THE HARVARD FOREST 1998 – 1999
Harvard University

Front Cover: *Sunlight on the leaves of American chestnut*

ANNUAL REPORT OF THE HARVARD FOREST 1998-1999

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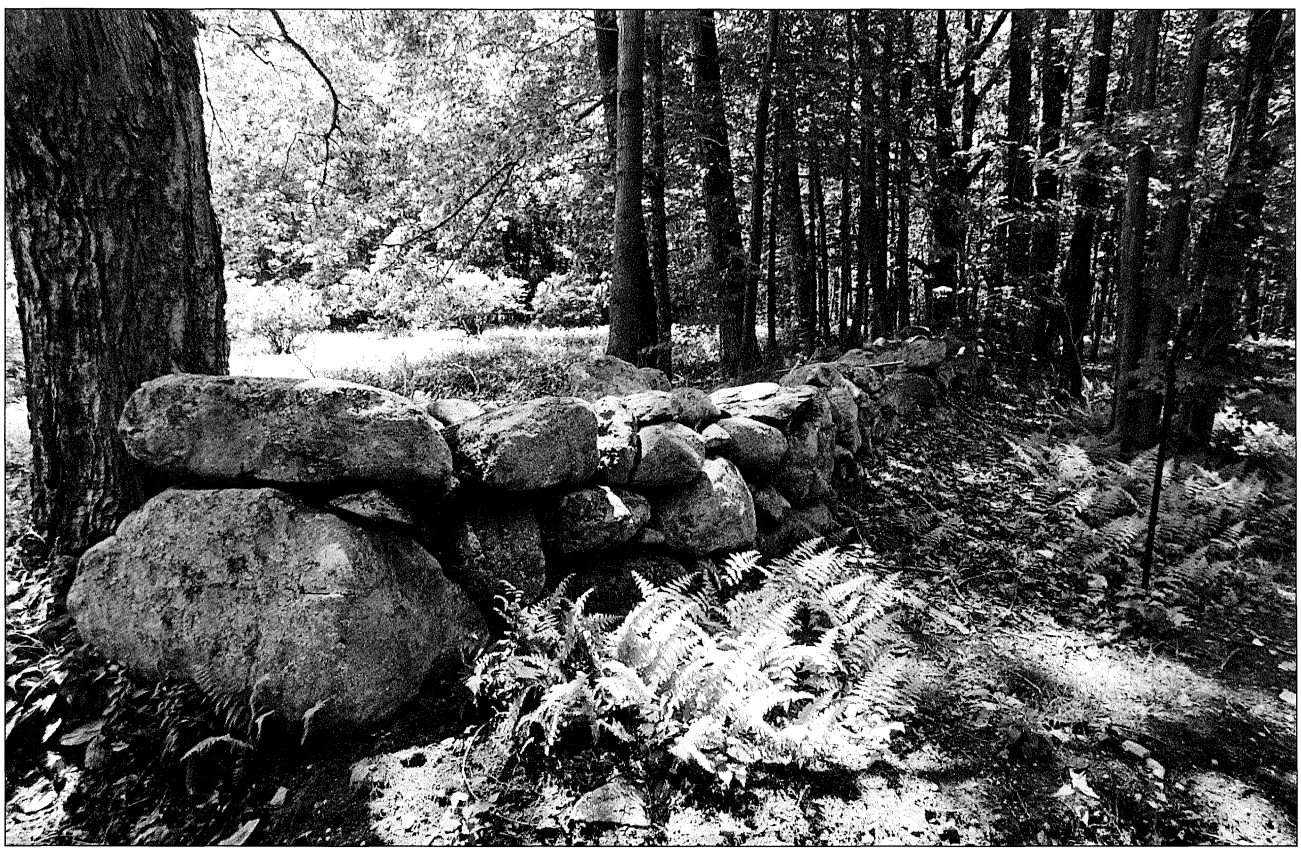


Photography by Jim Gipe

PERSONNEL AT HARVARD FOREST 1998-1999

Marc Abrams	Bullard Fellow
Rebecca Anderson	MFS Candidate
Audrey Barker Plotkin	Research Assistant
Jesse Bellemere	MFS Candidate
Emery Boose	Information and Computer Manager
Jeanne Boutelle	Part-time Custodian
Jeannette Bowlen	Accountant
Matthias Burgii	Research Associate
John Burk	Research Assistant
Alexis Calvi	Part-time Assistant
Susan Clayden	Research Assistant
Richard Cobb	Research Assistant
Willard Cole	Woods Crew
Thia Cooper	Summer Program Assistant
Edythe Ellin	Adminstrator
Claire Dacey	Research Assistant
Elaine Doughty	Laboratory Assistant
Natalie Drake	Palynologist
Robert Eberhardt	MFS Candidate
John Edwards	Forest Manager
Neal Enright	Bullard Fellow
Rebecca Field	LTER Associate
Barbara Flye	Librarian/Secretary
Charles W. Foster	Associate
David Foster	Director
Donna Francis	Research Associate
Janice Fuller	Research Associate
Alexander Golub	Bullard Fellow
Julian Hadley	Research Associate
Brian Hall	Research Assistant
Linda Hampson	Secretarial Assistant
Jon Harrod	Research Associate
Donald Hesselton	Woods Crew
Susan Johnson	Research Assistant (part-time)
Ruth Kern	Research Associate
Roger Kitching	Bullard Fellow
David Kittredge	Forest Policy Analyst
Matt Kizlinski	Research Assistant
Takashi Kohyama	Bullard Fellow
Christopher Kruegler	Administrator
Oscar Lacwasan	Custodian
Cathy Langtimm	LTER Associate
Deborah Lawrence	Research Associate
David Lee	Bullard Fellow
Lisa Marselle	Summer Cook
Glenn Motzkin	Plant Ecologist
John O'Keefe	Museum Coordinator
David Orwig	Forest Ecologist
Julie Pallant	Assistant Information and Computer Manager
Tim Parshall	Post-doctoral Fellow
Diego Perez-Salicrup	Post-doctoral Fellow
Dorothy Recos-Smith	Staff Assistant
Emily Russell	Visiting Scholar
Mayra Serrano	Research Assistant
Ben Slater	Research Assistant
Charles Spooner	Woods Crew
P. Barry Tomlinson	E. C. Jeffrey Professor of Biology
Susan Trumbore	Bullard Fellow
Dennis Whigham	Bullard Fellow
John Wisnewski	Woods Crew
Steven Wofsy	Associate
Maciej Zwieniecki	Research Associate

INTRODUCTION TO THE HARVARD FOREST

Since its establishment in 1907 the Harvard Forest has served as a center for research and education in forest biology. Through the years researchers at the Forest have focussed on silviculture and forest management, soils and the development of forest site concepts, the biology of temperate and tropical trees, forest ecology, forest economics and ecosystem dynamics. Today, this legacy of research and education continues 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 forest ecosystems. This activity is epitomized by the Harvard Forest Long Term Ecological Research (HF LTER) program, which was established in 1988 through funding by the National Science Foundation (NSF).

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

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

The staff and visiting faculty of approximately 50 work collaboratively to achieve the research, educational and management objectives of the Harvard Forest. A management group comprised of the Director, Administrator, Coordinator of the Fisher Museum, and Forest Manager meets monthly to discuss current activities and to plan future programs. Regular meetings with the HF LTER science team provide for an infusion of outside perspectives. Forest management and physical plant activities are undertaken by our four-member Woods Crew and directed by the Forest Manager. The Coordinator of the Fisher Museum oversees many of our educational and outreach programs.

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

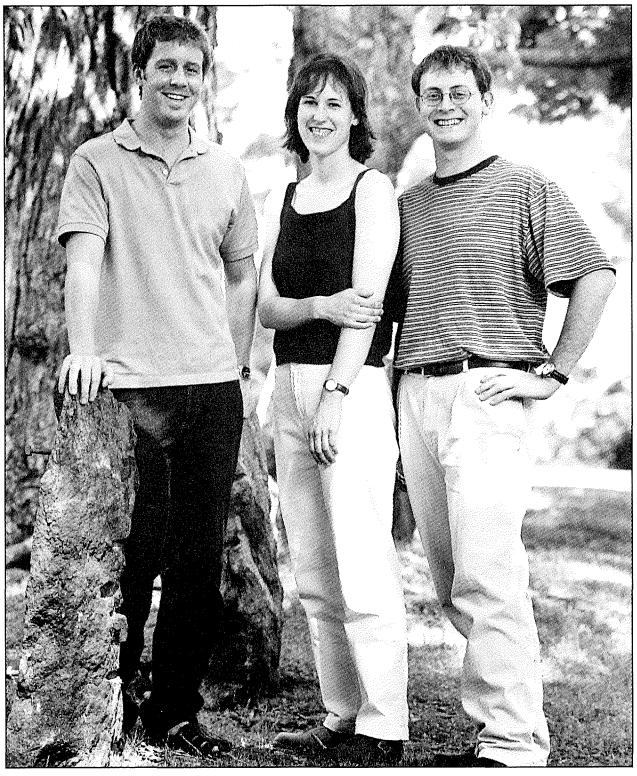
NEW STAFF

Edythe Ellin, a graduate of Wesleyan University and Boston College Law School, replaced Chris Kruegler as Administrator and became immediately involved in coordinating personnel and financial activities and organizing the summer student research program.

Jon Harrod, a Harvard College graduate who began his botanical and ecological studies at the Forest with Barry Tomlinson, David Foster, and Glenn Motzkin, returned as a research associate working on the Cape Cod and Islands project. Jon completed his Ph.D. this year at the University of North Carolina.

