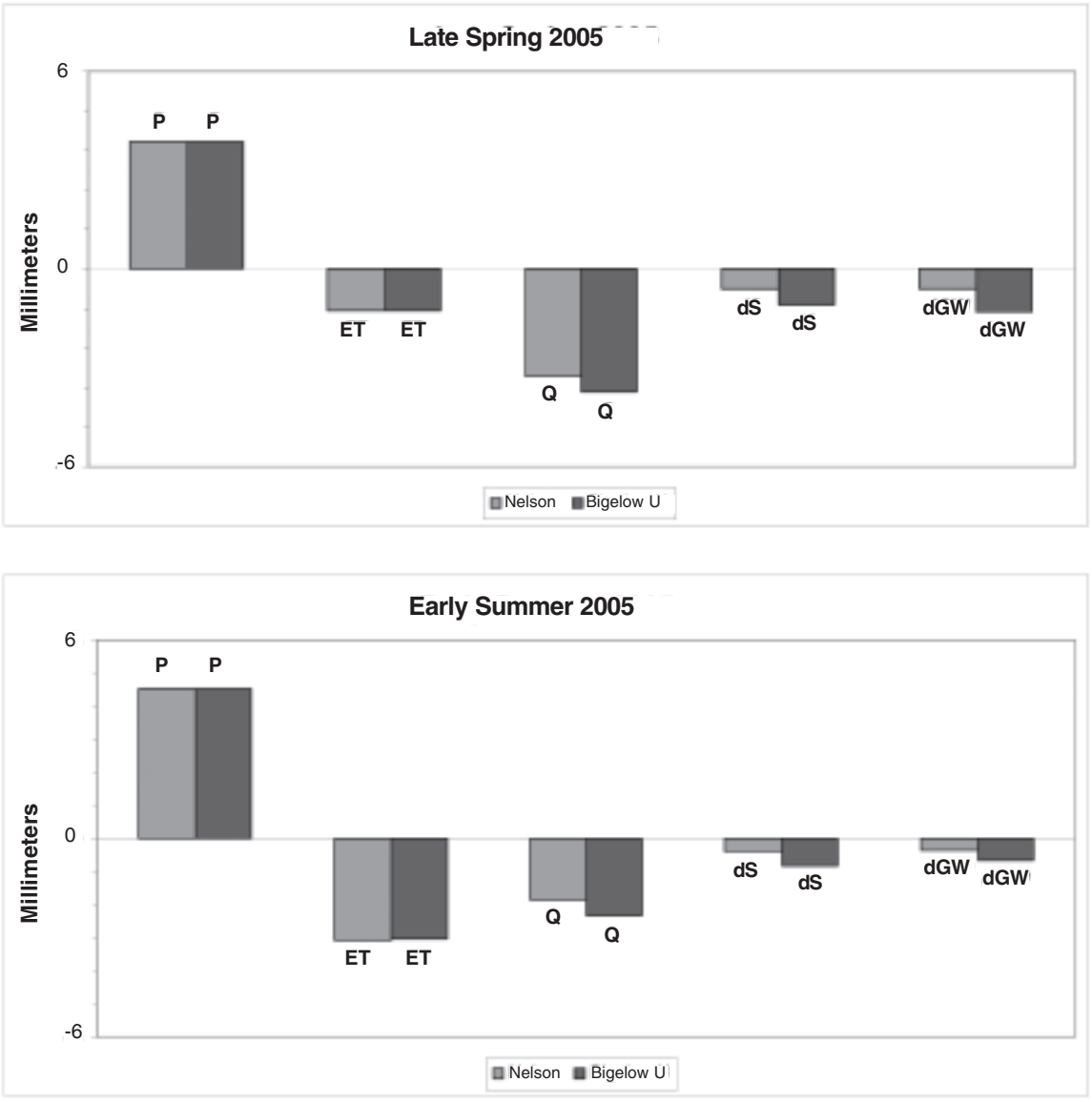
multivariate comparison of kettle ponds in relation to their chemistry, basin characteristics, and other limnological variables. Processing of aquatic invertebrate samples from the ponds is continuing, and the results will ultimately be combined with the physical-chemical data.

STREAM ECOLOGY AND POTENTIAL IMPLICATIONS OF HEMLOCK DECLINE MEDIATED BY THE HEMLOCK WOOLLY ADELGID

Harvard Forest Aquatic Ecologist Betsy Colburn and Bill Sobczak from College of the Holy Cross's Biology department continued baseline research on headwater streams in north central Massachusetts, in conjunction with ongoing forest studies by Dave Orwig and other Harvard Forest researchers. Former 2004 REU student Bridget Collins worked with Bill to prepare a manuscript for submission to *Wetlands,* detailing the results of her examination of chemical and biological characteristics of surface reaches and subsurface flow chutes in Bigelow Brook.

In summer 2005, Betsy Colburn and Bill Sobczak co-mentored two summer REU students: James Willaker from the SUNY College of the Environment and Forestry and Matthew Kaufman from Keene State College. The students carried out intensive habitat surveys in headwater streams in northern Worcester county, adding substantially to our database on physical, hydrological, and watershed characteristics of streams in hemlock-dominated and deciduous watersheds. In addition to collecting standardized stream habitat data, James and Matt applied standard forestry

Boose, Hadley, and Singh. Preliminary Water Budget for Prospect Hill



Preliminary water budgets for Nelson and Upper Bigelow watersheds for late spring (April 20–June 5) and early summer (June 6–July 26) 2005. Values are daily averages. Positive values represent a gain and negative values a loss of water to the forest ecosystem. **P** = precipitation measured at Fisher Meteorological Station. **ET** = evapotranspiration measured at Hemock and Little Prospect Hill eddy flux towers, with values weighted according to the proportion of hemlock and hardwoods in each watershed. **Q** = yield measured at steam gages, with gaps in data filled by simple runoff model. **dS** = chnge in ecosystem wter storage, calculated as **dS** = P + ET + Q. **dGW** = change in ground water storage measured at two nearby wells chosen to represent poorly-drained and well-drained soils, with values weighted according to the percentage of wet and dry soils in each watershed. (Boose, Hadley, and Singh, *unpublished data.*)

survey techniques to quantify forest composition in the catchments of study streams. This information, along with results from previous and ongoing surveys, serves as a solid baseline for future comparisons if and when the hemlock woolly adelgid (HWA) becomes established in northern Massachusetts and kills hemlocks along headwater streams. Dr. Sobczak continued much of the survey work through the year with students in his undergraduate aquatic ecology class.

As an independent project, James Willaker compared the aquatic invertebrate communities in the eastern and western branches of Bigelow Brook, respectively deciduous and hemlock-dominated headwater streams at the HF Prospect Hill Tract, and continued his analysis of the communities as a senior thesis during the following year. For his project, Matt Kaufman installed two parallel transects of groundwater wells perpendicular to the upper channel of the west tributary of Bigelow Brook, and examined relationships between streamflow, groundwater elevations, and precipitation. The wells remain in situ for future research in this area.

Betsy compared Dave Orwig's digitized aerial photographic data on the distribution and density of hemlock and hemlock woolly adelgid in Massachusetts with topographic map evidence of stream channels, and identified a number of potential candidate streams for focusing future research on short-term impacts of HWA on streams. In summer 2006, field surveys by Bill Sobczak and two REU students, Lori Saunders and Tim Rowell, are focusing on streams dominated by hemlock and affected by HWA.

In spring, 2006, Betsy quantified light inputs to deciduous and hemlock streams and, with Joan Milam, sampled mosses from the eastern and western branches of Bigelow Brook. The results, along with an overview of habitat and community data from Harvard Forest headwater stream surveys to date, were presented in a poster at the North American Benthological Society Annual Meeting in Anchorage, Alaska, in June 2006.

CHANGING DYNAMICS OF HEMLOCK WOOLLY ADELGID POPULATIONS AND ASSOCIATED IMPACTS ACROSS SOUTHERN NEW ENGLAND

As part of a larger Harvard Forest research emphasis on invasive species, work continued on several studies led by Dave Orwig investigating the impact of the introduced insect pest, the hemlock woolly adelgid. During the summer of 2006, Dave and Heidi Lux continued to examine the response of ecosystem processes to the stress and mortality caused by the HWA in Connecticut hemlocks. Over the eight-year study differences in nitrogen availability between heavily infested and lightly infested sites were obvious for the first four years then recently declined, probably due to HWA declines resulting from cold winter temperatures November 2004 through spring 2005, and November 2003 through spring 2004. Interestingly, overstory mortality has continued at sites in central and northern Connecticut (15 percent to 35 percent in 2005), but not at the rates experienced in southern Connecticut (all sampled sites have now lost >80 percent overstory hemlock). Dave worked with summer student Christie Rollinson (Oberlin College) to establish additional permanent plots in Massachusetts to follow the long-term forest dynamics associated with HWA infestation at the northern edge of the invasion.

As a follow-up to examining the distribution of hemlock, HWA, and HWA-related damage across the landscape of Connecticut and Massachusetts, a large resampling effort has now been completed across our 7,500 km^2 study area. We assessed the spread and community-level impact of the HWA and another invasive insect attacking hemlock, the elongate hemlock scale (EHS), on southern New England hemlock forests by resurveying 141 hemlock stands. All of these stands had been previously identified via aerial photography and surveyed in either 1997–98 (CT) or 2002–04 (MA) for HWA and EHS density as well as hemlock stand vigor. We rated two branches on each of fifty trees per stand on a scale of 0–3 (0=none; 1=1–10 organisms/m branch; 2=11–100/m branch; 3=100+/m branch) for HWA and EHS density. We also assessed percent overstory hemlock mortality as well as percent canopy loss in each stand.

Canopy loss and hemlock overstory mortality increased with increasing HWA density, with the most damaged stands located in southern Connecticut and the most undamaged stands in northern Massachusetts. HWA density decreased with increasing latitude, possibly due to climatic limitations, and was absent from much of northern Massachusetts. Although the total number of HWA-infested sites increased between the initial and 2005 surveys, mean HWA density per site has decreased over this same period, perhaps due to extreme cold spells in 2004 and 2005. EHS distribution and density per site has

increased dramatically since 1997–98 and is now present in every Connecticut stand and many Massachusetts stands. Within the survey transect, EHS appears to be moving rapidly northeast from the site of its initial introduction on Long Island in 1908. Despite its rapid increase in abundance, EHS density was not correlated with overstory hemlock mortality when the effect of HWA presence was taken into account. There was a positive correlation between HWA and EHS density on trees within individual sites in sites with low overall HWA densities. As overall HWA density increased, however, this correlation shifted from positive to negative (likely as a result of resource competition). This large project is a collaborative effort that includes Dave, undergraduate student Sasha Lodge, Kenyon College; Evan Preisser, University of Rhode Island; and Joe Elkinton, University of Massachusetts–Amherst.

Forests in Massachusetts and Connecticut are increasingly affected by the invasion of the hemlock woolly adelgid (*Adelges tsugae*) both through direct effects of mortality from infestation and from salvage logging. Over the past five years the impact of salvage logging in these systems has been studied by our group and, in some cases, it has been clear that logging of damaged stands has a greater impact on ecosystem function than the effects of deterioration due to adelgid driven mortality alone.

For example, an infested site that was cut in 2002 has been replaced with black birch, raspberries, and other herbaceous species. Soil temperature and nitrogen availability have increased tremendously since the cutting and exceed the values observed in any of the infested forests. Organic soil moisture at the cut site has continued to decrease since the logging. We will monitor these sites with ion-exchange resin bags to examine the spatial availability of N within sites and the extent to which NO_3 is being lost over time.

In 2003, Heidi Lux and Dave Orwig began to study post-adelgid logging and ecosystem function at the urban Arnold Arboretum, just outside of Boston. During 2004, six 15 × 15 m plots were fenced off, and baseline data on soil nutrient cycling, microclimate, and vegetation information were collected. Hemlocks were removed from four plots in February of 2005, while two remain untouched as control plots. Slash was chipped and left on site in the chipped treatment plots or removed from the logged (only) treatment. The logging operation was conducted by crane and had low impact on the soils. This series of treatments coincides with those at the Harvard Forest's Hemlock Removal Experiment at the Simes Tract in Petersham, where they are collecting analogous data.

Dave and Heidi are currently in their second year of post-treatment measurements at both of these sites, following one year of baseline data collection. In general, both nitrogen availability and nitrogen cycling rates are very high at the Arboretum, particularly for nitrate. This was true even before treatments began, with availability and rates from two to twenty times higher than had been observed at the more rural study sites. Nutrient cycling responses are likely to be even more dramatic this growing season and next, based on observations at logged, infested sites in Connecticut, where the mobilization of nutrients peaks in the second and third years following cutting. Vegetation responses to cutting at the Arboretum have been rapid and dramatic, with shoulder-high cover of up to 50 percent in the summer of 2005, just months after cutting. While they expected a proliferation of weedy and shrubby

Heidi Lux at the Arnold Arboretum in 2004.

Heidi in the same area in 2005!

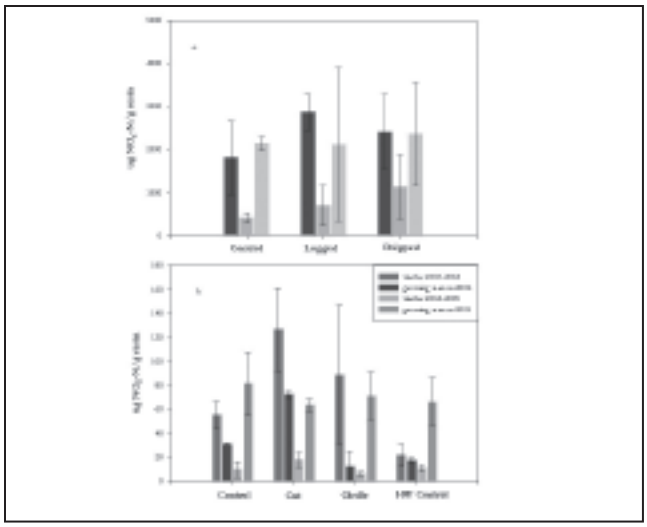
species, Dave and Heidi were astonished by the dramatic response as vegetation at other logged sites has taken a year or two to establish significantly.