David Kittredge, Associate Professor in the Department of Forestry and Wildlife Management at the University of Massachusetts, was appointed Forest Policy Analyst at the Harvard Forest. Dave will be spending his summer months working on a range of projects commencing with an analysis of the rate and pattern of forest cutting in the North Quabbin Region of Massachusetts.

Julie Pallant, a graduate of Oberlin College with research and computer experience in a variety of settings, including the Ecosystems Center at MBL and Woods Hole Oceanographic Institution, joined the staff to assist with computer and information management tasks.



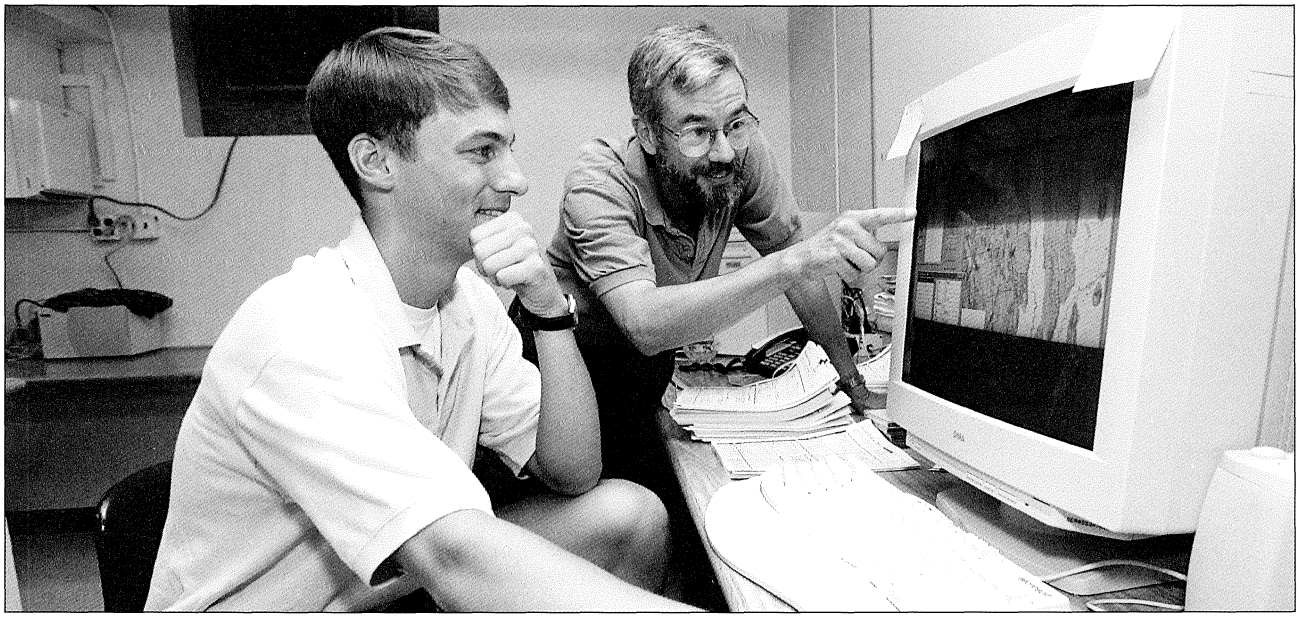
Jesse Bellemere, Rebecca Andersen, and Matt Kizlinski

Susan Clayden and Tim Parshall

Tim Parshall, who received his Ph.D. from the University of Minnesota working with Margaret Davis, a former graduate student of Hugh Raup's at the Forest, arrived as a research associate in paleoecology on the coastal project.

New MFS students include Matthew Kizlinski, Jesse Bellemere and Rebecca Andersen. Matt, who received a BA in soil science from the University of New Hampshire, and worked for two years as a Forest staff member studying the hemlock woolly adelgid (HWA), will begin studies on the ecological effects of logging in hemlock forests. Rebecca received her BA in biology from Tufts University and will investigate patterns of wetland development in New England. Jesse, who is a recent graduate of the University of Massachusetts and former summer student at the Forest, is conducting research on environmental and historical influences on rich mesic woodlands in western Massachusetts.

Research Assistants joining the Harvard Forest Staff include Richard Cobb who received his MFS degree from the University of Maine and is working with Dave Orwig on the HWA project, Claire Dacey, a graduate of Stanford University, who is working with Julian Hadley on the NIGEC project, and Susan Johnson, who received her MS from Acadia University and is working part-time with John O'Keefe on the phenology project. Alexis Calvi, a senior at Athol High School, is assisting Dave Orwig as a part-time lab technician.



Summer student Andy Finley and Dave Kittredge

RECENT PUBLICATIONS

In addition to the regular journal articles on research findings, Harvard Forest researchers have produced a series of new books and booklets that are directed towards a broader readership. After a twenty-year hiatus, the series of Harvard Forest Papers was revitalized through the publication of two issues in a new color format. In *Historical Influences on the Landscape of Martha's Vineyard* (Harvard Forest Paper 23) David Foster and Glenn Motzkin review the long-term history of human activity and vegetation change on the island with specific focus on the Correllus State Forest, part of the broad sandplain that occupies the center of Martha's Vineyard. They present a broad and ambitious plan for the restoration of native vegetation on this 5200-acre tract, which represents one of the largest intact areas of sandplain vegetation along the northeastern coast. The recommendations for this important conservation area were strongly endorsed by an editorial in the Vineyard Gazette newspaper and were described in the Boston Globe as the largest proposal for ecological restoration in Massachusetts's history.

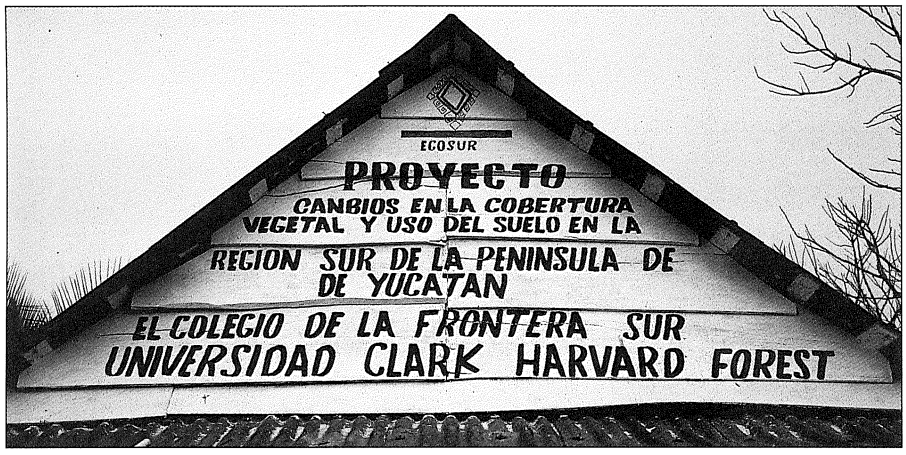
Thinking in Forest Time: A Strategy for the Massachusetts Forest (Harvard Forest Paper 24) by Henry and David Foster argues that a long-term vision and comprehensive plan is needed for Massachusetts forest lands to thwart the impacts of suburban sprawl and to protect open space in the Commonwealth. The paper's recommendations were broadly endorsed by a state legislative commission and an editorial in the *Boston Globe.*

Three recent books have emerged from writing and publishing efforts at the Forest. In *Thoreau's Country: Journey Through a Transformed Landscape* (Harvard University Press) David Foster uses the journal writings of Henry Thoreau to describe the ecological and social transformations that have occurred in New England. The book illustrates how an understanding of this history aids in the interpretation and conservation of the modern landscape.

The Harvard Forest has teamed up with Dr. Lloyd Irland to publish *The Northeast's Changing Forest,* a comprehensive revision of Irland's *Wildlands and Woodlots* in which he describes and interprets the varied forest conditions across the Northeastern U.S.

David Foster and John O'Keefe have underscored the theme of using forest history to inform ecology and management in *New England Forests Through Time: Insights from the Harvard Forest Dioramas.* This full color 80-page booklet uses all of the scenes from the dioramas to tell the story of New England land-use change, to illustrate a number of modern and historical conservation themes, and to describe a range of silvicultural approaches that are useful for local woodland management. The booklet is dedicated to R. T. Fisher, first director of the Forest and Ernest G. Stillman, his friend and benefactor of the Fisher Museum and the Forest.

The diorama booklet and HF Papers 23 and 24 are available through the Harvard Forest. Foster's and Irland's books are available through Harvard University Press.



Field house and research base in the Yucatan

RESEARCH ACTIVITIES

Land Use and Land Cover Change in the Yucatan

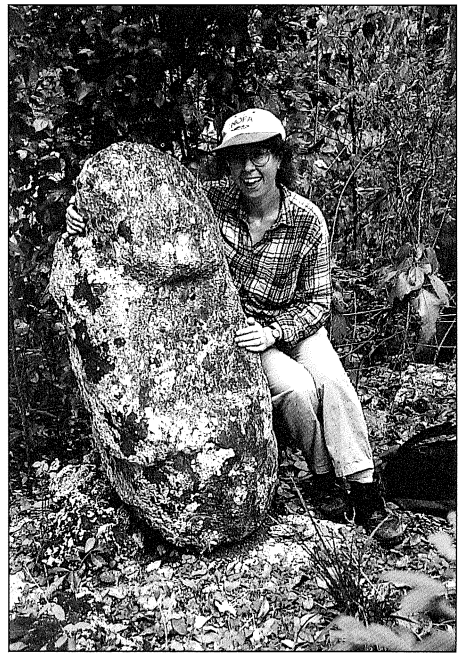
With colleagues from Clark University and the College of the Frontier (Ecosur), Mexico, Harvard Forest researchers are conducting an interdisciplinary study based on remote sensing and field studies in the southern Yucatan region of Mexico. The project, which is funded by NASA, the LTER program, the A. W. Mellon Foundation, and Conservation Research Foundation, is attempting to document the major historical, social, and natural factors that control vegetation patterns and ecosystem processes in this extensive forested region. The Southern Yucatan Peninsular Region (SYPR) contains the largest and most understudied expanse of tropical vegetation in Mexico. However, due to recent, very intense land-use pressure the area is changing rapidly through deforestation and shifting agriculture. Consequently, in addition to addressing fundamental scientific questions, this large project intends to aid efforts to conserve biological resources in the region.