Soil nutrient cycling and vegetation responses at the Harvard Forest Simes tract were muted in the first year post-treatment, and in line with other commercially logged sites. The next several years will present many opportunities for comparison between the urban and rural study sites.

Many landowners are choosing to pre-emptively harvest their hemlock stands with the advent or threat of HWA. Information from timber harvesters, state agencies, and Harvard Forest studies indicate that the recent broadscale increase in logging associated with HWA is occurring with little ecological assessment and in the absence of scientific background for conservationists, land managers, or policy makers. Dave Orwig and David Kittredge have incorporated findings from several previous and ongoing Harvard Forest studies of HWA and hemlock logging into a pamphlet for landowners that provides various silvicultural options for managing hemlock forests. Options range from doing nothing to light selective cutting to high-intensity cutting, depending on landowner objectives, overall hemlock health, and stand conditions. In addition, the pamphlet includes planting options and addresses HWA best-management practices. All options and costs should be considered carefully when planning the appropriate management strategies to effectively meet desired goals and make an informed decision about hemlock and the threat of HWA.

Local high-school graduate Eowyn Connelly-Brown assisted for a second year with many of the laboratory and field activities associated with these labor-intensive studies. In addition, Shelley Raymond, an undergraduate of the University of Massachusetts–Amherst, volunteered during the summer of 2006 on several HWA-related projects.

Dave Kittredge and REU student Kelly Grogan.



Available nitrate at the experimental plots on Hemlock Hill, at the Arnold Aboretum (a) and at the Hemlock Removal Experiment at the Simes Tract, Harvard Forest (b). The first bar on the left of each group in b. represent an additional collection of pretreatment data in the winter of 2003–2004. Manipulations began at both sides of the winter-spring of 2005.

EXPERIMENTAL LOGGING AND GIRDLING OF HEMLOCK

To complement the extensive work on the HWA and experimental plots at the Arnold Arboretum, in 2003, Aaron Ellison, Audrey Barker Plotkin, and Dave Orwig began a large-scale Hemlock Removal Experiment to simulate the effects of hemlock removal from the forest ecosystem by adelgid and by logging. There are two replicates (0.8 ha plots) of the following treatments: hemlock girdling (to simulate many of the effects of HWA), hemlock commercial logging (to simulate the preemptive logging that is occurring in hemlock forests in our region), hemlock control (no treatment), and hardwood control (representing a possible future composition of post-hemlock forest). Logging and girdling treatments were completed in winter and spring 2005.

The Hemlock Removal Experiment is now fully up and running. Ongoing measurements include hourly measurements of soil and air temperature (by Aaron Ellison – HF); twice-yearly measurements of light quantity from hemispherical canopy photo-

graphs (Aaron Ellison); soil respiration (Kathleen Savage, Emily Austin, and Eric Davidson – WHRC and Hampshire College); nitrogen availability and mineralization rates (Heidi Lux and Dave Orwig – HF); throughfall chemistry (Pamela Templer – BU); primary productivity (litterfall) and rates of decay of coarse woody debris (Audrey Barker Plotkin – HF); species composition of understory herbs and shrubs (Audrey Barker Plotkin); ants and beetles (Aaron Ellison, REU students Laura Briscoe, Grace Wu, Alex Arguello, and Rachel Osborn, and UMass Ph.D. student Sydne Record); birds (volunteers Ernie and Linda LeBlanc of Royalston), and salamanders (Brooks Mathewson – HF); overstory tree size and vigor (Audrey Barker Plotkin). Data are being used to parameterize models forecasting changes in net ecosystem productivity in response to adelgid infestation (Paul Moorcroft – OEB). Parallel experiments are underway at the Coweeta LTER site (hemlock removal) and the Black Rock Forest in eastern New York (oak removal).

Initial data, including two-year-before treatments and one-year-after treatments, show clear changes in microclimate, plant and animal species composition, and ecosystem properties in logged plots vs. controls. Girdled hemlocks began to disintegrate in summer 2006, and although girdled plots are noticeably brighter due to thinning of the hemlock canopy and falling branches and trees, few measured variables show significant responses to treatments.

Eric Davidson and Kathleen Savage (WHRC) are examining the change in carbon released thorough soil respiration as a result of hemlock death. The balance between the components of soil respiration (root respiration and microbial respiration) may shift during the disturbance period. With the girdling treatment they can see how soil respiration rates change as the hemlocks die. This will also give insight into how to partition between the root versus microbial components of soil respiration; microbial respiration should dominate in girdled plots. In collaboration with Sue Trumbore from the University of California, Davidson's group will also look at the C14 signatures from the girdled experiment and compare those to the control stand, which will help determine the age of the carbon being respired.

REU students Dave Diaz and Chelsea Kammerer-Burnham with Aaron Ellison.

Aaron presented preliminary result of this large collaborative experiment in a poster at the triennial LTER All Scientist's Meeting in September 2006, and in a workshop at the meeting on foundation species that he organized with Brian Kloeppel from Coweeta LTER.

Ant controls on ecosystem dynamics

With a lot of backbreaking labor contributed by Jess Butler, Jim Karagatzides, Emily Austin, and Tony D'Amato, Aaron also established a set of 3 × 3-m ant exclosures and disturbance controls to determine if ants really are the "little things that run the world" or at least run the soil ecosystem dynamics at the Simes Tract. This experiment builds on observations published by Walter Lyford in 1963 (Harvard Forest Paper no. 7) and is also being replicated at Coweeta by Aimée Classen (Oak Ridge) and Nate Sanders (University of Tennessee).

Doctoral student Sydne Record and 2006 REU student Alex Arguello are working with Aaron to completely inventory the ant diversity of the Simes Tract. Focal areas for sampling in summer 2006 were based on unique vegetation identified by Jerry Jenkins and Glenn Motzkin in their Flora of Harvard Forest project. 2006 REU student Rachel Osborn worked with Aaron to extend work by 2005 REU students Grace Wu and Laura Briscoe to inventory key groups of beetles – carabids, cerambycids, and elatyrids – at the Simes Tract. In the long run, this work will contribute to an inventory of the insect fauna of Harvard Forest.

FOREST EXCHANGES AND INTERACTIONS WITH THE ATMOSPHERE

New heating x warming experiment

Serita Frey from the University of New Hampshire received a NSF Career grant to establish a new

Ant exclosure.

experiment at Harvard Forest to examine the interactive effects of soil warming and N additions on microbial community structure and nutrient cycling dynamics. The plots were established in fall 2005. There are four treatments (control, heated +N, heated –N, +N only) and six replicates in a completely randomized design (twenty-four 3 × 3 m plots). Average soil temperature in the heated plots is elevated 5º C above ambient by the use of buried heating cables placed at 10 cm depth in the soil and spaced 20 cm apart. The heating cables are controlled by a data logger that monitors thermistors in each plot every ten minutes. Plots automatically turn on and off to maintain a 5º C temperature difference between the heated and control plots. The N addition plots (heated only, +N only) are fertilized following the protocol of the Chronic N Addition Study. An aqueous solution of NH_4NO_3 is applied at a rate equivalent to the low N plots at the chronic N study (5 g m^{-2} yr^{-1}). Fertilizer is being applied in equal monthly doses during the growing season (April through October). The control plots and unfertilized, heated plots (heated only) receive water only. Routine measurements will include soil respiration, N mineralization, microbial biomass, and metabolism, and C and N pools (total C and N, dissolved organic C, inorganic N). This study will experimentally show how anthropogenic change, i.e., warming, N deposition affects microbial community composition and diversity, and how shifts in the microbial community impact C and N cycling at the ecosystem level. Serita is developing a new approach (calorespirometry) to assess microbial metabolism, with an emphasis on carbon-utilization efficiency. Alix Contosta, a doctoral student in Serita's lab, will focus her dissertation on the fungal community and whether shifts in fungal species composition, in response to warming and/or N additions, are linked to changes in litter decomposition rates.

Soil respiration studies

In 2005, Eric Davidson and Kathleen Savage from the Woods Hole Research Center began their eleventh year measuring soil respiration at the Forest, and added two new plots to their long-term transect sites. These long-term 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 and higher during wet summers. Recent expansion of measurements in areas to the north and east of the EMS tower also

show important spatial heterogeneity, with lower fluxes from the shallow soils on steep slopes in these areas. They are working toward an understanding of how to integrate the spatial heterogeneity of soil CO_2 efflux with the tower-based measurements of total ecosystem respiration.

Fast time response measurements of volatile organic compound (VOC) concentrations and fluxes at Harvard Forest

Karena McKinney, Assistant Professor of Atmospheric and Environmental Chemistry at Amherst College, continued measurements of volatile organic compounds (VOCs) at the Harvard Forest Environmental Measurement Site. Through reactions with the major atmospheric oxidizing agents and NOx, VOCs play a key role in determining the oxidizing capacity of the atmosphere. The goal of this project is to quantify sources and sinks of VOCs at the Harvard Forest and investigate their reactivity in the atmosphere by making direct field observations of ambient concentrations, concentration gradients, and fluxes of VOCs.

During the summer and fall of 2005, measurements of many VOCs, including isoprene, monoterpenes, methyl vinyl ketone, methacrolein, benzene, tolulene, xylenes, acetone, and acetaldehyde were obtained. Biogenic species such as isoprene and monoterpenes are the dominant VOCs over Harvard Forest in the summer, although measurable quantities of anthropogenic species are also present, indicating that the forest atmosphere is impacted by anthropogenic hydrocarbon emissions from nearby urban and industrial areas. Diurnal cycles of isoprene and its oxidation products, methyl vinyl ketone and methacrolein are being used to understand the fate of forest emissions, which are both removed chemically and redistributed through dynamical processes. The relative importance of these mechanisms affects the production of ozone due to VOC oxidation in the vicinity of the forest. Additional measurements of VOC concentrations, concentration gradients, and fluxes, took place in 2006.

NATIONAL INSTITUTE FOR GLOBAL ENVIRONMENTAL CHANGE

Julian Hadley continued to measure forest-atmosphere exchange of carbon and water at the Little Prospect Hill and Hemlock forest flux measurement towers, and completed analysis of data through the end of 2004. In the deciduous forest at Little Prospect Hill, which largely established after a 1957 forest fire, higher annual carbon storage was observed in 2004 compared to either of the preceding two years. However, annual estimated net C storage at Little Prospect Hill was again similar to the value calculated for the Environmental Measurement Site (EMS) tower, which is surrounded by older forest encompassing a wetland area and moister soils. In 2004 as in 2003, both the maximum rate of carbon storage above ground and the average rate of carbon production in the forest (ecosystem respiration) were lower for the younger, drier forest on Little Prospect Hill compared to the EMS forest. These two differences again roughly balanced each other, resulting in similar net carbon storage. Carbon uptake by the hemlock forest in the summer of 2004 was much lower than of the deciduous forests, and was similar to past measurements.

In the summer of 2005, Julian worked with two summer students, Susan Cheng and Jennifer McInnis, to measure aboveground carbon storage on Little Prospect Hill using tree-ring analysis and variation in dissolved carbon dioxide content of the Beaver Swamp northwest of the EMS tower. The tree-ring analysis showed that C storage increased rapidly following the 1957 forest fire as a new forest was established, but that there was a sharp drop in storage in 1980 and 1981, probably due to severe defoliation by gypsy moths. The study of dissolved CO_2 levels in the Beaver Swamp was stimulated by unusually high rates of CO^2 release observed in winds blowing over the Beaver Swamp. Data from the swamp in 2004 showed large fluctuations in dissolved CO_2 concentration, ranging from above 15,000 parts per million (ppm) to less than 4,000 ppm. An experiment using a floating wind tunnel also showed that the flux of CO_2 from swamp water to the atmosphere increased sharply as wind speed above the water's surface increased. This pattern is consistent with the observations of large carbon releases from the direction of the swamp.

STUDIES IN TREE AND PLANT BIOLOGY

Biophysics of plant form and function

Research conducted collaboratively by the N. Michele Holbrook, Department of Organismic and Evolutionary Biology and Maciej Zwieniecki, Arnold

Arboretum, focuses on the biophysics of plant form and function with an emphasis on the vascular system of trees.

Research over the past year, led by post-doctoral fellow Brendan Choat, addressed the role of ion-mediated changes in xylem hydraulic conductivity on water transport in sugar maple trees. Assisted by REU student Melissa Whittaker, this project explores the hypothesis that potassium ion (K+) concentrations in the xylem are up-regulated in branches experiencing good condition for photosynthesis, possibly as a result of recirculation from the

View of EMS tower.

phloem. The group recorded significant differences in K+ concentrations in relation to both canopy position and light environment, but the predicted impact on xylem hydraulic conductivity is small. They have also recorded substantial variability in both the sensitivity by which different branches respond to cation concentrations – the significance of which is unknown – but which seriously complicates analysis of these interactions. Further work will focus on understanding the source of this variation in sensitivity and its possible connection with wound-related responses of cut branches.

During summer 2006, REU student Kaya Schmandt continued work on the xylem vulnerability of red oak leaves. Capitalizing on the exceptionally wet spring, Kaya has documented a significant shift in the vulnerability of red oak leaves, compared with data collected in 2003. Maximum leaf hydraulic conductivity, however, was higher in the wetter year (2003). Such developmental plasticity is somewhat unexpected, and suggests that there might be significant costs associated with building leaves that are more resistant to cavitation and/or tradeoffs between hydraulic safety and efficiency.