Broad-scale Patterns of Vegetation Change

To gain a baseline of human activity in the southern Yucatan before widespread settlement, Audrey Barker Plotkin and David Foster are interpreting land-use and disturbance patterns from aerial photos taken in 1969. Agriculture in the region was extensive only around the larger towns, but evidence of forest disturbance from logging activity covers large areas. The resulting maps will be digitized into a GIS and used in conjunction with satellite images developed by colleagues at Clark to document and interpret long-term changes in vegetation and human activity.

Composition, Structure and Dynamics of Forests

One major objective is to determine what forest types within the SYPR are more vulnerable to current land transformation pressures and how regional biodiversity is being affected by this land conversion. As the first step in evaluating forest response and vulnerability to natural disturbances and modern land use transformation, Diego Perez-Salicrup is leading an effort to classify the forest types and determine the major factors controlling their structure and composition Research focuses on six regions selected to sample important gradients in rainfall, soil depth, topography, and hurricane frequency. Within each region, vegetation and environmental factors are

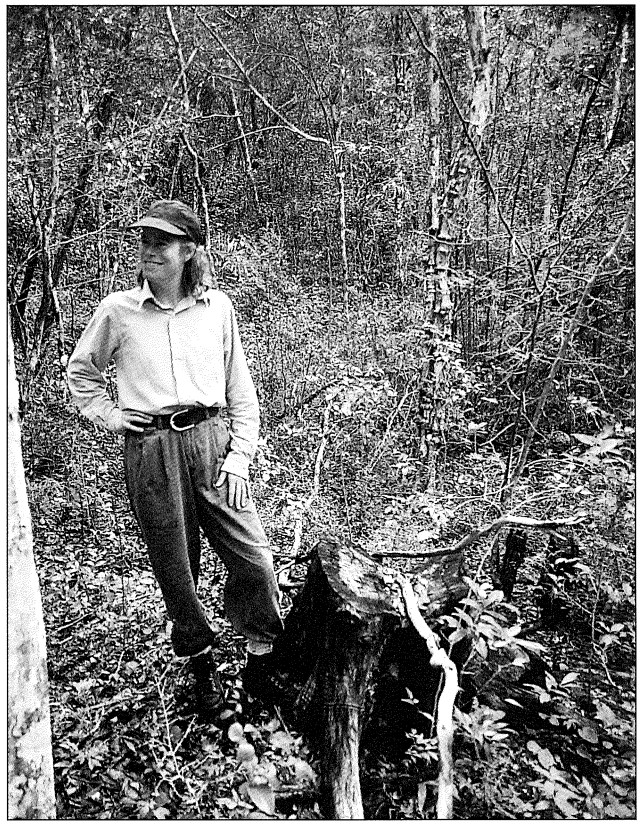


Audrey Barker Plotkin with Mayan figure

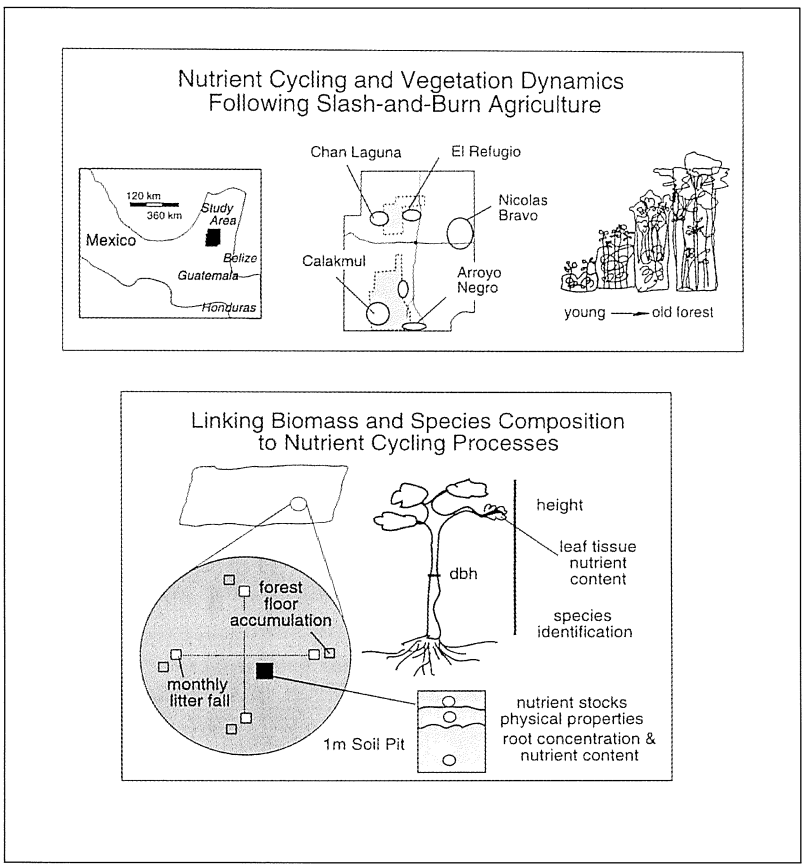
being sampled in randomly established plots.

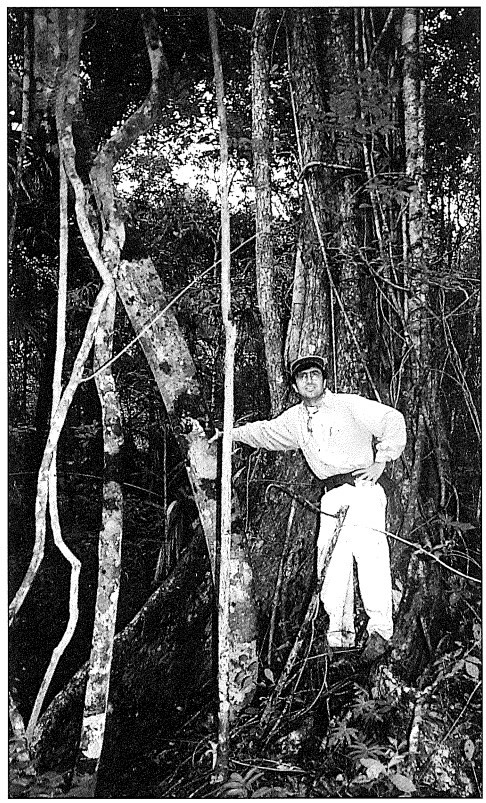
Based on preliminary analyses, Diego has identified two very distinct forest types that differ in species and structural features, such as canopy height, number of trees, density of lianas, and presence of trees with epiphytes. Analysis of species richness and tree species composition has shown that the low-stature forests ("bosque bajo" in Spanish) have more tree species than mid-stature forest ("bosque mediano"), but that many of the species of mid-stature forest are represented in lower densities in low-stature forests. Current agricultural practices in the region tend to focus more on mid-stature forests than low-stature forests. Consequently rare species and habitat are being affected differentially between these types.

Another aspect of interest is the age at which forests recover their structural attributes and species composition following the abandonment phase of shifting agriculture. Initial studies indicate that forest regeneration is relatively fast, with 30-year-old forests being similar in structure and composition to older growth forest. Equally important are ongoing investigations into the history and age of the older-growth forests that are being used for comparison. Since the entire region was

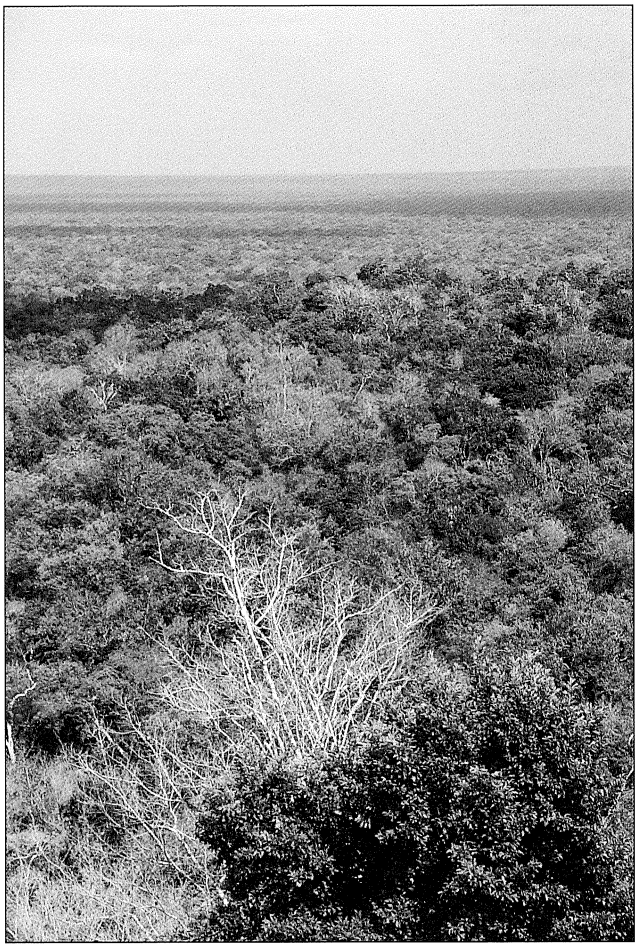


Deborah Lawrence





Diego Perez-Salicrup



Fer-de-lance

Unbroken seasonally deciduous forest covers the Calakmul Biosphere Reserve.