Physiology of water transport in trees all year round

Tree stem diameter varies diurnally because of changing water tension inside the stem, which is a measure of water availability for transpiration. Sanna Sevanto, a post-doctoral researcher in Missy Holbrook's lab, measured this variation on several species at Harvard Forest in order to evaluate the diameter variation method against other methods for measuring sap flow and transpiration and to shed light on physiology and tree-level dynamics of water transport of those species. Diameter variations are measured using linear displacement transducers attached to tree stems. The measurements are accurate and easy to maintain and the two water pathways in trees (xylem for water and phloem for sugars) can easily be detected separately, which makes them an interesting new approach to detect tree-level water dynamics through all seasons.

Sanna's work at Harvard Forest consisted of three projects: 1) Diameter variations vs. sap-flow measurements in collaboration with Nathan Phillips's group from Boston University, 2) Water transport during leaf fall and budbreak in collaboration with Steve Wofsy's group from Harvard University and 3) Phloem-xylem water transport dynamics. All the projects included measurements on red maple, paper birch and black birch. In projects one and two red oaks were also measured.

The results of these projects show that in well-watered conditions the daily amplitude of xylem diameter variation per water lost is directly proportional to the content of living cells in xylem.

This indicates that the elasticity of the xylem tissue is determined by the amount of living cells and that water tension is readily transmitted between the dead conduction vessels and the living cells, which means high cell-vessel conductivity. In all the species phloem contributed about two thirds to the total diameter variation of the stem, which also can be explained by the higher content of living cells of

REU student Kay Schmandt dyeing leaves.

phloem tissue. Project three showed that the radial conductivity between xylem and phloem is fairly high and the sugar transport modifies diurnal phloem diameter only slightly. This was supported by the results from project three where in the absence of transpiration, i.e., leaf-less trees, the phloem diameter was observed to swell during the day as a result of translocation of sugars. In contrast, during summertime with full transpiration phloem shrinks with the xylem during daytime. The wintertime swelling of phloem results in either local or overall water circulation in the stem. In the absence of transpiration, local water circulation might be the only oxygen supply for living cells in the xylem. However, maintaining overall circulation throughout the winter would serve the same function as well as provide means of transporting sugars from stem reserves fuel to the living cells in the roots. Roots are the largest complex of living tissue in deciduous trees wintertime and would need resources stored elsewhere to remain functional through the winter.

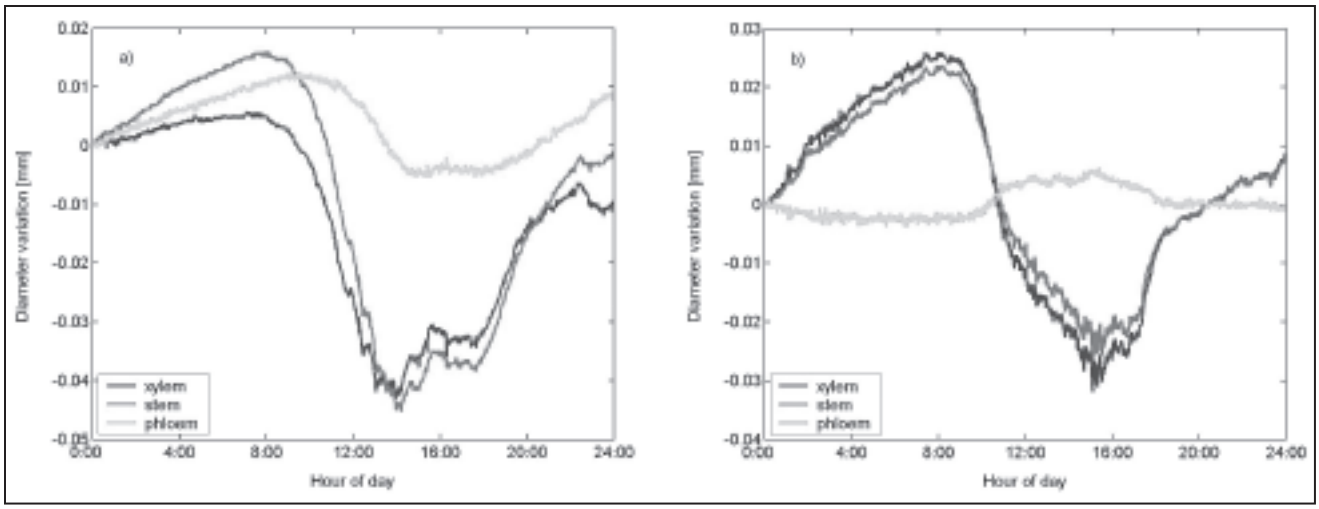
LONG-TERM CHANGES IN CLIMATE AND VEGETATION

The paleoecology laboratory at the Harvard Forest explores long-term changes in climate and vegetation by analyzing sediment cores from lakes and ponds. Researchers and collaborators, including Wyatt Oswald, Elaine Doughty, David Foster from the Harvard Forest, Jason McLachlan the University of Notre Dame, and Barbara Hansen from the University of Minnesota are currently synthesizing pollen data from across southern New England in an effort to reconstruct regional patterns of vegetation. In one study, comparison of several coastal and inland records reveals contrasting dynamics in response to climate change at ~5500 years ago. Similarly, in-depth analyses of records from central Massachusetts and the coastal region show spatial variations in vegetation related to climate, disturbance, substrate, and physiography.

Undergraduate researchers in the Harvard Forest REU program have made important contributions to our efforts this year. Sarah Truebe, student at Stanford University, analyzed a pollen record from Benson Pond in the Berkshires, and greatly improved our understanding of the vegetation history of western Massachusetts.

Alex Ireland, a student from Clarion University used tree-ring data, historical records, and a sediment core from a small pond to reconstruct the past

The diameter variation measurement system. The sensors (LVDT: Solartron Inc, UK) are attached to a rigid metal frame mounted around the stem. For measuring xylem diameter variation (the right-hand side sensor) two screws are screwed through the bark on opposite sides of the stem. The sensor tip rests on one and the frame on the other. The sensor on the left measures diameter variation on the bark (phloem included) and comparisons of xylem and whole-stem diameter variations reveal information of xylem-phloem interactions. The cable is a thermo-couple measuring frame temperature for the correction for thermal expansion of the frame and the cover protects the system from heating by direct sunlight.



Diurnal diameter variation on a maple tree a) with full leaves (September 18, 2005) and b) with no leaves (October 30, 2005). The phloem starts to swell during daytime when about half of the leaves are present. Phloem curve is calculated by subtracting xylem from the measurement on the bark.

changes in forest composition in the French Road area of Prospect Hill. His work provides an interdisciplinary view of post-agricultural forest dynamics in a little-studied part of the Harvard Forest.

Harvard Forest paleoecological research is also expanding to other parts of New England. Sediment cores recently collected from Umpawaug Pond and Highstead Swamp will provide long-term context for studies of the land-use history and present-day ecosystems in Redding, Connecticut, an oak-dominated region of New England that has been ignored by paleoecologists. Similarly, paleo lab members are collaborating with Kendra McLauchlan and Joe Craine of Dartmouth College on a study of past ecosystem processes in the White Mountains of New Hampshire. Geochemical analyses of a new sediment core from Mirror Lake are being used to reconstruct changes in nitrogen availability, a study that will complement decades of research by Gene Likens and Hubbard Brook researchers on the lake ecosystem.

REU student Sarah Truebe and Wyatt Oswald.

STRUCTURE, DYNAMICS, AND PROPERTIES OF OLD-GROWTH FOREST ECOSYSTEMS IN WESTERN MASSACHUSETTS

Tony D'Amato, a doctoral candidate working with Dave Orwig, continued studies examining the composition and structure, disturbance dynamics, and ecosystem properties of old-growth forest systems in western Massachusetts. In these studies, eighteen old-growth and eight second-growth forest stands have been intensively sampled to determine the range of variation in ecosystem attributes, including coarse woody debris (CWD) abundance, disturbance dynamics, and nitrogen cycling patterns among eastern hemlock (*Tsuga candensis*) dominated old-growth and second-growth forest ecosystems.

This work has demonstrated that these old-growth forests contain a higher degree of structural complexity than second-growth forests and that variation in structural attributes, such as CWD abundance and tree size distributions, among old-growth stands is strongly correlated with disturbance history. In particular, old-growth forest stands experiencing higher rates of natural disturbance over the past 130 years, e.g., 5.4–9.9 percent canopy area disturbed per decade, tend to have higher levels of structural complexity indicating the importance of natural disturbances in generating many of the structural attributes commonly associated with old-growth forest ecosystems. Currently, information gained through this research is being used to assist State planning efforts

REU student Alex Ireland and Wyatt Oswald.

for large-scale reserves on public land in Massachusetts, as well providing a framework for efforts aimed at developing silvicultural strategies for restoring old-growth forest attributes to managed systems.

HISTORICAL ECOLOGY IN REGIONAL STUDIES

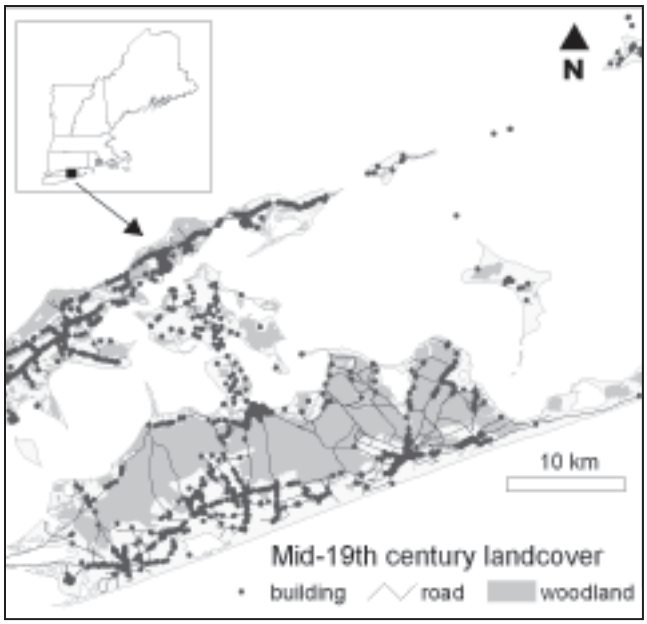
Drivers of mid-nineteenth-century woodland location in coastal New England

Forests on the coastal islands of southern New England and New York are important for the region's biodiversity due to their high number of unusual plant and animal species and communities. Ecologists at Harvard Forest are gaining an appreciation of the importance that historic landscape patterns play in shaping modern vegetation patterns. Therefore conservationists and land managers must consider the land-use history of these forests to explain current vegetation patterns. As part of an effort to more fully understand the coastal landscapes of Long Island, Block Island, Martha's Vineyard, Nantucket, and Cape Cod, Brian Hall, Glenn Motzkin, and David Foster have been using the U.S. Coast and Geodetic Survey maps from the mid-nineteenth century in a GIS-based study to determine which broadscale environmental and socioeconomic factors are most responsible for determining where woodlands remained during the peak of agricultural land clearance. As with modern landscapes, they found that woodlands were more likely to be found farther from mid-nineteenth-century buildings and roads. Buildings and roads in turn tended to be closer to the coast, near fresh water, and at lower elevations.

Historical descriptions of seventeeth-century coastal New England

To complement this effort, John Burk gathered seventeenth-century historical data for the coastal region as part of a broad effort, including paleoecologial and archaeological studies, to understand vegetation composition, structure, and dynamics of the area prior to European settlement. Some 230 primary sources, covering the region from Long Island to Cape Cod and the North Shore, were researched, yielding 550 distinct landscape and vegetation descriptions with varying length and detail. Explorer accounts checked in the past year included the voyages of Henry Hudson, Thomas Dermer, and Samuel de Champlain. The papers of Colonial figures such as Roger Williams, John Winthrop, Thomas Morton, John Jos-

Tony D'Amato next to a 489-year-old eastern hemlock in an old-growth forest within Mohawk Trail State Forest



selyn, Alexander Hamilton, and others provided information about native populations and lifestyles, trade, and travel descriptions, as did Indian war journals of John Mason, John Underhill, and Benjamin Church.

A search of town, state, and colony records was conducted as a follow up to the explorer accounts, with initial emphasis on geographic areas not addressed in the former, i.e., areas of Connecticut and Rhode Island. The town records included ordinances to burn woods, uplands, and underbrush; citations of woodlands to be divided by proprietors, depletion of wood by liming and mill operations; and locations of grasslands, meadows, Indian fields, and sawmills. Every town checked enacted some sort of timber conservation act by the early 1700s, with many citing considerable losses of forest. A number of towns, including those on Cape Cod, also passed acts to protect and/or grant permission to "box," "milk," or "turpentine" pine trees. Similar citations, on a wider geographic scale, were found in the Massachusetts Bay, Plymouth Colony, Rhode Island, Connecticut, and New York Colonial government records.

Historical ecology of southwestern Connecticut

As part of the Highstead Arboretum project, John Burk and Brian Hall researched historical records related to the town of Redding and Fairfield County, Connecticut at a variety of repositories. To date, a dataset of over 500 witness trees has been compiled from deed surveys in the town land records to 1800, and other relevant sources such as historical maps, diaries, farm journals, town records, photographs, and publications have also been checked and entered into a comprehensive bibliography. These trees will be summarized for each of the ten districts in Redding, allowing us to describe spatial variation in early-settlement forest tree species composition.

Brian Hall has also gathered a wide variety of digital datalayers and historical maps to utilize in a GIS. Historical atlases will be used to document changing patterns in roads and houses since 1857, and determine the locations of wood-intensive industries. Maps of surficial and bedrock geology will help characterize the town's environment while GIS layers from the University of Connecticut will help us identify patterns of landcover change since the 1980s.