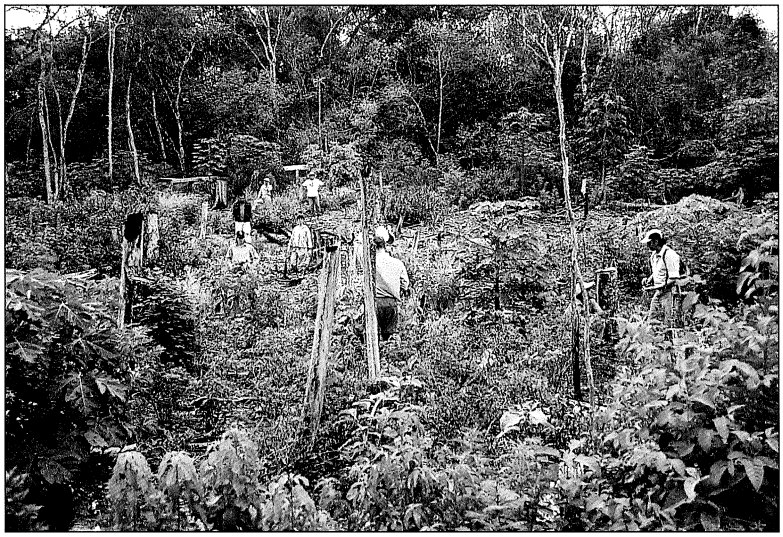
intensively deforested in Mayan times, and much of the region has been subjected to widespread logging in the earlier part of the twenthieth century, understanding the long-term history of the region's forests will provide critical insights into their modern characteristics.

Ecosystem processes following shifting cultivation

Increasingly the study region is being converted to secondary forest that has regenerated from traditional "milpa" shifting cultivation of maize. Subsistence maize cultivation is practiced by almost all the householders in the region, thus it will continue to be a major driver in forest dynamics. The system has a profound influence on the rate of recovery of forest ecosystem properties and community structure and on the future productivity of land for all purposes. Projections of future responses to regional land-use and forest cover change depend on a thorough understanding of ecosystem processes and tree community structure following shifting cultivation.

Deborah Lawrence is coordinating two studies essential to understanding the process of succession following milpa cultivation: first, characterizing the recovery of ecosystem and community properties, and second, investigating the mechanisms controlling the rate and trajectory of this process. The first set of studies quantifies change as a function of forest age (from 3 to 50 years), in part to determine the ecological status of various secondary forest types detectable by remote sensing (for incorporation into regional evaluations of land-use/cover change), and in part to determine when, if ever, a secondary forest becomes indistinguishable from old-growth forest on the ground. The second set of studies will help us understand the process and will provide insight into possibilities for and constraints on future management.

Deborah is sampling across the precipitation and land-use gradients in the region at three different areas: two sites in the north, El Refugio and Nicolas Bravo, are dry and intermediate, whereas Arroyo Negro in the south is the wettest. Nicolas Bravo is the



Sampling in a milpa

A one thousand year-old Mayan temple emerges from the forest at Calakmul

oldest settlement, with significant agricultural development over the past 40–50 years. El Refugio and Arroyo Negro were settled only 20 years ago. Nevertheless, all of our stands have experienced no more than two cycles of forest clearing, burning, cultivation, and regrowth. We have sampled 3–4 stands per successional stage per site, including mature stands that have not been cleared for agriculture in this century.

We will generate estimates of basal area and total aboveground biomass from field data. In conjunction with soil nutrient availability, total biomass is likely to determine the rate of nutrient accumulation and cycling. These characteristics are also useful indicators of how the structure of the tree community changes during recovery from shifting cultivation.

We will also characterize changes in the nutrient stocks in above ground vegetation, forest floor, roots, and soil, as a function of stand age. We have collected samples of coarse woody debris and fine litter and surface soils (0–15 cm depth), and hope to collect root and leaf tissue samples in the near future. We collect litterfall monthly from a set of four 1-m^2 traps per stand to determine litter mass and nutrient content.

We are analyzing the soils to elucidate the relationship between rates of nutrient cycling and soil nutrient status. Major nutrients of interest that will be investigated include nitrogen, phosphorus, potassium, calcium, and magnesium. We will also examine soil texture, cation exchange capacity, pH, and gravimetric soil water content.

In so doing, we hope to understand how water and nutrients limit plant productivity in regenerating forests, and how these relationships vary depending on precipitation, soil depth, and land-use history.

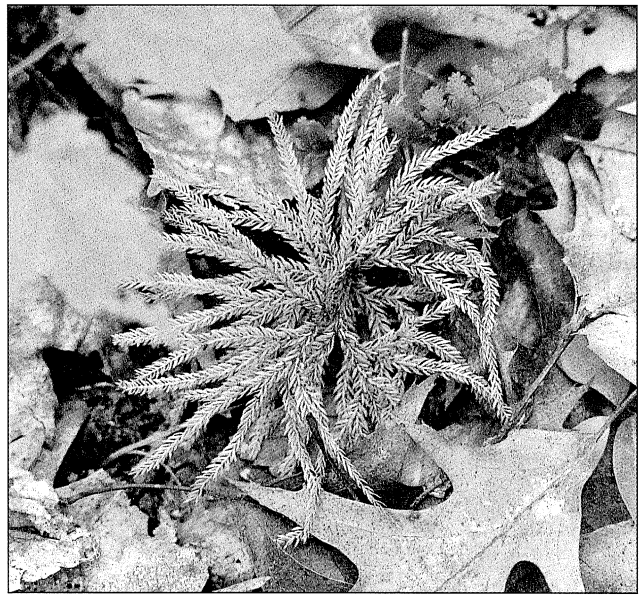
Forest Response to Experimental Hurricane

With the help of Elaine Doughty, Rebecca Anderson and Jesse Bellemare, Audrey Barker Plotkin is remeasuring tree regeneration in the hurricane pulldown this summer. Nine years after the simulated hurricane, the sapling and sprout layer now forms a continuous canopy nearly twenty feet tall. As light becomes more limiting, fewer new seedlings are surviving, and competition among existing saplings is intense. Such continuing measurements add to the research synthesized by Sarah Cooper-Ellis, David Foster, Gary Carlton and Ann Lezberg in a paper soon to be published in *Ecology*.

The Long-term Effect of Land-Use History on Tree and Shrub Distributions

Ruth Kern has been investigating the spatial pattern of clonal shrub and overstory tree distributions with respect to past land-use (plowed vs. unplowed) on the Montague Sand Plain in central Massachusetts. This area of homogeneous topography and soils is a model system in which to study the effects of past land-use on plant distribution and demography, since differences in vegetation between formerly plowed and unplowed areas are largely due to the legacy of disturbance rather than site differences. Distributions

Medeola virginiana



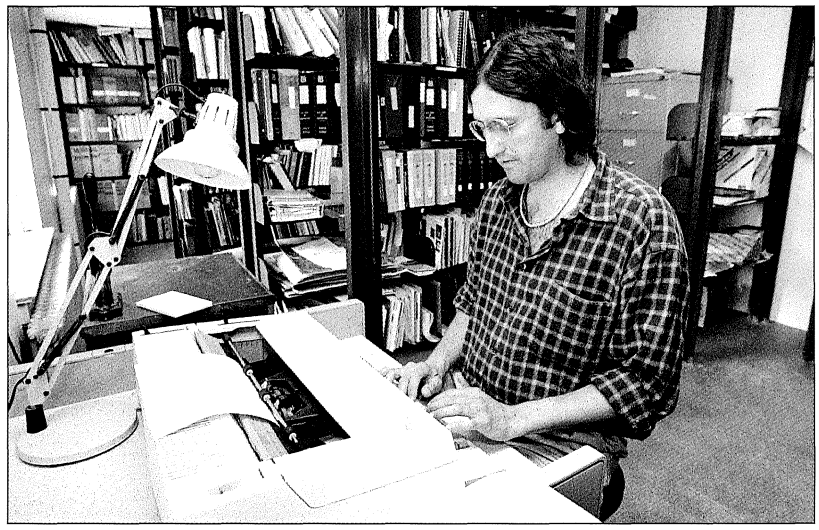
Lycopodium obscurum

of 14 clonal shrub species and 15 tree species were mapped in a 4.9-hectare plot that includes formerly plowed and unplowed areas to interpret the pattern of species dispersal into areas where they had been eradicated by plowing. Although most tree species are uniformly distributed across the land-use boundary, pitch pine *(Pinus rigida)* and red maple *(Acer rubrum)* have virtually non-overlapping distributions, with pine occupying the plowed area.

Although specific patterns of density and distribution vary among species, shrub density was higher in unplowed areas and dropped sharply at plow boundaries. Wintergreen *(Gaultheria procumbens)* is highly restricted to the unplowed sections and appears to have spread only by clonal growth into the formerly plowed area. Huckleberry *(Gaylussacia baccata)* and two species of blueberries *(Vaccinium angustifolium and V. vacillans)* have successfully established in the formerly plowed field, but their patterns of clone size and dispersion suggest differing dispersal and growth rates. Modern shrub distributions appear to be more strongly linked to historical land-use than are most of the tree distribution patterns.