HARVARD FOREST ECOLOGY SYMPOSIUM 2005 (*DENOTES SUMMER STUDENTS)

M. Albani, A. M. Ellison, D. M. Medvigy, P. Moorcroft, and D. A. Orwig. *Modeling HWA Impact at the Regional Scale with the Ecosystem Demography Model.*

J. E. Anderson, J. Blair, R. Dubayah, M. Hofton, P. Hyde, R. Knox, M. Martin, B. Peterson, and M. Smith. *The Use of Waveform Lidar to Measure Temperate Mixed Deciduous Forest.*

M. Bank and R. I. McDonald. *Landscape-level Effects of Forest Harvesting on Vascular Plant Composition in Massachusetts.*

A. Barker Plotkin, A. M. Ellison, D. R. Foster, and D. R. Orwig. *Logging in the Hemlock Manipulation Study.*

A. Barker Plotkin and D. R. Foster. *The Tom Swamp Mapped Overstory Plots, 1990–2003.*

E. Boose, P. Barten, and B. Colburn. *Prospect Hill Hydrological Stations.*

J. Burk, D. R. Foster, and G. Motzkin. *Early Historical Records of the Northeast Coast.*

P. E. Busby, D. R. Foster, and G. Motzkin. *Stand Dynamics and Vegetation History of Beech Forests on Naushon Island, MA.*

J. Butler and A. M. Ellison. *Nitrogen Uptake and Translocation in Sarracenia purpurea.*

J. Butler, A. M. Ellison, and N. J. Gotelli. *Cycling of Inorganic Nitrogen through the Pitcher Plant Food Web.*

H. S. Callahan, J. Aber, K. del Fierro, A. E. Patterson, and H. Zafar. *Impacts of Chronic N Amendments on Tree Reproduction in an Oak-Dominated Stand at Harvard Forest.*

B. Choat, M. Holbrook, and E. C. Lahr. *The Spatial Pattern of Air Seeding Thresholds in Mature Sugar Maple Trees.*

B. Colburn, M. Bank, E. Boose, D. R. Foster, and D. A. Orwig. *Predicting How Changes in Forest Stand Composition Will Alter Stream Ecosystems at Multiple Spatial and Ecological Scales.*

B. M. Collins*, B. Colburn, and B. Sobczak. *Subsurface Flowpaths Drive Spatial Variation in the Macroinvertebrate Community of an Intermittent Headwater Stream in Central New England.*

T. D'Amato and D. A. Orwig. *The Structure, Composition, and Dynamics Of Old-Growth Forests in the Berkshire Hills and Taconic Mountains, Western Massachusetts.*

B. Dail, J. Aber, E. Davidson, and D. Hollinger. *Seeing the Forest for the Soils: Fate of a 15N Foliar N Addition in a Mature Spruce-Hemlock Stand, Howland, Maine.*

M. J. Daley and N. Phillips. *Interspecific Variation in Nighttime Transpiration and Stomatal Conductance.*

E. Davidson, K. Savage, and S. Trumbore. *Decadal-Scale Measurements of Decadal-Cycling Forest Soil Carbon.*

E. Davidson, B. Dail, D. Hollinger, A. Richardson, and K. Savage. *A Distinct Seasonal Pattern of the Ratio of Soil Respiration to Total Ecosystem Respiration in a Spruce-Dominated Forest.*

B. G. DeGasperis, D. R. Foster, and G. Motzkin. *Effects of Historical and Modern Anthropogenic Disturbances on the Distribution and Demography of Berberis thunbergii (Japanese barberry).*

J. W. Elkins, G. S. Dutton, E. Gottlieb, M. B. McElroy, and S. Wofsy. *A Harvard Forest Perspective: Are EPA U.S. Emissions of the Greenhouse Gases Correct.*

E. Faison and D. R. Foster. *The Effects of Moose and Deer on Harvested Oak-Pine Forests of Central Massachusetts.*

J. Hadley and P. Kuzeja. *Water Use by Eastern Hemlock (Tsuga canadensis) Forest and Deciduous Forests in Central Massachusetts: Hydrologic Implication.*

R. Hanifin*, J. Melillo, and J. Mohan. *First-Year Reproductive Responses of Two Herbaceous Species to Experimental Soil Warming at Harvard Forest.*

S. Jefts and D. A. Orwig. *The Effects of HWA Outbreaks on Ecosystem Level Changes in Southern New England.*

J. Jenkins, K. McKnight*, and G. Motzkin. *The Flora of Harvard Forest.*

C. Jones, D. Gonzalez-Kreisberg*, L. Hutyra, K. McKain*, W. Munger, E. Pyle, and S. Wofsy. *Carbon Exchange Studies at Harvard Forest Using Eddy Flux Tower Measurements and Ground-based Ecological Measurements.*

J. Karagatzides, J. Butler, and A. M. Ellison. *Sarracenia Can Directly Acquire Organic Nitrogen and Short-Circuit the Inorganic Nitrogen Cycle.*

D. Kittredge and K. Grogan*. *The Parcelization of Forests and Timber Harvest.*

C. Lai and J. Ehleringer. *Carbon Isotope Ratio of Nighttime Respiration, Leaf, and Soil Organic Matter in a Temperate Deciduous Forest.*

W. H. Liu, A. V. Bright, J. Budney, D. Curran, B. C. Daube, L. Hutyra, C. Jones, W. Munger, E. Pyle, S. R.

Saleska, and S. Wofsy. *The Effects of Selective Management on Carbon in Woody Debris: Measurements of Respiration and Environmental Conditions*.

A. Magill and J. Aber. *Chronic Nitrogen Amendment Study*.

B. Mathewson, B. Colburn, and D. R. Foster. *Eastern Redback Salamander (Plethodon cinereus) and Juvenile Eastern Red-Spotted Newt (Notophthalmus viridescens) Abundance in Eastern Hemlock-Dominated Stands and Mixed Deciduous Stands*.

K. A. McKinney, H. A. Fuchs, and A. Lone. *Fast Time Response Measurements of Volatile Organic Compound (VOC) Concentrations and Fluxes at Harvard Forest*.

Q. Min. *A Regional Climatology of Cloud and Aerosol for Forest-Atmosphere Exchange*.

R. Minocha and S. L. Long. *Effects of Nitrogen Fertilization/Deposition on the Foliar Nutrition and Stress Physiology of Coniferous and Broadleaf Trees Across Northeastern US*.

J. Mohan, J. H. Blanchard, E. Burrows, J. Melillo, and P. Steudler. *Soil Warming at Harvard Forest: Effects on Biogeochemistry and Forest Trees*.

P. Moorcroft, M. Albani, D. M. Medvigy, and S. Wofsy. *Constraining the Exchange of Carbon, Water, and Energy Between North-Eastern Ecosystems and the Atmosphere: Results From a Regional-Scale Coupled Terrestrial Biosphere Model*.

J. O'Keefe. *Woody Species Phenology, Prospect Hill Tract, Harvard Forest – 2004*.

J. O'Keefe and P. Snow. *Regeneration Following Clearcutting of Red Pine verstory – Year 15*.

D. A. Orwig, L. Barbash, D. R. Foster, and H. Lux. *Community and Ecosystem effects of HWA-induced Logging*.

D. A. Orwig, P. Del Tredici, D. Foster, H. Lux, and R. Schulhof. *Comparison of Hemlock Cutting Following HWA Infestations in Urban vs. Rural Forests*.

D. A. Orwig, M. Manner*, D. Niebyl*, and N. Povak*. *Landscape Level Analyses of Hemlock Woolly Adelgid Outbreaks in Massachusetts*.

W. Oswald and D. R. Foster. *Lake-Sediment Evidence for Late Holocene Climatic Variability Across Southern New England*.

W. Oswald, D. R. Foster, and G. Motzkin. *Long-Term History of Vegetation and Fire in the Pine Barrens Region of Long Island, New York*.

W. Oswald, E. Faison, and D. R. Foster. *Vegetation Dynamics Across Southern New England During the Middle Holocene*.

N. Pederson, A. Barker Plotkin, G. C. Jacoby, E. Pyle, and S. Wofsy. *A Regional Context for Northern Red Oak Growth Rates at the Harvard Forest*.

N. Phillips and M. J. Daley. *Dynamic Coupling of Stomata and Tree Hydraulics*.

F. E. Rockwell and D. Hollinger. *The Contribution of Gas-Filled Fibers to Positive Sap Pressures in Sugar Maple*.

N. A. Scott, B. Dail, E. Davidson, D. Hollinger, H. Hughes, J. T. Lee, and C. Rodrigues. *Recovery of Net Ecosystem Carbon Sequestration Following a Shelterwood Harvest at Howland Forest, Maine, U.S.A*.

S. Sevanto, M. Holbrook, W. Munger, and S. Wofsy. *Diurnal Stem Diameter Variations: A New Tool for Detecting Sap Flow*.

B. Stadler, T. Muller, and D. A. Orwig. *The Ecology of Energy and Nutrient Fluxes in Hemlock Forests Invaded by Hemlock Woolly Adelgid*.

K. Stinson, L. Durbin*, S. Kaufman, and F. Lowenstein. *Responses of a New England Forest Community to Increasing Levels of Invasion*.

K. Stinson and J. Klironomos. *Exotic Plant Invasion Degrades Local Mycorrhizal Association, Alters Community Succession and Limits Restoration*.

K. Stinson, C. Chang*, and K. Donohue. *Effects of Varying Environmental and Maternal Habitats on the Performance, Demographic Structure, and Population Dynamics of Alliaria petiolata*.

E. T. Sundquist. *Monitoring and Modeling of Soil Heat, Water, and Gas Transport*.

R. K. Varner and P. M. Crill. *Two Years of High Temporal Frequency Measurements of CO2 Efflux from Soil*.

B. Von Holle. *Ecosystem Effects and Legacies of the Introduced N-Fixing Tree, Robinia Pseudoacacia, in the Upland Coastal Forests of Cape Cod, MA*.

H. Wu and X. Lee. *Response of Soil Respiration to Rain in a Temperate, Hardwood Forest in Massachusetts*.

HARVARD FOREST ECOLOGY SYMPOSIUM 2006 (*DENOTES SUMMER STUDENTS)

A. Barker Plotkin, D. R. Foster, and N. Levy*. *Coarse woody debris dynamics after hemlock removal.*

J. Blanchard, F. Bowles, E. Burrows, H. Lux, J. Melillo, J. Mohan, and P. Steudler. *Barre Woods Soil Warming Project: Effects on biogeochemistry and forest trees after three years of warming.*

E. Boose, J. Hadley, and S. Singh*. *Preliminary water budget for Prospect Hill Tract.*

T. Brodribb and N. M. Holbrook. *Leaf hydraulic conductance is highly variable and sensitive to leaf water potential.*

J. Burk, D. R. Foster, and G. Motzkin. *"The Paradise of these Parts:" 17th century primary accounts of the northeast coastal landscape.*

P. Busby, C. Canham, D. R. Foster, and G. Motzkin. *Tree response to hurricane disturbance in coastal New England.*

J. Butler and A. M. Ellison. *Nitrogen cycling dynamics in the northern pitcher plant, Sarracenia purpurea.*

B. Choat, J. Anderson, N. M. Holbrook, and M. Zwieniecki. *Dynamic changes in xylem hydraulic resistance via modulation of xylem sap ionic composition.*

R. Cobb and D. A. Orwig. *Vegetation driven decomposition changes resulting from hemlock woolly adelgid.*

A. D'Amato and D. A. Orwig. *The structure, composition, and dynamics of old-growth forests in the Berkshire Hills and Taconic Mountains, western Massachusetts.*

M. Daley, J. Hadley, J. Pettijohn, and N. Phillips. *A comparison of transpiration in black birch and eastern hemlock stands.*

E. Davidson and K. Savage. *Reconciling landscape-scale measurements of soil respiration with estimates of total ecosystem respiration.*

B. DeGasperis and G. Motzkin. *Being in the right place at the right time: a historical perspective on Japanese barberry invasion.*

D. Diaz* and N. Tuross. *Nitrogen isotope evidence for ecological changes and adaptations relating to agricultural land-use legacies in the foliage of four New England plant species.*

A. M. Ellison. *The Hemlock Removal Experiment: Initial changes in environmental variables following treatments.*

A. M. Ellison, E. Boose, L. Clarke, D. R. Foster, J. Hadley, L. Osterweil, and A. Wise. *Ensuring reliable datasets for valid environmental models and useful environmental forecasts.*

E. Faison, D. R. Foster, and G. Motzkin. *Moose foraging ecology at their southern range boundary: the temperate forests of central Massachusetts.*

E. Farnsworth and A. M. Ellison. *Prey availability directly affects physiology and nutrient allocation in ten carnivorous plant species.*

D. Fitzjarrald and A. Tsoyref. *Forest-atmosphere exchange processes related to regional carbon budgets.*

S. Frey, A. Contosta, and M. Knorr. *Microbial responses to soil warming and nitrogen additions.*

J. Jenkins, K. McKnight*, and G. Motzkin. *The flora of Harvard Forest.*

C-T. Lai and J. Ehleringer. *Interannual variability of carbon isotope ratios of ecosystem respiration in Harvard Forest between 2001-2005.*

H. Lux, P. Del Tredici and D. A. Orwig. *Ecosystem responses to forest cutting after HWA infestation: New insights from an urban site.*

B. Mathewson, B. Colburn, and D. R. Foster. *Differences in eastern red-backed salamander populations in eastern hemlock forests and mixed deciduous forests.*

R. McDonald, D. R. Foster, and G. Motzkin. *Land-use legacies, present-day forest fragmentation and harvesting, and invasive species.*

K. McKain*, J. Bubier, E. Hammond Pyle, and S. Wofsy. *Carbon accumulation at the Harvard Forest: A comparison of methods for measuring tree biomass for regional extrapolation of the eddy-flux tower footprint.*

D. Medvigy, P. Moorcroft, and S. Wofsy. *The state of the regional carbon cycle: Results from a constrained coupled ecosystem-atmosphere model.*

Q. Min, D. Fitzjarrald, and S. Wang. *Clouds, a controlling factor in terrestrial carbon uptake.*

J. Munger, C. Barford, J. Budney, D. Curran, E. Hammond Pyle, and K. McKain. *Accelerating carbon uptake rates at the Harvard Forest environmental measurement site.*

J. O'Keefe. *Woody species phenology, Prospect Hill Tract, Harvard Forest – 2005.*

S. Ollinger, J. Jenkins, M. Martin, J. Munger, L. Plourde, and M-L. Smith. *Canopy nitrogen and forest carbon assimilation: Validation of local patterns and broad-scale satellite estimates*.