Ruth is also investigating the life-history factors regulating plant population and community patterns in relation to land-use history. Previous studies at the Forest and Montague indicate that environmental factors and historical land use control plant distributions and forest composition but that these influences may vary between sites. Within each of these areas there is a range of historical land-use practices including sites that were plowed and subsequently

Glenn Motzkin



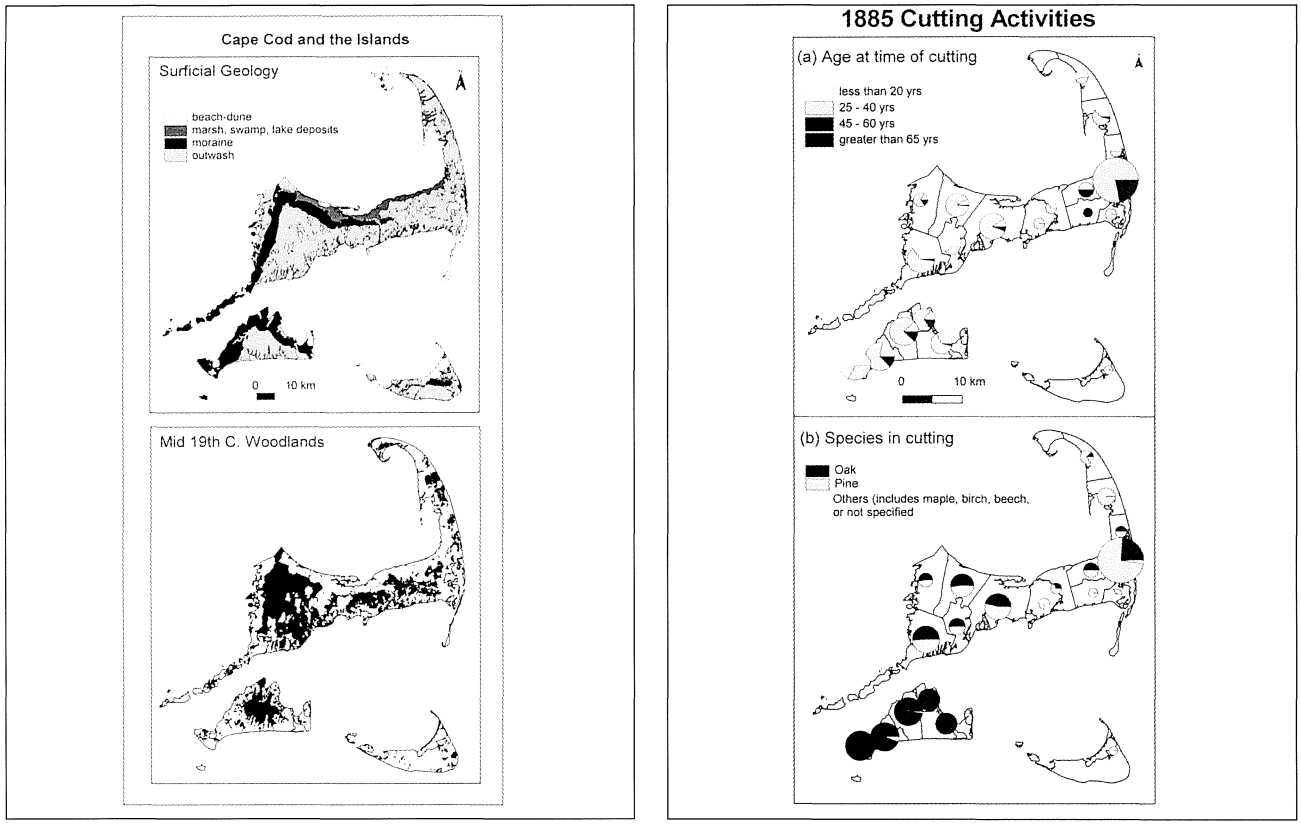
abandoned and areas that were not plowed but were used as pasture or woodlot. The areas contrast in edaphic conditions: Montague is a plain that is highly prone to drought whereas the Prospect Hill site is a rolling upland with a wide range of moist loam soils. As expected, some species are well dispersed and occur in all areas regardless of past land-use, while others favor one of the different land uses. Curiously, some species that are restricted to a particular land-use at one site are not subject to the same restriction at the other site. By employing an analysis of life-history traits of these species, we hope to determine where in the plant's life-cycle the restriction occurs — reproduction, dispersal, germination, or survival, and what environmental or inherent biological trait is controlling the population dynamics. This will lead to a better understanding of the legacies of historical land-use in the modern landscape.

Lake Response To Land-use History

Donna Francis finished paleolimnological studies of three small headwater lakes in southern New England, looking at their response to disturbance by forest clearance and agriculture, as well as recovery rates when the disturbance ceases and the forests re-grow. The watersheds represent a range of past land-use activity and are now completely reforested. Sedimentation rates and aquatic productivity increased in all ponds in response to human activity. However, responses were complex. Productivity changes, as indicated by organic material, C:N ratios, and chironomid assemblages, are more pronounced in North Round and Wickett Ponds than in Pecker Pond, even though agricultural activity was most intense at Pecker Pond. North Round and Wickett Ponds are shallower than Pecker, and showed more evidence of sediment and nutrient inputs from the watershed. Although North Round Pond was the least impacted site, with only minimal logging, major changes did occur as a consequence. Sedimentation rates and productivity continue to be greater than pre-settlement levels at all ponds, and the systems have not returned to pre-disturbance states. Interestingly, lake response and forest response to regional land–use history show similarities. In both systems, fundamental changes in ecosystem function and composition were initiated by even light land use. These changes persist even decades or centuries after the disturbances cease and apparently natural and stable conditions develop in forest cover and watersheds.

Post-settlement Vegetation Changes in Relationship to Little Ice Age Climate Changes

Our studies of forest history in Central Massachusetts document that some compositional changes began well before European settlement. In an effort to examine the factors underlying these changes, and to examine historical vegetation dynamics in the context of long-term changes, we are undertaking a multi-proxy study using paleoecological, paleolimnological, and historical approaches to reconstruct climate, vegetation, and cultural dynamics over the past 1500 years. Janice Fuller, Donna Francis, Brett Wolfe and David Foster are examining eight sites arrayed across the climatic and forest gradients of New England from southern Connecticut to central New Hampshire and Vermont. Part of the study will focus on climate change (the Little Ice Age) as a potential



Study areas in Cape Cod, Martha's Vineyard and Nantucket showing variation in surficial geology, historical woodlands and forest cutting activity in 1885. By the mid-nineteenth century remaining woodlands were concentrated on sandy outwash areas. However, as indicated by the cutting maps, these forests were comprised of stands primarily less than 40 years old. Interestingly, pine was widely available on the Cape, but largely absent from Martha's Vineyard.

driver of vegetation change. Temperature and precipitation regimes will be investigated using chironomid remains and stable isotopes. A calibration set of chironomid/temperature data is being collected from surficial sediments along the north-south transect. These data will then be used to infer temperature changes from fossil chironomid assemblages in sediment cores. Results of the study will provide: (1) an objective characterization of the Little Ice Age and climate history in New England; (2) comparison of pre and postEuropean forest dynamics in relationship to independent environmental and landuse histories; (3) a reexamination of historical vegetation dynamics in light of prior climate and vegetation change.

Historical-Ecological Approaches to Understanding and Conserving Coastal Landscapes

A major goal of conservation is to use information on the factors that control species distributions and plant and animal assemblages in order to perpetuate them through time. Although vegetation patterns result, in part from species-specific responses to environmental factors such as soil conditions, actual plant distributions often differ from potential distributions as a result of historical factors including natural and human disturbance. Disturbance may influence community patterns by: (1) altering the environment; (2) creating opportunities for new species to establish; or (3) reducing populations of established species. For instance, our work has shown that plants with slow rates of dispersal or establishment may be absent from a site for decades simply because the species were removed by prior disturbance and have not had sufficient time to re-colonize. Consequently a major challenge exists to evaluate the relative contribution of the current environment and historical factors in determining modern vegetation patterns and dynamics.

Following-up on our prior research in central Massachusetts, the Connecticut Valley, and Martha's Vineyard, we have initiated a comprehensive investigation of the history and vegetation of the coastal

Glenn Motzkin, Jon Harrod, Rob Eberhardt, Art Allen, Erin Largay and Georgine Yorkey examining soils on Cape Cod

regional that includes Cape Cod, Martha's Vineyard, Nantucket, Block Island, and Long Island. This region is a high priority for conservation because it supports numerous rare and uncommon plant and animal species and communities and because it is highly threatened by development. With support from the A. W. Mellon Foundation, The Nature Conservancy's Ecological Research Program, and the National Science Foundation we are investigating the link between the landscape history of the coastal region and the modern abundance and distribution of upland plant communities, including grasslands, heathlands, barrens, and woodlands. Although the New England coast has a long history of human occupation and intensive use, there has never been a rigorous historical-ecological study conducted across this region. Results from such an effort will be critical in identifying appropriate ecological goals for conservation and developing management approaches for achieving those objectives.