D. A. Orwig, D. Niebyl*, and N. Povak*. *Landscape level analyses of hemlock woolly adelgid outbreaks in Massachusetts*.

D. A. Orwig, L. Barbash, D. R. Foster, and H. Lux. *Community and ecosystem effects of HWA-induced logging*.

W. Oswald and D. R. Foster. *Late-Holocene history of coastal ecosystems of New England and New York*.

A. Paradis and J. Elkinton. *Population dynamics of the hemlock woolly adelgid*.

J. Pettijohn and M. Daley, N. Phillips, and G. Salvucci. *Evaluating the sensitivity of Acer rubrum L. sap flux to environmental stress under two root-zone soil water limitation scenarios*.

E. Preisser, J. Elkinton, A. Lodge*, and D. A. Orwig. *Range expansion and community impact of the invasive herbivores Adelges tsugae and Fiorinia externa in New England*.

S. Record and A. M. Ellison. *Seed Dispersal: Implications for forest regeneration*.

S. Sevanto, M. Daley, N. M. Holbrook, J. Pettijohn, and N. Phillips. *Estimating sap flow using diurnal stem diameter variations*.

T. Sipe and S. Strouse. *Herbaceous stratum effects on nearground enriched CO_2 profiles*.

B. Sobczak, E. Boose, B. Colburn, and J. Hadley. *Examination of terrestrial and aquatic ecosystem linkages at Harvard Forest*.

P. Steudler. *Carbon monoxide uptake kinetics in unamended and long-term nitrogen amended temperate forest soils*.

K. Stinson, J. Klironomos, and B. Wolfe. *The enemy of my friend: an invasive plant disrupts native tree seedling – mycorrhizal fungi mutualism.*

M. Trumbull*, A. Barker Plotkin, and D. R. Foster. *Understory response over 15 years following simulated hurricane at the Harvard Forest*.

R. Varner and P. Crill. *Three years of high frequency measurements of soil surface CO_2 efflux at Harvard Forest*.

J. Weishampel, J. B. Blair, A. Cooper, J. Drake, D. R. Foster, M. Hofton, and G. Motzkin. *Forest canopy recovery from the 1938 hurricane and subsequent salvage damage measured with airborne LiDAR*.

B. Wolfe, J. Klironomos, A. Pringle, V. Rodgers, and K. Stinson. *Impacts of the invasion of garlic mustard (Alliaria petiolata) on forest fungi*.

BULLARD FELLOWS

John Briggs (Arizona State University and the Central Arizona Phoenix LTER site) collaborated with David Foster, Aaron Ellison, and Emery Boose, to explore use of historical data to help explain and understand modern day ecological patterns and in particular plant distributions. John applied these skills to help analyze data that he has collected for over twenty years at the Konza Prairie Biological Station (a LTER research site since 1981). John also worked on manuscripts and on finishing a book *The Biology of Grasslands* (Oxford University Press) that he had recently started with Alan Knapp (Colorado State University) and Scott Collins (University of New Mexico).

Conghe Song's (University of North Carolina) research was primarily focused on remote sensing of vegetation and ecological modeling. He investigated the potential of extracting forest canopy structure from high-resolution optical remotely sensed imagery based on field data collected during the summer of 2005. On ecological modeling, he has linked his MVP model with Farquhar's photosynthesis model and Leuning's stomatal conductance model to understand the importance of canopy structure on radiation interception, latent heat transfer, and carbon assimilation of forest ecosystem. In addition, he collaborated with a colleague in China to study the forest cover change in China from 1949 to 2003 as a result of afforestation, deforestation, and reforestation.

Richard D. Bowden (Allegheny College) spent his sabbatical year working on projects related to long-term and current anthropogenic alterations to forest C and N dynamics. Continuing a Collaborative Research at Undergraduate Institutions project begun in 2000 with Tim Sipe (Franklin and Marshall College) and Chuck McClaugherty (Mt. Union College), Bowden continued investigations into the long-term influences of historic agriculture on current forest ecosystem patterns and processes. Building on the strong history of land-use research at the forest, Rich and his colleagues investigated vegetation and soil in forests that had been formerly cultivated, pastured, or left as woodlots, and which were then released from agriculture during the height of agricultural production in the mid-1800s.

Richard D. Bowden.

In this study, despite nearly two centuries of forest regrowth, soils show profound differences among the former land-use sites. For example, total soil carbon is much lower in the former agricultural sites than in the former woodlots. This information is critical because up to 85 percent of the regional landscape has been either plowed or pastured during the nineteenth-century agricultural era, and because understanding soil stores of carbon is important in quantifying links between the global carbon cycle and global climate change.

Rich also continued work on the Detritus Input and Removal Treatment (DIRT) project. Collaborating with colleagues at Debrecen University in Hungary, he examined soils at the Sikfokut (Hungary) International LTER DIRT site.

Elizabeth Farnsworth.

Since beginning her Bullard Fellowship in February 2005, Elizabeth Farnsworth (New England Wild Flower Society) has completed two manuscripts analyzing a large data set on dozens of rare plant species in New England. She finished writing and illustrating her book (with Cheryl Lowe), the *Peterson Field Guide to Ferns and Their Related Families*. With co-authors John and Wendy Sinton, Elizabeth began research on a guide to the Connecticut River.

She also collaborated with Aaron Ellison and REU student Cheryl Hester, from Pueblo Community College, on an experiment examining nutrient limitation and photosynthetic physiology of ten species of carnivorous plants. Elizabeth gave research talks at Harvard Forest, Wesleyan University, Eastern Connecticut State University, and Bates College and has led/co-led two workshops in scientific ethics for Harvard Forest staff and REU students.

Julia Jones (Oregon State University) completed drafts of five articles, became an editor for *Ecology*, and completed a draft of a book intended as a graduate text, entitled *Spatiotemporal Statistics in Ecology and Earth Science*. In collaboration with Aaron Ellison, she applied spatiotemporal analysis techniques to look for patterns in tree species in pollen cores that David Foster and his group have amassed. Julia's analysis of long-term streamflow records from Harvard Forest's "sister" LTER sites, such as Hubbard Brook, Coweeta, and the Andrews has proven relevant to the plans for establishing stream gaging at Harvard Forest.

Greg Jordan (University of Tasmania, Hobart) investigated the plant macrofossil flora from Stony Creek Basin, a remarkable fossil assemblage provides a continuous record of vegetation and insect faunas spanning some 300,000 years (approximately 1.8–1.5 million years ago), as dated using radiometric and sedimentological methods.

Greg's work involved scanning electron microscopy and comparative analyses to identify several thousand specimens from approximately eighty species of plants. The sampling covered depth range of approximately four meters from the upper part of the section, and corresponded to a full climatic cycle.

David Lee, (Florida International University) completed a book manuscript and illustrations, which are now in review by University of Chicago Press. With John O'Keefe, David completed a survey of leaf senescence color and anthocyanin production in herbaceous plants at the forest (sixty species). He created and installed autumn foliage website (http://harvardforest.fas.harvard.edu/research/leaves/autumn_leaves.html) with Julie Pallant and John O'Keefe, and conducted pilot measurements on the spectral distribution of radiation within leaf traps and reflected from outside, in *Sarracenia leucophylla* and *S. alata*.

Gidon Ne'eman (Department of Biology, University of Haifa-Oranim, Israel), assisted by his wife Rina (Anne Frank High School, Branco Weiss Institute, Kibbutz Sasa, Israel) collaborated with Aaron Ellison to study pollinator-prey conflict in the carnivorous pitcher plant *Sarracenia purpurea*.

The pitchers and flowers of *S. purpurea* both are mostly red and produce nectar, traits which attract pollinators to flowers and prey to pitchers. Therefore,

it has been suggested that pitchers may mimic flowers to capture prey, potentially resulting in a prey-pollinator conflict; however this conflict has never been experimentally tested.

Gidon Ne'eman.

The results indicated that none of the major pollinators of *S. purpurea* was found captured within the pitchers, indicating that the flowers and pitchers attract different organisms, minimizing competition as well as the possible existence of a prey-pollinator conflict.

Rina Ne'eman, in collaboration with the Wyatt

Rina Ne'eman.

Oswald and Elaine Doughty, prepared a collection of pollen of all *Sarracenia* species growing in Harvard Forest greenhouse. With Aaron Ellison she also performed phenological observations and measurements to determine the degree of temporal and spatial separation between the flowers, production of new pitchers, and senescence of old pitchers in all *Sarracenia* species growing in the Harvard Forest greenhouse.

Peter Thomas (Keele University, UK) completed a textbook on forest ecology, a joint project with John Packham of the University of Wolverhampton, UK, to be published by Cambridge University Press. As a result of his time in Petersham, the book has a strong Harvard Forest flavor. He also finished a paper on a sixteen-year experiment on grassland fires on cacti in Arizona (published in *Plant Ecology*), and wrote two popular science articles on forests for the *Journal of the International Tree Foundation* and *The Dendrologist*. In between he rewrote a chapter of a previous book *Trees: Their Natural History* with an

Peter and Judy Thomas.

eye to a second edition, and used the excellent libraries to work on a monograph on juniper for the Biological Flora of the British Isles series in *Journal of Ecology*, cowritten with colleagues at Keele and Garyounis University, Libya. His wife, Judy, thoroughly enjoyed voluntary work at the Petersham elementary school, and their younger son experienced the culture shock of attending Mahar Regional High School for a semester.

Jill Thompson (Luquillo LTER site, University of Puerto Rico) enjoyed a wonderful year and all the seasons at Harvard Forest. During the year she continued her research on the effects of land-use history and hurricane damage on the subtropical wet forest in Puerto Rico using census data from the Luquillo Forest Dynamics Plot (LFDP). She also worked on a variety of papers about the LFDP concerning alien species dynamics, orchid distribution, methods for

measuring biodiversity, nonrandom processes and diversity in tropical forests, effects of hurricane damage on light availability, seedling recruitment in hurricane driven forest, Bayesian analysis of hurricane damage and tree survival, phylogenetic patterns in tropical forest, and tropical wet forest versus riparian vegetation. Jill gave a seminar on her research in tropical forest, a workshop about using relational databases for data management, explained canopy fisheye photography analysis to Kristina Stinson and Anna Bellafiore, spent a week helping Posy Busby core trees on Naushon Island, and taught the summer REU students Scottish country dancing.

Jill Thompson.

EDUCATIONAL ACTIVITIES

Betsy Colburn mentored MFS student Brooks Mathewson in his research on terrestrial salamanders in hemlock and deciduous forest stands. She also reviewed the master's thesis of Holly Jensen (Antioch New England Graduate School), in which Holly presented the results of surveys carried out on headwater streams at Mt. Wachusett; advised (informally) graduate students from Wheaton College (IL), UMass, and Clark University; and judged student papers at the annual meeting of the North American Benthological Society.

Each spring Glenn Motzkin, John O'Keefe, and Dave Orwig joined David Foster 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 concludes with each student undertaking an independent study.

P. Barry Tomlinson taught two courses at the Kampong Garden of the National Tropical Botanical Garden in Coconut Grove, Miami, Florida. The Kenan College Professors Course June 12–24 demonstrated teaching methods in tropical botany so that instructors could increase the coverage of botany in introductory biology courses. "Biodiversity of Tropical Plants," was held June 26–July 21. It is a Harvard Summer School course for graduate students, which expanded on existing botanical knowledge in a tropical environment.

Serita Frey (University of New Hampshire) prepared a dataset for publication in Teaching Issues and Experiments in Ecology (http://tiee.ecoed.net/) using data collected over the past fifteen years at the Chronic Nitrogen Addition Study. The activity guides students to ask and address questions about the long-term effects of chronic N additions on net primary productivity, tree photosynthetic capacity, soil respiration, and soil microbial biomass in two forest types. Students examine the data, ask their own questions, and then propose and prepare the most meaningful figures to get at these questions.

Summer Research Program

The Harvard Forest Summer Student Research program, coordinated by Edythe Ellin and assisted by Hilary Crowell attracted a diverse group of 22 students to receive training in scientific investigations, and to gain 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 in Millbrook, NY, 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.