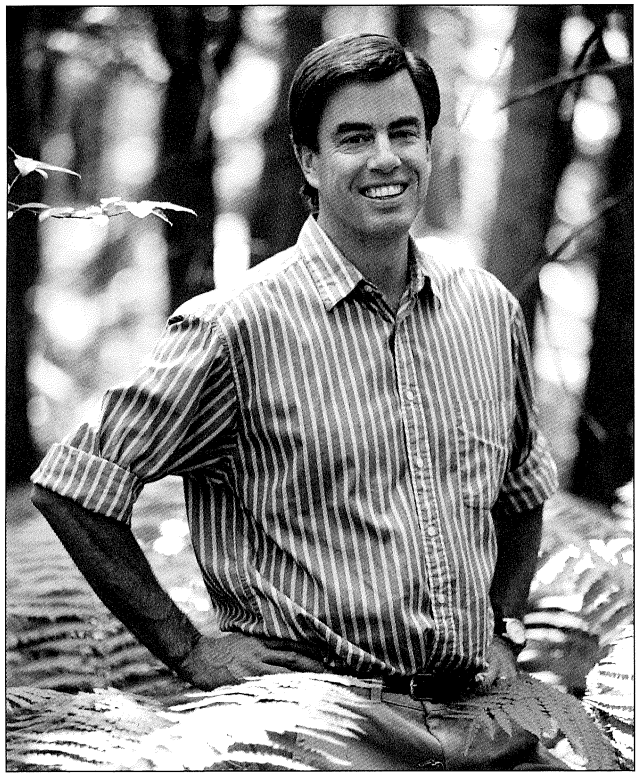
Our coastal effort integrates paleoecological, historical, and field studies. Jon Harrod and Rob Eberhardt are working with David Foster and Glenn Motzkin to evaluate the relationship between modern vegetation, site factors, and disturbance history. Field studies this year are focussed on the forests of Cape Cod and Martha's Vineyard, and will expand in the future to include woodlands throughout the region, as well as grasslands and shrublands. Brian Hall is gathering a wide range of historical data, including excellent maps from the seventeenth century to the present, to develop an extensive Geographic Information System (GIS) data base. Together, the field and historical studies will link the legacy of forest cutting, agriculture, fire, and hurricane disturbance with changes in vegetation over the past 400 years and the development of the modern landscape.

Paleoecological studies by Tim Parshall and David Foster will reconstruct changes in vegetation, fire, and human activity over the past 2000 years by analyzing the sediments from small lakes throughout the region. The interest here is to understand the characteristics and dynamics of the landscape during the pre-European period as a background for evaluating subsequent changes in historical times. Our approach is to reconstruct landscape-scale vegetation dynamics for a number of relatively small (10–50 ha) areas with high enough temporal resolution that changes before, during and after European settlement can be evaluated.

We are considering two main landscape attributes when selecting study lakes. The first one is landform type, because soils and landforms influence both vegetation composition and fire occurrence. Pitch pine and oak forests were probably more abundant on sandy, outwash soils while hardwood trees like hickory, beech and maple may have been more common on fine-grained, morainal soils. The second landscape attribute is proximity to human settlement and intensity of human land-use activity. By selecting lakes with these landscape attributes in mind, we will address the following questions:

What were the predominant plant communities before European settlement?

Because land-use history has greatly altered plant communities, one of the major goals is to determine the type and range of pre-settlement vegetation before this time period for comparison with historical changes. Other coastal studies have suggested large changes in vegetation composition corresponding to the period of European settlement. For example, Block Island, now largely deforested, was once covered with trees and the forests of Cape Cod supported a



David Foster

much larger proportion of oak trees than today. The pre-settlement prevalence of grasslands and heathlands throughout the region is also a major question, especially on Martha's Vineyard and the outer Cape.

How dynamic were plant communities along the coast over the past 2000 years?

Some aspects of vegetation change are not apparent from historical records or modern observations because they occur over long time intervals. For example, in central Massachusetts many of the vegetation changes interpreted as resulting from European activity, such as the decline in hemlock and beech, were already underway in the 1400s, presumably as a result of climate change related to the Little Ice Age. Climate change over the past 2000 years may have been an important factor influencing vegetation along with Indian activity in the coastal region.

Similarly, the role of disturbance, for example fire or Native American activity, is only apparent in the context of long intervals of time. In general, fire activity has been much greater along the coast of New England than inland and the overall frequency of fire has increased since European settlement. However, some coastal areas show a decline of fire with European arrival. Resolving the actual patterns across the coastal region and determining the former abundance of fire will provide important information for current conservation and management decisions.

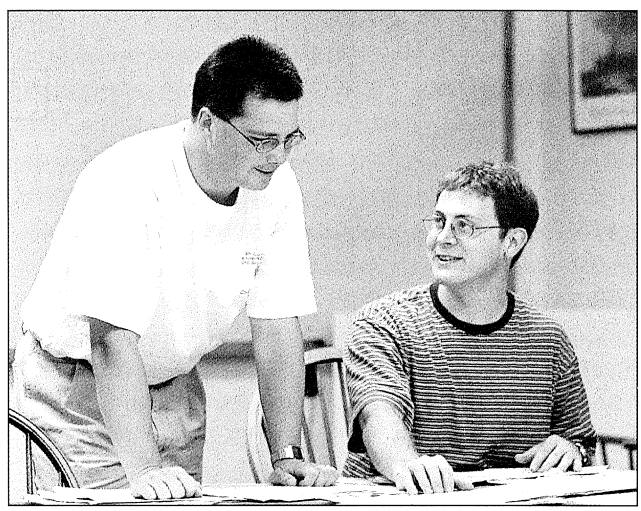
How prevalent were human impacts before European settlement?

Although our main interest centers on the dramatic vegetation changes initiated in the seventeenth century by European settlement, human impacts before this time may also have been important. Native American populations were concentrated along the coast and may have influenced the abundance and distribution of many plants, particularly through intentional use of fire. The fine-scale records of charcoal and pollen that we are developing for the past 2000 years will allow us to directly address fire and vegetation dynamics with respect to known human settlements for this period.

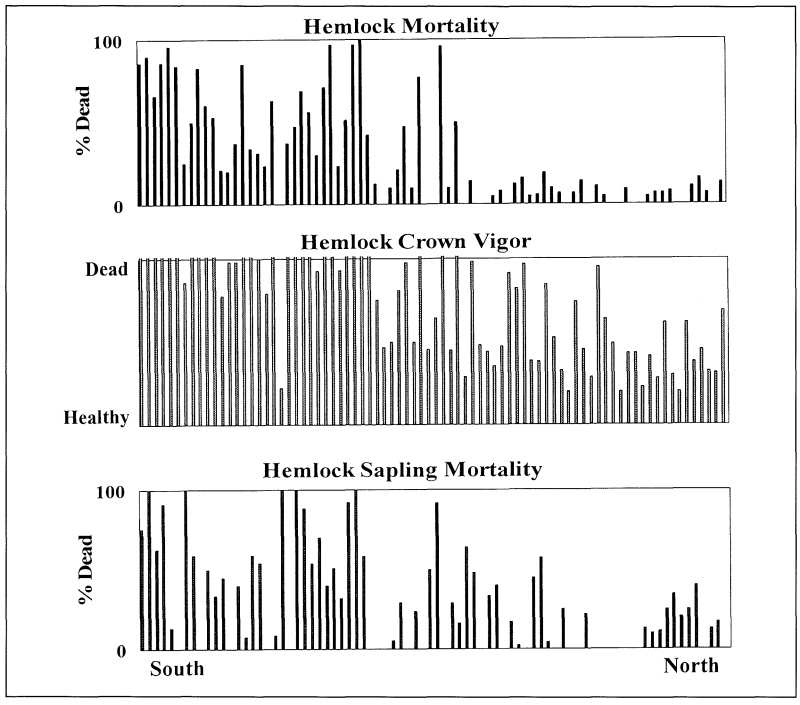
Forest Ecosystem Dynamics and Hemlock Woolly Adelgid Infestation

Since 1985, when the hemlock woolly adelgid (HWA), a small aphid-like insect from Japan, arrived in southern Connecticut it has been spreading through and devastating hemlock forests. In order to evaluate the ecological effects of this infestation David Orwig and David Foster initiated a regional study of adelgid movement and hemlock forest response.

Field sampling of hemlock stands mapped as part of our landscape-level study was completed during fall of 1998. We have now compiled information on stand composition and structure, presence of HWA,



David Orwig and Matt Kizlinski



Impact of the hemlock woolly adelgid on the forests of Connecticut. Data came from a transect extending from Long Island Sound (South) to Massachusetts (North) and depict a gradient of decreasing damage to the north where the adelgid is currently spreading.

degree of overstory and understory mortality, seedling densities, and site characteristics from 114 stands located along a north/south transect through central Connecticut. HWA presence was observed in nearly 90% of all stands visited and hemlock sapling and overstory trees experienced higher rates of mortality (20 to 100%) in the southern part of the state compared to the north (0 to 15%). The health of remaining trees exhibits a pattern similar to mortality, with healthier trees located in the northern part of the transect. The data suggest that site factors play a minor role in forest susceptibility to adelgid and that most infested stands will suffer heavy or complete mortality following infestation.

During the summer of 1999, Dave Orwig and summer student Saskia van de Gevel resampled permanent plots established in 1995 to examine the ongoing dynamics in declining hemlock forests that have been infested with HWA. Overstory and understory hemlock mortality has continued to increase 5 to 15% per year and the health and vigor of remaining trees has deteriorated in all stands, with the majority of trees containing less than 25% of their foliage. We have observed no sign of tree recovery on these sites and predict that all sampled trees will die within the next few years. A rapid recolonization of these forests with seedlings of black birch, red maple, and oak as well as herb species has continued to occur as hemlocks die.