Summer Students 2005

Emily Austin	Hampshire College
Ryan Barba	Assumption College
Charles Boyd	Centre College
Daniel Brese	Bennington College
Laura Briscoe	College of the Atlantic
Jonah Butler	New College of Florida
Susan Cheng	Columbia University
Robin Collins	University of Florida
Antoinnine Cooper	Oakwood College
David Diaz	Harvard College
Cheryl Hester	Pueblo Community College
Kristin Ivy	Grambling State University
Daniel Katz	Bard College
Matthew Kaufman	Keene State College
Nicholas Kuzma	Franklin & Marshall
Phil Labranche	Holyoke Community College
Katherine Lenoir	Wellesley College
Bennet Leon	Bates College
Natalie Levy	University of California–Berkeley
Alexandra Lodge	Kenyon College
Kathleen Logothetis	Franklin & Marshall
Jennifer McGinnis	Cornell University
Safina Singh	Mount Holyoke College
Jens Stevens	Carleton College
Stephanie Strouse	Franklin & Marshall
Sarah Truebe	Stanford University
Mathew Trumbull	Hampshire College
Linh Vuong	University of Puget Sound
Kelly Walton	State University of New York
Kirsten Ward	Brigham Young University
Brian Warshay	Cornell University
Melissa Whitaker	Prescott College
Marit Wilkerson	University of Texas, Austin
James Willacker, Jr.	State University of New York
Grace Wu	Pomona College

Assistant Program Coordinators

Kathryn McKain
Thomas Mulcahy

Summer Students 2006

Alex Arguello	St. Mary's College of Maryland
Laura Briscoe	College of the Atlantic
Kevin Burls	Mount Union College
Stephanie Day	Howard University
Justin Frisino	SUNY Albany University of Albany
Dana Graef	Princeton University
Alison Grantham	Mount Holyoke
Alex Ireland	Clarion University
Frances O'Donnell	Harvard University
Rebecca Orozco	University of Kansas
Rachel Osborn	Hampshire College
Christine Rollinson	Oberlin College
Timothy Rowell	College of the Holy Cross
Lisa Schauer	New Mexico State University
Kaya Schmandt	Brown University
Stephanie Searle	Columbia University
Brynne Simmons	Johnson C. Smith University
Lori Simpers	Susquehanna University
Safina Singh	Mount Holyoke College
Rachel Stahr	Hampshire College
Chelsea Vario	University of New Hampshire
Jessica Megan Woltz	North Carolina State University

Assistant Program Coordinator

Hilary Crowell

Master of Forest Science Program

In Spring 2006, four students graduated from the Harvard Forest MFS program. Posy Busby, thesis title: *Beech dynamics and dominance in coastal New England forests.* Brian DeGasperis, thesis title: *Windows of opportunity: historical and ecological insights into plant invasions*. Edward Faison, thesis title: *Moose foraging in the temperate forests of central Massachusetts: a natural re-wilding experiment*. Brooks Mathewson, thesis title: *A comparison of eastern red-backed salamander populations in hemlock-dominated and mixed deciduous forests in north central Massachusetts*.

Posy Busby, Brooks Mathewson, Ed Faison, and Brian DeGasperis.

Building the LTER Schoolyard Program

With funding from NSF's Schoolyard (sLTER) and Ed En Venture Fund programs, along with the Massachusetts Environmental Trust, we were able to support twenty-seven teachers in implementing field research projects in their schoolyards. Pam Snow, environmental educator, led this project with John O'Keefe. In this effort, we continued our collaborations with the Hitchcock Center for the Environment in Amherst and the Millers River Environmental Center in Athol, while formalizing our partnership with the Nashua River Watershed Association. We were also able to bring this schoolyard model west to schools in the Deerfield River Watershed. To reach these schools, we collaborated with the Student Conservation Association Mass. Parks AmeriCorps, based in Hawley, Massachusetts.

Harvard Forest ecologists Betsy Colburn, David Orwig, and John O'Keefe continued to help train teachers in implementing freshwater and forest ecology protocols modified for school use. This training included a two-day Summer Institute and two day-long workshops at Harvard Forest during the school year. Ecologists, environmental educators, and our information manager, Emery Boose, assisted in these formal trainings at the Harvard Forest. Water-level fluctuations in streams and vernal pools were one of the subjects studied by teachers. Betsy Colburn worked with Emery Boose and Pam Snow on metadata and data formatting, and with teachers and Pam

on data analysis. Each participant was also coached by an environmental educator on site at their school as needed throughout the school year. Dr. Boose was able to make a host of data-management documents and tools available to teachers on our HF Web site this year. Among the Web postings are two years of student data from participating schools. We expect to continue to post student data for future year's projects and eventually develop a long-term dataset of student data.

Budding ecologists.

As a result of these professional development efforts, not only did teachers successfully implement field ecology protocols, but three teachers also went on to train fellow teachers, including these protocols in their presentations. Kate Bennett and Mary Gagnon of Briggs Elementary School in Ashburnham recommended use of HF protocols to teachers attending the Massachusetts Environmental Education Society's annual conference. Michael Silverstone of Wildwood Elementary School in Amherst shared the protocols as a teaching tool for teachers attending a workshop in strategies for English Language Learners.

Elaine Senechal of Tewksbury High School spread the news of our program to the general public by contacting a *Boston Globe* reporter, who published a full-length story about their schoolyard project along with color photos and a cartoon. Our program was also featured in a number of community newspapers in our region, featuring teachers and coaches from Athol, Ashburnham, Warwick, and Tewskbury.

In an effort to strengthen our connections to the national LTER education community, Pam attended a national LTER Education/Children's Book Committee meeting in September 2005 and presented Harvard Forest's "Buds, Leaves, and Global Warming" schoolyard protocol at a teacher institute led by PIE-sLTER representative, Liz Duff.

Harvard Forest has once again been awarded funding from the NSF sLTER program to allow us to continue to support some teachers in implementing field ecology studies at their schools during FY07. However, the Ed En Venture program, which provided the bulk of our funding in the past two years, was not offered this year. Fortunately, we have received a three-year grant from the Cardinal Brook Trust to help support our local schoolyard projects. We will continue to work with the Millers River Environmental Center and the Nashua River Watershed Association to support them in their efforts to involve teachers in Warwick, Athol, and Ashburnham in our schoolyard field studies, with the support of the Massachusetts Environmental Trust.

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 and he is assisted by Pam Snow.

Our great group of Museum volunteers continue to allow the Fisher Museum to provide a very much appreciated weekend schedule from May through October. Each November the group shares food, fellowship, and ideas at our traditional Volunteer Recognition Dinner. In 2005, Bob Clark, Walt Davidson, and Bob Lane received special recognition for being the most active volunteers during the season. In 2006 Bob Clark was again recognized for being the most active volunteer during the season. At each dinner, volunteer coordinator Mary Ann Walker received sincere thanks for her tireless and enthusiastic work to keep the program running

smoothly. The group has been deeply saddened by the death of two of its founding members, Peter Strong during the winter of 2004–05, and Hector Cameron the following winter. A memorial service for Peter, Mary Ann's husband, was held in the Museum on Saturday, February 5, 2005. Peter's eclectic knowledge, recitations, and twinkle will be sincerely missed.

During 2004–05 the Museum provided programs for twenty-five elementary and secondary schools, thirty-five college and university classes, and thirty-eight community and professional groups. During the summer the Museum hosted two groups of inner-city youth in our continuing collaboration with the University of Massachusetts Extension "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.

During 2005-06 the Museum provided programs for thirty-two elementary and secondary schools, fifty-three college and university classes, and twenty-nine professional and community groups. Although these programs varied considerably depending upon each group's age, background, and areas of interest, each group learned about the land-use history of the region and current research and conservation activities at Harvard Forest.

Meetings, Conferences, Seminars 2004–05

In August the Museum and Forest hosted a three-day workshop on soil microbial communities and processes organized by Serita Frey, one of our collaborators at the University of New Hampshire. In January, in collaboration with the Harvard Medical School Center for Health and the Global Environment, we hosted a three-day meeting of the International Agriculture and Human Health Task Force. In February we hosted a workshop cosponsored by the National Science Foundation LTER program network office and organized by Aaron Ellison on the impact of removal of foundational species by pest and pathogens on the structure and dynamics of forested ecosystems. This workshop brought together representatives from several LTER sites studying similar processes to better coordinate cross-site research projects. And in May the National Science Foundation and Woods Hole Oceanographic Institute cosponsored a week-long meeting at Harvard Forest focusing on the population biology of albatrosses. The Sixteenth Annual Harvard Forest Long-Term Ecological Research Symposium and National Institute for Global Environmental Change meeting was held in the Museum on February 23.

Meetings, Conferences, Seminars 2005–06

In August the Museum and Forest hosted a weeklong seminar course on research methods organized by Lynn Adler, a recently hired faculty member at the University of Massachusetts. Over the winter the Forest hosted a series of retreats, one for each cohort of Harvard University Organismic and Evolutionary Biology (OEB) graduate students. In January and again in April Harvard Forest hosted planning meetings for the National Science Foundation's NEON initiative and in May we hosted a joint retreat for a group of Harvard Medical School and FAS faculty. The Seventeenth Annual Harvard Forest Long-Term Ecological Research Symposium and National Institute for Global Environmental Change meeting was held in the Museum on April 12.

Other groups meeting at Harvard Forest included the Greater Worcester Community Foundation Student Grant Workshop, Irish Foresters Society North American tour, Massachusetts Audubon Society, Massachusetts Barn Preservation Task Force, Massachusetts Chapter of the American Chestnut Foundation, Massachusetts Department of Conservation and Recreation, Massachusetts Executive Office of Environmental Affairs/Land Trust Retreat, Massachusetts Extension Service Coverts Program, Massachusetts Forestry Association, Massachusetts Forestry Forum, Massachusetts Forest Steward's Training, Massachusetts State Forestry Committee, Mount Grace Land Conservation Trust, Mount Wachusett Community College, New England Forestry Foundation, National Tree Farm Convention tour, Northeast Soil and Water Conservation Association, North Quabbin Regional Landscape Partnership, The Nature Conservancy, Quabbin to Cardigan Conservation Collaborative, The Trustees of Reservations, U.S. Fish and Wildlife Service and U.S. Department of Agriculture Natural Resources Conservation Service.

Speakers in the Harvard Forest Seminar 2005–2006 series included:

Lynn Adler, University of Massachusetts, *Ecology and evolutionary consequences of attraction and defense in plant-animal interactions.*

Robert Bertin, Holy Cross College, *The flora of Worcester County: patterns and changes.*

John Briggs, Arizona State University and Harvard Bullard Fellow, *Ecosystems in transitions: tallgrass prairie and Sonoran desert.*

Posy Busby, Harvard Forest, *Beech dynamics and dominance in coastal New England forests.*

Liza Knapp, University of Massachusetts, *Correlates and components of growth in native and invasive woody plants.*

Charles Davis, Organismic & Evolutionary Biology, Harvard University, *Phylogenetic studies in Malpighiales: dating the origin of tropical rain forests, host-to-parasite gene transfer, and the geography of gene swapping.*

Brian DeGasperis, Harvard Forest, *Being in the right place at the right time: a historical perspective on Japanese barberry invasion.*

Brian Donahue, Brandeis University and Harvard Bullard Fellow, *Husbandry was once a sacred art: environmental history and conservation.*

Edward Faison, Harvard Forest, *Moose foraging in the temperate forests of Central Massachusetts: a natural re-wilding experiment.*

Mark Harmon, Oregon State University and Harvard Bullard Fellow, *Developing a multi-scale perspective of forest carbon dynamics.*

Martha Hoopes, Mount Holyoke College, *Invasions on the horizon: the spread and impact of non-native species.*

Jerry Jenkins, Glenn Motzkin, and Kirsten Ward, Harvard Forest, *The flora of Harvard Forest.*

Charles Lord and Eric Strauss, Urban Ecology Institute, *The Urban Ecology Collaborative: an experiment in cross-city research for urban communities.*

Brooks Mathewson, Harvard Forest, *Differences in eastern red-back salamander populations in eastern hemlock-dominated and mixed deciduous forests in north central Massachusetts.*

Mark McDonnell, University of Melbourne, Australia
The challenges and opportunities of studying the ecology of human settlements Down Under.

Laura Meyerson, University of Rhode Island, *Tracking nonnative species at the national and state level.*

Jacqueline Mohan, The Ecosystems Center, Marine Biological Laboratory
Global change impacts on eastern forests.

Anne Pringle, Organismic & Evolutionary Biology, Harvard University, *Last chance to know Using clues from the literature and a genome to understand the biogeography of the death cap mushroom Amanita phalloides.*

Richard Primack and Abe Miller-Rushing, Boston University, *The impact of climate change on the birds and plants of Massachusetts.*

Ferran Roda, Autonomous University of Barcelona, *Land-use patterns, forest fragmentation and biodiversity in the Barcelona metropolitan area.*

Dana Royer, Dept. of Earth & Environmental Sciences, Wesleyan University, *A new approach for reconstructing paleoclimatic and paleoecological variables from the sizes and shapes of fossil leaves.*

Richard Schulhof, Harvard University–Arnold Arboretum, *Management response to hemlock woolly adelgid.*

Conghe Song, University of North Carolina and Harvard Bullard Fellow, *Impacts of landuse history on regional carbon budget: a remote sensing approach.*

Conrad Vispo, Hawthorne Valley Farm, New York, *A preliminary description of the history and ecology of an eastern New York farmscape.*

John Weishampel, University of Central Florida and Harvard Bullard Fellow, *Exploring forest textures.*

Guthrie Zimmerma, University of Minnesota, *Ruffed grouse habitat use in Minnesota: integrating multiple spatial scales for management.*

Logs produced from the logging manipulation plots in the Hemlock Removal Experiment are loaded onto a log truck. Some of this wood was sawn and used for the new garage at the Forest.

FOREST MANAGEMENT AND INFRASTRUCTURE

Several significant projects were undertaken during the past two years, all with long-term impacts on the future of research and education at the Forest.

Shaler Hall underwent its first extensive renovation since it was built in 1942, with the assistance of Kuhn Riddle Architects and Teagno Construction, Inc. from Amherst. The first- and second-floor offices and meeting spaces were renovated with new lighting, ceilings, doors, electrical systems, flooring and paint. In addition to having an attractive new appearance, the space is now more energy efficient, provides noise control, creates additional universally accessible meeting and classroom spaces and provides increased life safety protections with a new fire alarm system. The common room area was completely renovated and several walls were removed to create a flexible education and research space for groups. With a full multimedia AV suite, classes ranging from three to fifty can comfortably meet for formal presentations or informal meals.

In addition, the woods crew has been busy completing a new maintenance garage on Prospect Hill Road, a quarter of a mile beyond the Fisher House. The new two-bay garage will reduce the impact of Forest operations on research sites and the watershed that serves Prospect Hill. The garage, which is 30' × 52', was constructed of lumber that was harvested, milled, and planed on site by the woods crew. The garage features a composting toilet, a solid fuel heating system, and will have an array of solar panels to produce electricity on site. All work except for the foundation and electricity was performed by the Harvard Forest woods crew. The total cost of the building is estimated to be $72,000 exclusive of Forest staff time.

An ancillary project of the garage construction will be the installation of a new solar array with a maximum rated output of 9.98kW (DC), providing between 10–15 percent of the electricity needed by all of Prospect Hill research projects (EMS Tower, Hemlock Walk Up, Little Prospect Hill, and Soil Warming) as well as the new garage. The solar array will cost an estimated $95,000, with approximately $30,000 being provided by the Massachusetts Technology Collaborative Small Renewables Initiative and $20,000 by a matching grant from the FAS Dean's Office. The garage will also be serviced by a new electric line from the main Prospect Hill primary connection. This line will provide single-phase power to the garage and triple-phase power to the sawmill. Eventually, this line will be connected up with the electrical line running on Locust Opening Road, creating a complete electrical circuit to the experiments on Prospect Hill.

Other significant projects included renovating a Torrey ecophysiology lab for general-use plant lab space. Two Community House apartments were converted to use for long-term dorm stays. Finally, the crew assisted with rebuilding the soil warming shed after it burned after a lightening strike in July 2005.

LIBRARY AND ARCHIVES

Judy Warnement and Sheila Connor from the Botanical and Arnold Arboretum Libraries continued to catalog the library holdings in our Library of Congress classification. To date, 1,239 books have been entered in the Harvard University (HOLLIS) catalog. John Burk provided assistance to this project and also completed sorting of the collections. During the process, material was transferred or donated to the Harvard Cabot Science and Wolbach Astrophysics libraries, the Petersham Historical Society, the Barre, Royalston and Fitchburg public libraries, and the National Weather Service. The library journals were

sorted, inventoried (all foreign titles were transferred to the Cabot Library in February 2005), and alphabetized. With input from Judy, Sheila, and other Harvard Forest staff, the library committee of Emery Boose, John Burk, Edythe Ellin, and Glenn Motzkin continued meetings to plan future library projects, including a collections development policy.

As preliminary work for the LDI (Library Digital Initiative) project, John Burk, Julie Pallant, and summer proctor Hilary Crowell expanded and updated the archive databases, and inventoried several of the collections that were previously uncataloged, including the Forest's large early twentieth-century historical photograph collection.

In conjunction with the land-management plan and various administrative projects, the Harvard Forest property, deed, and map files were expanded and cataloged. A new flatbed scanner, with photo restoration software, was purchased and used regularly for a variety of projects.

INFORMATION MANAGEMENT AND TECHNOLOGY ADVANCEMENT

Research data and documentation from studies conducted at the Forest are available in the Data Archive(http://harvardforest.fas.harvard.edu/data/archive.html) on the Harvard Forest web page. The Data Archive was extensively revised and updated this year in conjunction with submission of the LTER IV renewal proposal.

Harvard Forest datasets are now registered in a database at the LTER Network Office (http://metacat.lternet.edu) where they may be searched along with datasets from other LTER sites.

The Schoolyard LTER web page (http://harvardforest.fas.harvard.edu/museum/schoolyard.html) was also completely revised and updated this year to include field data collected by participating K-12 classes.

ACTIVITIES OF THE HARVARD FOREST STAFF

Audrey Barker Plotkin coordinated the annual Harvard Forest Ecology Symposium and Friday seminar series at the Forest. She mentored three undergraduate students and served as a member of Mathew Trumbull's undergraduate capstone project committee at Hampshire College.

Emery Boose served as a reader for a senior thesis at Brown University on hurricane impacts in Taiwan. He gave talks on hurricane studies at the University of Massachusetts, and at the annual Ecological Society of America meeting in Montreal. Emery also attended annual meetings of the LTER Information Managers Committee, the LTER Information Managers Executive Committee, and LTER Network Information System Advisory Committee.

REU student Mathew Trumbull.

John Burk continued to attend and participate in conservation groups, including the Tully Lake and Quabbin use meetings, and led several local field trips. John contributed to several publications, including the Mount Grace Conservation Trust twentieth anniversary book.

Betsy Colburn was the keynote speaker at the Cleveland Museum of Natural History's conservation symposium: "Ephemeral Gems: Exploring Seasonal Ponds," and she presented public lectures on vernal pool ecology and the application of the "Wildlands and Woodlands" approach to pool conservation at the Lincoln (Massachusetts) Garden Club, the Lowell National Historic Park, and the Northwest Conservation District of Connecticut. Betsy coauthored the chapter on invertebrates in a new book, focusing on best management practices for activities carried out in the vicinity on vernal pools, and was also asked to speak on the importance of funding for systematics and natural history research at the special session on systematics and life history at the North American Benthological Society Annual Meeting in Anchorage, Alaska in June 2006.

Aaron Ellison spent a modest amount of time on the road, riding the rails, and in the air this year. In addition to his apparently annual lecture on Bayesian statistics at the University of Massachusetts, Aaron gave a keynote address at the second Mangrove Macrobenthos Meeting in Australia. This meeting

afforded him the opportunity to revisit research areas and data that he has not paid much attention to for nearly a decade. Aaron also visited Howard University and Delaware State University, where he presented research seminars and recruited students for the Harvard Forest summer research program in ecology, and he was invited to a four-day workshop on uncertainty in ecological analysis at the Mathematical Biosciences Institute at Ohio State, where he presented a talk on statistical challenges in detecting sudden ecosystem changes and alternative stable states in ecological communities. Aaron was appointed an Adjunct Professor in the Biology Department at the University of Massachusetts, and is currently supervising his first UMass Ph.D. student, Sydne Record. He is also on the M.Sc. committee of Justine Roths at the University of Southern Maine at Portland, who is testing a hypothesis that Aaron proposed in 1991, that moths can alter competitive dynamics between two salt-marsh plants. Aaron is hosting a post-doc, Jim Karagatzides (Queen's University, Ontario), who received a two-year fellowship from NSERC, Canada's NSF-equivalent. Aaron continued his stints as associate editor-in-chief for *Ecology* and *Ecological Monographs*, as a member of the Ecological Society's publications committee, and as a subject matter editor for *Ecology Letters*. Closer to home, Aaron continued his terms on the Royalston Conservation Commission and the Royalston Open Space Committee, and stepped down from the Land Protection Committee of the Mt. Grace Land Trust after three years of work. Perhaps most importantly, Aaron's ongoing work with the Friends of Tully Lake led to a key land-use victory in June 2006 when the Athol Planning Board rejected a definitive plan for a subdivision to be built overlooking Tully Lake.

Jessica Butler with pitcher plants in the greenhouse.

In September, Brian DeGasperis attended an Invasive Plant Summit in Framingham, Massachusetts, evaluating the interactions between historical land use and modern disturbances.

Ed Faison conducting vegetation surveys.

Ed Faison spent the summer and early fall of 2005 in the Quabbin and Ware River forests gathering data for his MFS thesis on moose-foraging ecology. He also helped initiate a pilot study of moose movements in Royalston, Massachusetts for the month of July and advised Christian Foster and Ben Ewing for this project. During the fall and winter, Ed collaborated with David Foster, Wyatt Oswald, and Elaine Doughty on three paleoecology papers. In March of 2006, Ed gave a talk at the Athol Bird and Nature Club on moose, and in April was awarded Harvard University's Bowdoin Prize for his essay on the paleoecology of ragweed. In May Ed successfully defended his thesis and began a research assistant position at Highstead Arboretum in Redding, Connecticut where he collaborates with David Foster on a study of invasive species and other vegetation patterns. Ed advises two REU students Dana Graef and Lisa Schauer for this project at Highstead. In June Ed attended Harvard's graduation along with MFS classmate Brooks Mathewson.

Brian Hall acted as reviewer for articles published in *Landscape Ecology, Journal of Biogeography,* and *Northeast Naturalist.* Brian also continued with online courses in Visual Basic for Applications for programming in GIS software for automating repetitive tasks.

Jim Karagatzides is coinvestigator for the "Youth Science Outreach in the Mushkegowuk Territory of Sub-Arctic Ontario, Canada." Jim's contribution includes field trips to the local muskeg using the

northern pitcher plant (*Sarracenia purpurea*) as a microecosystem to teach food web dynamics. In this context of understanding a changing environment, they include bird surveys and fossil hunts in the region.

Dave Kittredge gave several local presentations on the wildlands and woodlands vision to land trusts and watershed associations. He has sought examples of woodland council functionality as part of this greater wildlands and woodlands vision. He continued his collaboration on analysis of the forest harvest data (McDonald, et al. 2006). Dave also published a paper in the *Natural Areas Journal* on timber harvesting and the protection of rare species habitat in Massachusetts.

Heidi Lux worked on HWA projects at the Arnold Arboretum, the Simes Tract of Harvard Forest, and nine ecosystem sites in Connecticut. Heidi attended the ninetieth ESA annual meeting in Montreal, Canada in August of 2005, presenting HWA research at a poster session titled: "Changes in Ecosystem Response Associated with Hemlock Woolly Adelgid Infestation and Preemptive Logging in Southern New England." In January of 2006 Heidi presented on the current status of Harvard Forest research on Hemlock Hill at the Arnold Arboretum in Jamaica Plain, Boston: "Hemlock Woolly Adelgid and Logging at the Arnold Arboretum: Pre- and Post-treatment Results." At the Harvard Forest Symposium in March of 2006, Heidi gave a talk titled: "Ecosystem Responses to Forest Cutting after HWA Infestation – New Insights from an Urban Site." In the summer of 2006, Heidi assisted David Orwig with the mentoring of REU student Christy Rollinson. High-school student Eowyn Connolly-Brown continued with the HWA group through the early summer of 2006, with Heidi as her main supervisor.

Robert McDonald spent much of his year writing a manuscript in conjunction with the Agricultural Landscapes in Transition project. This manuscript involves collaboration among many personnel at Harvard Forest, Coweeta Hydrological Lab, and Phoenix/Central Arizona LTERs. Rob has presented articles at two conferences, one in San Diego at the meeting of the International Association of Landscape Ecologists and one in San Jose at the meeting of the Society for Conservation Biology.

Rob McDonald.

Jackie Mohan, Rob Hanifin and Liz Burrows.

Since July 1, 2005, Jackie Mohan and the group from MBL (Marine Biological Laboratory) has started a new physiological girdling study of forest trees and started a new study of fine-root biomass responses to warming. They have also continued their extensive research work (biogeochemistry, growth, survivorship, reproduction, tissue chemistry, litter production, and decomposition) at their two soil warming experiments. In summer 2006 Jackie (MBL) mentored REU student, Rebecca Orozco. Jackie has two new RAs: Rob Hanifin and Katherine Lenoir (Rob was REU student in the summer of 2004). Jackie also gave seminars at Purdue University, Michigan State University, the Kellogg Biological Station at Indiana University, and the University of Texas–Austin, during the spring of 2006.

Glenn Motzkin continues to serve as an ecology advisor for The Trustees of Reservations, an associate member of the Massachusetts Natural Heritage and Endangered Species Program Advisory Committee, and a member of the board of editors for *Northeastern Naturalist.* Glenn also served on the thesis committees of Posy Busby, Gretel Clarke (UMass), Brian DeGasperis, and Ed Faison and led a field trip to the Connecticut River for an ENPP class in Conservation Biology and a trip to Montague Plain for the Conway School of Landscape Design. Glenn,

Dave Orwig, and John O'Keefe led field trips for the Freshman Seminar class.

In 2004-05 John O'Keefe gave talks on Harvard Forest research and the history of northeastern forests at the annual meeting of the Massachusetts Chapter of the American Chestnut Foundation, the Millers River Environmental Center, and the Town of Bedford Arbor Day Commemoration and in 2005–06 at the Pioneer Valley Institute in October, the Massachusetts Audubon Society's Arcadia Nature Center in March and the Eastern Forest Resource Program Leaders Conference in May. In 2005 John completed nine years (the maximum consecutive years allowed) as a director and vice president of Mount Grace Land Conservation Trust (MGLCT) and stepped down. He continues to serve on the MGLCT Land Committee, on the boards of the Massachusetts Forestry Association, Millers River Environmental Center, and the Spannocchia Foundation, on the executive committee of the North Quabbin Regional Landscape Partnership, and on the steering committee of the Quabbin to Cardigan (Q2C) conservation collaborative. He also continues to serve on the secretary of Environmental Affairs' Advisory Group on Environmental Education. In March 2005, John and his wife, Lynne Stopen, traveled to China to meet and bring home their second daughter, Erin.

Dave Orwig gave invited talks about hemlock woolly adelgid at Williams College in Williamstown, Massachusetts, and at Westfield State University in Westfield, Massachusetts. With David Kittredge, he spoke about managing hemlock forests at the Southern New England Logger Education Program in Gardner, Massachusetts. He led field trips at Harvard Forest, Ashburnham Elementary School, and Warwick Elementary School as part of the HF LTER Schoolyard Program and as part of the Harvard University Freshman Seminar Class. Dave continued to serve on the Ph.D. committee of Kenn Clark and as the Ph.D. dissertation advisor to Anthony D'Amato at the University of Massachusetts. Dave actively participated in a working group on Pests, Pathogens, and Invasive species held at UMass, Boston as part of a larger effort run by the coalition, NE Forests 2100.