In order to examine the effect of hemlock decline and mortality on the timing and extent of nitrogen cycling changes, Dave Orwig, Matt Kizlinski, Richard Cobb and summer student Steven Currie continued to measure the rates of nitrogen mineralization in Connecticut sites infested with HWA. Additional soil analyses, including pH, moisture, carbon to nitrogen ratios, texture, and total soil organic matter have been completed and we will quantify macronutrients such as Ca, Mg, P, and K. To complement this ongoing study, Richard and Steve have initiated a 2-year project examining the effect of HWA infestation on foliar decomposition rates, which we predict will increase with thinning hemlock canopies. To document the microenvironmental changes associated with thinning, organic-layer and mineral-layer soil temperatures are being recorded and hemispherical photographs are being examined to quantify increases in light reaching the understory.

Forest composition data from infested stands will be useful in predicting the species that will eventually replace hemlock. Currently, black birch, red oak, and red maple are present in the overstory of most stands and are starting to become established in the understory. Due to high hemlock sapling and seedling mortality and the short-term viability of hemlock seed, we predict a complete change in cover type in hemlock stands from hemlock to hardwood-dominated forests across most of southern New England.

We observed hemlock being cut on over 20% of the 114 stands visited in central Connecticut confirming that logging is increasing in frequency as a

management option in infested stands. However, we do not know how cutting infested hemlock stands will affect regeneration composition or ecosystem processes. Therefore, Matt Kizlinski has initiated a research project for his MFS degree to examine the effect of hemlock logging on revegetation and ecosystem processes. This study will complement ongoing research efforts in uncut stands.

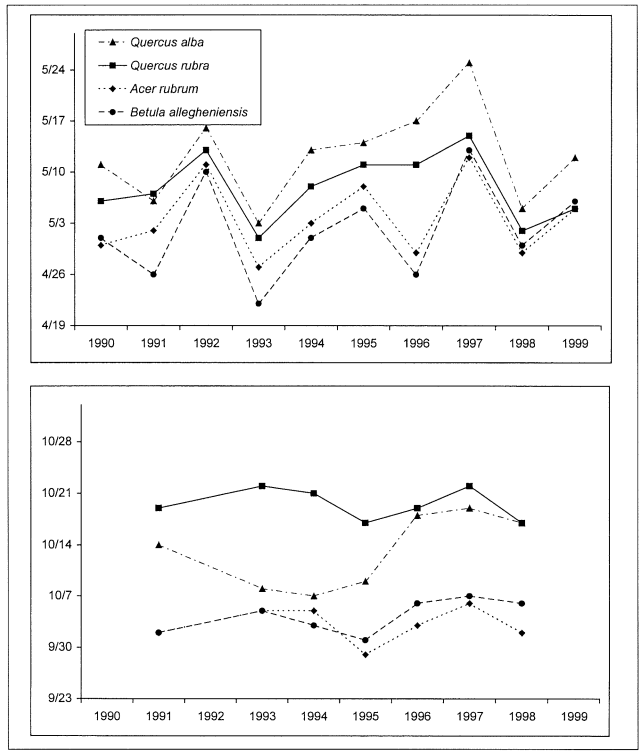
Phenology Studies

Phenology, the study of the relationship between climate and biological activity, has received renewed interest due, at least in part, to its potential to contribute to our understanding of global climate change. Long-term phenological data provide records of biosphere responses to climate change and local plant observations can be used to calibrate broad-scale satellite data and track mass energy transfers between the atmosphere and biosphere. Carbon exchange studies at Harvard Forest have shown that growing season length, especially the timing of leafout in the spring when days are long, water is available, and leaves are fresh, is an important factor in determining the amount of carbon stored by the forest in a given year. Moreover, in temperate regions, leafout and evapotranspiration influence meteorological phenomena such as cloud development and structure.

In 1990, John O'Keefe began a phenological study of native woody plants on the Prospect Hill tract. Many people have assisted with the collection and compilation of these data including Susan Johnson who joined us in May and is developing a computer database of our observations. Our study encompasses two to five individuals of 33 woody species (18 tree species and 15 shrub species) located within 1.5 km of Shaler Hall and within .5–1.5 km of the eddy-flux (EMS) tower, which measures carbon exchange between the atmosphere and the forest. Where it is possible individuals within a species represent different habitats and size classes.

Our spring observations, done at three to six day intervals from April through June, include bud development and leafout, leaf development, flowering, and fruit development. Our weekly fall observations include percent leaf coloration and percent leaf fall.

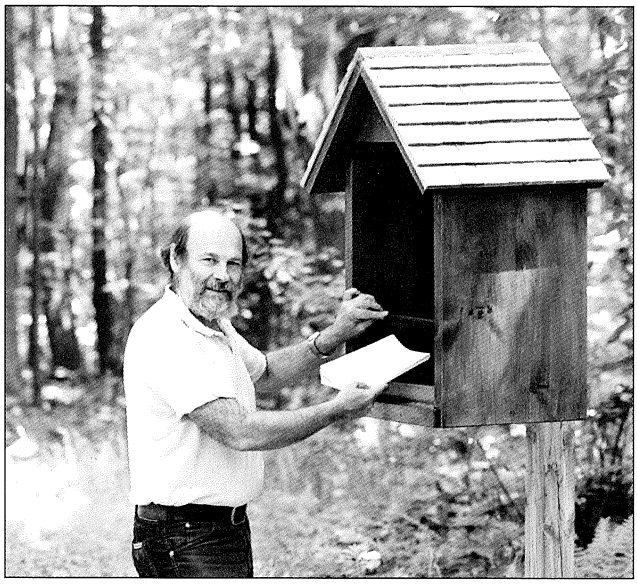
The major factors affecting the timing of leafout are the cumulative heat sum, or growing degree days, above a threshold temperature (often 5°C) after an initial cold treatment, and day length. There has been considerable variation in the timing of leafout from



Estimated dates of leafout (50% bud break) *(upper)* and peak fall color *(lower)* calculated as percent coloration multiplied by percent leaves remaining for four common tree species *(Acer rubrum, Betula alleghaniensis, Quercus alba, and Q. rubra)*. Fall data were not collected in 1990 and insufficient data were collected in fall 1992 to estimate leaf color dates.

year to year. Individual species range from 2 to 3.5 weeks between earliest and latest leafout, with 1991, 1993 and 1998 being early years and 1992 and 1997 being late years. Individuals within a species are fairly consistent in the timing of leafout. Years are not always consistently early or late, but may start early and end late or vice versa, depending upon weather conditions during the development period. There has been much less variability in the year to year timing of leaf fall, generally five to ten days difference from earliest to latest. This variability emphasizes the importance of long-term data sets for studying ecological phenomena and points out the increasing value of this data set as each additional year is incorporated

We are collaborating with Dr. Mark Schwartz, at the University of Wisconsin, who is developing a model to relate remotely sensed images of spring "green up" across North America to actual phenological events on the ground. Mark is using atmospheric data from the EMS tower to connect phenological events and climate. To further calibrate these observa-



John O'Keefe

tions we have planted cloned lilacs which have been distributed to scores of sites across eastern North America and we have helped develop a phenological observation protocol for use at the rapidly growing number of eddy-flux tower sites across the continent. Further information abut these studies is available at: www.uwm.edu/~mds/markph.html

Mice and Songbirds: Vertical Distributions and Predator-Prey Interactions in Oak Forests

Cathy Langtimm and Rebecca Field continue examining songbirds and white-footed mice, focussing on the possibility that mice are important predators on bird eggs.

White-footed mice *(Peromyscus leucopus)*, are ubiquitous in New England forests and are known to have both positive and negative effects on plants and animals. On the positive side they eat a variety of insects and have been identified as a major player in gypsy moth cycles as they feed on moth pupae. They also eat seeds and can either reduce regeneration of plant species by consuming the seed or assist with regeneration through lost stores of acorns and seeds that they cache for winter use. On the negative side ticks, which transmit Lyme disease to humans, initially become infected with the bacteria by feeding on infected mice.

A little studied aspect of the mice is their climbing behavior. Cathy Langtimm continued her work on the climbing activity of this species with the help of students Delia Santiago and Ana Laborde. They live-trapped small mammals on the ground, in shrubs, and in the crowns of canopy oak trees at two sites. Despite differences in population densities between this year and last and differences in habitat characteristics between sites, they confirmed that mice regularly occur in the canopy at least 40 feet above the forest floor. They also verified a seasonal pattern in climbing activity. There is a pronounced peak in the proportion of captures in shrubs and trees in July through September, with reduced activity in spring and fall. Increasing numbers of insects, fruit and seeds on plants of the understory and canopy in summer may induce mice to climb.

Estimates of acorn abundance at both trapping sites continued in a collaborative study with John O'Keefe. Last year's estimates successfully predicted an increase in mouse population numbers from the previous year, while this years estimates were lower and led to an expectation of lower mouse densities in the coming year due to the importance of acorns in supporting mice over winter.

Predation is the primary cause of nest failure for many open-nesting forest bird species, and understanding factors influencing nest predation is important for conservation of forest birds. Much of the research on nest predation has been limited to ground or shrub levels. Few studies have examined predation rates at bird nests above 2–3 m and the importance of mice as nest predators is largely unknown. In 1997, in parallel with Cathy's study of the vertical ecology of *P. leucopus,* Becky Field began to examine vertical nest predation in mixed oak forests, and to evaluate the role of mice as potential predators of those nests. Sites on the Harvard Forest and Quabbin reservation are being studied.