Julie Pallant attended an ArcGIS training session to become ESRI certified in November 2005, sponsored by the LTER Network Office.

P. Barry Tomlinson began a survey of the anatomy of all palms in Miami at Fairchild Tropical Botanical Garden, Coral Gables, Florida, October 2005 to April 2006. Emphasis is on leaf anatomy and uses extensive collections of palms cultivated in Florida and Hawaii. Barry's visit to New Zealand in February–March 2006 in the company of Professor Francis Hallé of Montpellier, France, in order to study architecture of native and introduced trees demonstrated the exceptional diversity of tree form concomitant with the vegetational history of New Zealand and its strong tropical components.

LAND PROTECTION EFFORTS

Previous reports have outlined the increasing threat to Harvard Forest's land base, research, and educational activities posed by the extensive exposure of its land to abutting public roads and developable private property. Fueled by rapid increases in housing prices and densities in areas to our east and improved transportation, our region is experiencing major increases in land prices and development. This development threatens Harvard Forest's hundred-year record of experiments and studies that gain irreplaceable value through time, many involving sensitive organisms or ecosystem processes such as gas fluxes and hydrology that are extremely vulnerable to even the indirect impacts of human activity. In response to these threats Harvard Forest has initiated major efforts to

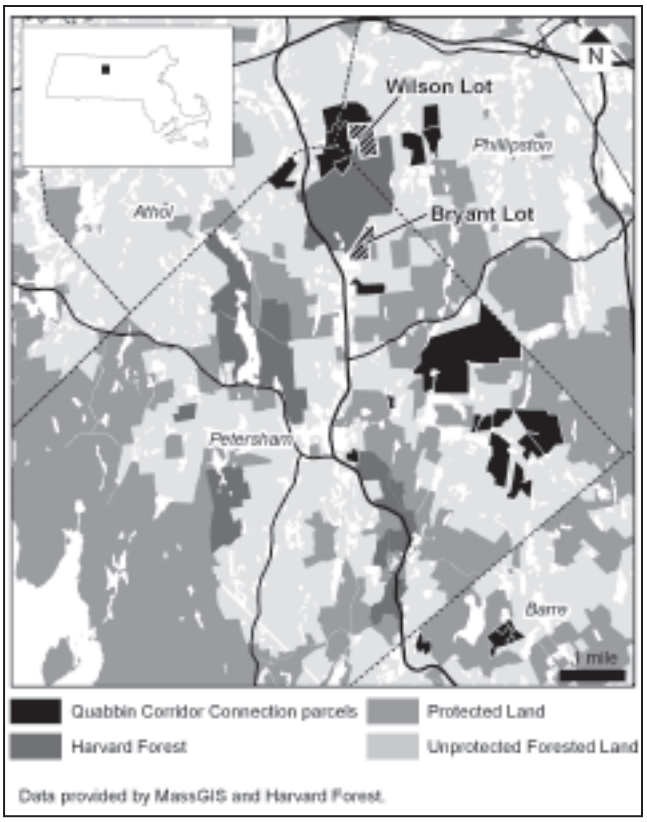
REU Student Lori Simper.

work with local government, regional and statewide conservation groups, state agencies, and the federal government to establish a buffer of protected land and ensure the Forest's continued viability as a research and educational facility.

The region surrounding the northeast corner of the Quabbin Reservation, which encompasses Harvard Forest, has been identified as an important focus area for land conservation by collaborative groups working at several scales. It has been selected as one of six initial focus areas by the Quabbin to Cardigan Conservation Collaborative (Q2C), a group of public and private conservation stakeholders led by the Society for the Protection of New Hampshire Forests (SPNHF).

A Harvard Forest study published in 1997 (Foster and Golodetz) documented a haphazard pattern of land protection within the north Quabbin region. This report led to the creation of the North Quabbin Regional Landscape Partnership (NQRLP) to coordinate all the public and private groups interested in land protection within a twenty-six town region.

In the fall of 2005, under the direction of John O'Keefe, Harvard Forest convened the East Quabbin Land Protection Group. With representatives from local towns (Athol, Barre, Hardwick, Petersham, Phillipston), regional land trusts, and nonprofits (Mount Grace Land Conservation Trust, East Quabbin Land Trust, The Trustees of Reservations, Massachusetts Audubon Society) and state agencies (DCR and DFG) this group seeks to identify priorities and coordinate land-protection activities within our immediate region. One outcome has been the very well supported (and ranked third nationally in FY06) U.S. Forest Service Forest Legacy program "Quabbin Corridor" grant application requesting funds to purchase conservation easements covering more than 2,000 acres on twenty-one properties in Petersham, Phillipston, and Barre. We anticipate sufficient funding to establish easements on two parcels abutting our Prospect Hill tract this year, the hundred-acre Wilson property abutting the north boundary and the sixty-eight-acre Bryant woodlot abutting the south boundary. Once these restrictions are in place, Harvard Forest will purchase the restricted properties as part of its buffer-creation plan. These purchases will be possible thanks to the very generous donations and pledges from our friends, alumni, neighbors, regional groups and foundations in support of our land-protection efforts. These two parcels represent the start of a strategic plan to provide a buffer of protected land around our research and educational operations.



In a related planning effort, John O'Keefe and Audrey Barker Plotkin are working with Harvard Forest staff and other senior researchers to develop a master plan for the Forest's properties. This plan will consolidate historical data for all the properties and define and map zones within Harvard Forest that would be appropriate for different levels of research, educational, recreational, and management activity. Certain zones would be restricted to minimal impact uses, other zones would be available for general research with consideration for any impacts to past or ongoing research, and other limited zones would be zoned for future infrastructure expansion if the need should arise. This master plan will provide a document to guide the use and management of Harvard Forest's properties as the Forest prepares to enter its second century.

VISITING RESEARCH SCIENTISTS AT THE HARVARD FOREST 2004–2005

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	University of New Hampshire
Jacqueline Aitkenhead	University of New Hampshire
Kate Ackerman	U.S. Geological Survey
Lynn Adler	University of Massachusetts
Jeanne Anderson	University of New Hampshire
Mark Ashton	Yale University
Paul Barten	University of Massachusetts
Mark Battle	Bowdoin College
Bryan Blair	NASA Goodard Space Flight Center
Joe Blanchard	Ecosystems Center – MBL
Richard Bowden	Allegheny College
Frank Bowles	Ecosystems Center – MBL
Hilary Callahan	Barnard College, Columbia University
Cynthia Chang	University of Maryland
Jonathan Chen	Oberlin College
Elizabeth Chilton	University of Massachusetts
Bridget Collins	Holy Cross College
Scott Costa	University of Vermont
Patrick Crill	University of New Hampshire
Bryan Dail	University of Maine
Michael Daley	Boston University
Tony D'Amato	University of Massachusetts
Eric Davidson	Woods Hole Research Center
Katrina del Fierro	Barnard College, Columbia University
R. Drijber	University of Nebraska
Ralph Dubayah	University of Maryland
Luke Durbin	Illinois Wesleyan University
Geoffrey Dutton	University of Colorado and NOAA/CMDL
Jim Ehleringer	University of Utah
James Elkins	University of Colorado and NOAA/CMDL
Serita Frey	University of New Hampshire

Heidi Fuchs	Amherst College
David Geiser	Pennsylvania State University
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Elizabeth Hane	Rochester Institute of Technology
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Gordon Jacoby	Columbia University
Jerry Jenkins	White Creek Field School
Chelsea Kammerer-Burnham	Clark University
Jim Karagatzides	Queen's University, Ontario
Sylvan Kaufman	Atkins Arboretum
Joel Kingsolver	University of North Carolina
John Klironomos	University of Guelph, Ontario
Robert Knox	NASA Goddard Space Flight Center
Döerte Köester	University of Waterloo, Ontario
Eleanor Lahr	Ithaca College
Chun-Ta Lai	University of Utah
Matthew Lau	Humboldt State University
John Lee	University of Maine
Xuhui Lee	Yale University
Wendy Liu	University of California–Berkeley
Anna Mari Lone	Amherst College
Stephanie Long	USDA Forest Service
Frank Lowenstein	The Nature Conservancy
Alison Magill	University of New Hampshire
Megan Manner	Duke University
Lynn Margulis	University of Massachusetts
Mary Martin	University of New Hampshire
Charles McClaugherty	Mount Union College
Karena McKinney	Amherst College
Kirsten McKnight	Brigham Young University
Mitch Mulholland	University of Massachusetts
Jerry Melillo	Ecosystems Center – MBL
Qilong Min	SUNY–Albany
Rakesh Minocha	USDA Forest Service
Jacqueline Mohan	Ecosystems Center – MBL
Thomas Muller	Centre for Agricultural Lanscape and Land Use Research–Muncheberg
Knute Nadelhoffer	University of Michigan
Donald Niebyl	Great Basin Institute
Scott Ollinger	University of New Hampshire
Colin Orians	Tufts University
Angelica Patterson	Barnard College, Columbia University
Neil Pederson	Columbia University
Brigit Peterson	University of Maryland
Cory Pettijohn	Boston University
Nathan Phillips	Boston University
Nick Povak	University of Wisconsin–Madison
Greg Ragland	University of North Carolina
Andrew Richardson	University of New Hampshire
Chuck Rodrigues	University of Maine
Nicholas Rosenstock	University of California–Berkeley
Scott Saleska	University of Arizona
Kathleen Savage	Woods Hole Research Center
Neal Scott	Woods Hole Research Center
Tristram Seidler	Imperial College at Silwood Park, UK
Tim Sipe	Franklin & Marshall College
Heather Smith	University of New Hampshire
Marie-Louise Smith	USDA Forest Service
William Sobczak	Holy Cross College
Bernhard Stadler	Bayreuth Institute for Terrestrial Ecosystem Research
Paul Steudler	Marine Biological Laboratories
Eric T Sundquist	U.S. Geological Survey
Ruth K Varner	University of New Hampshire
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Timothy Brodribb	Harvard University
Caroline Brophy	University College, Dublin
Robert Buchsbaum	Massachusetts Audubon Society
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Andrew Cavanagh	University of Massachusetts
Cynthia Chang	University of Maryland
Jonathan Chen	Oberlin College
Elizabeth Chilton	University of Massachusetts
Brendan Choat	Harvard University
Aimee Classen	Oak Ridge National Laboratory
Bridget Collins	Holy Cross College
Amanda Cooper	University of Central Florida
Scott Costa	University of Vermont
Patrick Crill	University of New Hampshire
Daniel Curran	Harvard University
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Ralph Dubayah	University of Maryland
David Dudley	USDA – States Department of Agriculture
Luke Durbin	Illinois Wesleyan University
Geoffrey Dutton	University of Colorado and NOAA/CMDL
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James Elkins	University of Colorado and NOAA/CMDL
Joe Elkinton	University of Massachusetts
David Fitzgarrald	State University of New York–Albany
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Nathan Phillips	Boston University
Nick Povak	University of Wisconsin–Madison
Anne Pringle	Harvard University
Elizabeth Hammond Pyle	Harvard University
Greg Ragland	University of North Carolina
Peter Raymond	Yale University
Sydne Record	University of Massachusetts
Andrew Richardson	University of New Hampshire
Chuck Rodrigues	University of Maine
Christine Rogers	Harvard University
Nicholas Rosenstock	University of California–Berkeley
Scott Saleska	University of Arizona
Nate Sanders	University of Tennessee
Kathleen Savage	Woods Hole Research Center
Sanna Sevanto	Harvard University
Neal Scott	Woods Hole Research Center
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Paul Steudler	Marine Biological Laboratories
Eric Sundquist	U.S. Geological Survey
Pamela Templer	Boston University
Susan Trumbore	University of California
Ruth Varner	University of New Hampshire
Rebecca Waysek	U.S. Geological Survey
John Weishampel	University of Central Florida
Steve Wofsy	Harvard University
Benjamin Wolfe	Harvard University
Hui-Ju Wu	Yale University
Hina Zafar	Barnard College, Columbia University

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**Indicates Summer Research Program for Undergraduates participant*

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GIFTS

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David Foster and Julian Hadley – Effects of Forest Age, Soil Drainage and Interannual Climate Variation on Deciduous Forest Carbon Exchange: A Comparison to Long-term Harvard Forest Measurements, in a Contrasting Forest Type; DOE NIGEC 011213-HU: $362,680.

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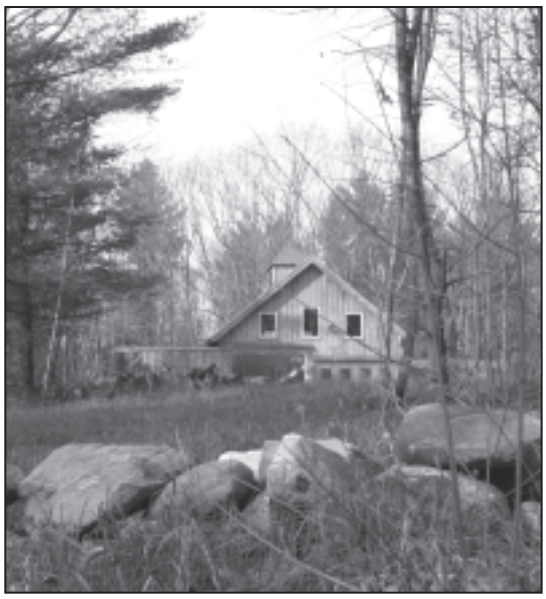

New maintenance garage on Prospect Hill.

David R. Foster
Director

Petersham, Massachusetts
December 2006