In 1997 thirty-five species of forest songbirds were

Cathy Langtimm and summer student Ana Laborde

identified on the study plots, 25 of which are probable breeders. In the artificial nest experiment 72 nests were made of small wicker baskets with two eggs in each, a commercially available zebra finch *(Poephila guttata)* egg and a plasticine egg of similar size, shape, and color. Potential nest predators were identified by impressions of tooth, claw, or bill marks left on the eggs. The nests were placed at sites on the ground, in shrubs, in the low subcanopy (mean height of 7.4 m), and in higher subcanopy (mean height 11.3 m). Access was gained to the higher nest sites using standard single-rope climbing methods.

Overall nest predation was 67.2%. Nest predation was lowest in Tom Swamp (56.3%), compared to Prospect Hill (68.8%) and the Quabbin site (76.6%). Ground, shrub, and low subcanopy predation were similar (63.1%, 69.0%, and 66.7% respectively), but there was more predation in the high subcanopy (83.3%); small sample sizes from the first year of data make it difficult to draw firm conclusions about differences in nest predation rates. Dental marks in the plasticine eggs indicated that small mammals were at the highest nests, up to 11.9 m. For the 1999 nesting season, the number of trees with subcanopy nests were doubled.

Carbon Exchange in Old-growth Hemlock Forests

Julian Hadley continued to develop a carbon exchange model for old-growth hemlock forests. This model will: provide new information about carbon exchange by this distinctive forest type; add to information gathered at the eddy-flux measurement tower; assist in understanding the total effect of northeastern U.S. forests on the global carbon cycle; provide a baseline estimate for carbon exchange by a healthy hemlock stand under various weather conditions; more accurately predict the effects of climate change on regional carbon balance; and provide a baseline against which the effects of the hemlock woolly adelgid can be measured.

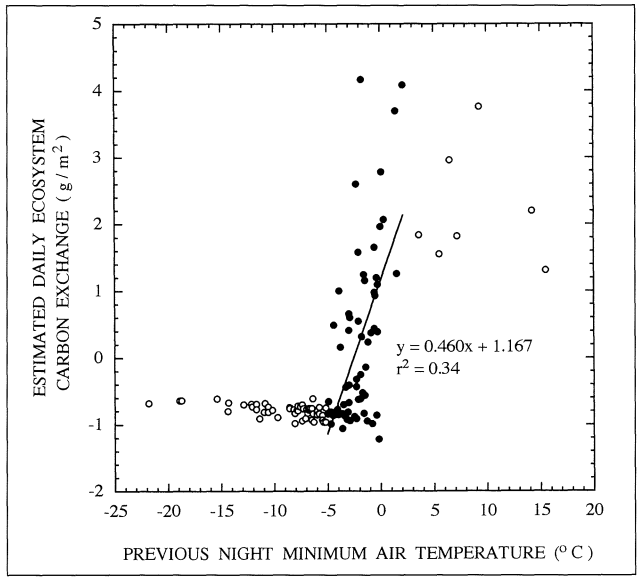
Major advances during this year were the development of an improved model to predict CO_2 release by soil and roots, and a model for respiration during seed cone development. The new model for soil CO_2 release takes into account both soil temperature and soil moisture, which are important during dry summers. An unusually large seed cone crop was produced in 1998, which had a major effect on the carbon balance of the hemlock stand. The seed cone respiration model produced one of the first estimates of the carbon cost of seed production in a forest tree species. Research assistant Claire Dacey and summer student Erica Goss made major contributions to the development of these new carbon exchange models.

In June 1999, summer student Sarah Cook began a study of carbon exchange by new foliage, which is initiated in May and takes a month or more to mature. In years without heavy seed production, the new foliage accounts for more than one third of all

Christine Muth and Sebastian Catovsky

foliage on hemlock trees. Therefore, the rate at which new foliage matures and reaches maximum photosynthesis is an important subject, which has heretofore not been studied.

The hemlock forest carbon exchange model estimates that from July 1997 through June 1998 the old-growth hemlock forest had near zero net carbon exchange. In summer, soil temperature was the most important environmental variable driving the model. Soil temperature above about 12°C resulted in carbon loss from the hemlock forest ecosystem, with the rate of carbon loss increasing rapidly as soil temperature increased above 12°C. In spring and fall, minimum daily air temperature was most important. Minimum air temperatures above –2°C allowed increasing amounts of carbon uptake, but after nights of –5°C or colder, there was a slight carbon loss from the ecosystem. These characteristics of the hemlock forest mean that rising summer temperature will lead to a net release of carbon to the atmosphere. This release will be enhanced by heavy seed production by hemlock trees. In contrast, mild spring and fall temperatures, especially at night, will allow more carbon storage.



Previous night minimum air temperature versus daily estimated hemlock forest carbon exchange from December 1997 through March 1998. Filled symbols are for minimum air temperatures of –5 to 2°C, for which the regression line was plotted. Positive numbers indicate carbon storage in the forest, negative numbers are for carbon released to the atmosphere.

How and Why do Leaves Turn Color?

A spectacular feature of New England forests is the production of brilliant red foliage during the autumn. Common knowledge has it that such color is due to the unmasking of anthocyanin pigments from chlorophyll degradation. David Lee, Bullard Fellow from Florida International University, collaborated with Missy Holbrook, professor of biology in OEB, and graduate student Taylor Field from OEB in documenting the dynamics of pigment change in species at the Forest, and in testing the potential functional significance of anthocyanin production during senescence. Of 89 taxa (in 31 families) examined, a surprisingly high 70% produced anthocyanin late in senescence. In an analysis of pigments of 9 red-leafed taxa, anthocyanin was produced only after 80% of chlorophyll had been degraded. Taylor examined the relationship of pigment composition to fluorescence in leaves of red-osier dogwood, showing clearly that anthocyanin plays a significant protective role. It was concluded that anthocyanin has a protective function during autumn leaf senescence, most likely in improving the recycling of nitrogen during leaf senescence.

Thus, leaves turn red by producing new pigments and these pigments may help to protect mechanisms in the leaves that improve their nutrient efficiency.

Tropical Plant Biology

Barry Tomlinson spent the academic year 1998–1999 on sabbatical, using the opportunity to travel extensively, conduct field research and work with colleagues at other institutions. His travels included a brief visit to New Zealand to collect material of southern conifers, fieldwork in Queensland, Australia, and Hawaii, and visits to Florida, Singapore and the United Kingdom.

For the fall and early part of the Spring, Barry was McBryde Visiting Professor at the National Tropical Botanical Garden, Kauai, Hawaii working on a broad diversity of tropical plants in the Garden's collection. The groups studied included cycads, Podocarpaceae, *Gnetum,* and the genus *Joinvillea,* which apparently shares a common ancestor with the grasses. In a study of mangroves, the mechanism of seedling establishment, long controversial, was elucidated. Barry also worked as mentor to a student studying fruit development in palms, and provided assistance with other research on the reproductive biology of rare and endangered tropical plants.

In his travels Barry was on a committee to evaluate the palm collection at the Montgomery Botanical Center,

Miami, Florida, and was an External Examiner for the Department of Biology, National Institute of Education, Nanyang Technological University, Singapore.

Harvard Forest LTER Program

The Harvard Forest is one of twenty-two sites in the Long Term Ecological Research (LTER) program sponsored by the National Science Foundation (NSF). Each site addresses questions of a long-term nature; collectively the sites undertake comparative studies across ecosystems. Representatives from each site and NSF meet twice annually to collaborate. The central theme of the Harvard Forest LTER is interpretation of the structure, composition, and function of forest ecosystems in terms of their history of natural and human disturbance and environmental change. This research is being addressed at the stand, landscape, sub-region (Central Massachusetts), and regional (New England) scale.

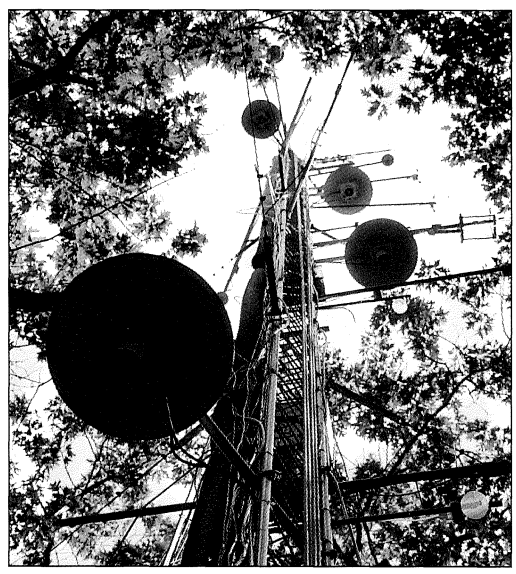
The research involves soil scientists, atmospheric chemists, and ecologists studying physiological, population, community and ecosystem processes. Investigators represent the Department of Biology (F. Bazzaz), Earth and Planetary Sciences (S. Wofsy), and Harvard Forest (D. Foster, G. Motzkin, D. Orwig) at Harvard University as well as the Ecosystems Center-MBL, Woods Hole (J. Melillo, K. Nadelhoffer, P. Steudler), the Complex Systems Research Center at the University of New Hampshire (J. Aber), Rutgers University (E. Russell), and the University of Massachusetts (M. Mulholland). Emery Boose is the LTER Data Manager. The research is organized to maximize the interactions among scientists from different disciplines. Four major scientific approaches include: (1) retrospective studies of historical changes in the environment and ecosystems; (2) long-term measurements of forest structure and function; (3) experimental manipulations; and (4) synthesis and modeling.

The LTER science group meets approximately monthly. The annual Harvard Forest Ecology Symposium is held to present current research. Abstracts from this meeting are published annually. The program for the 1999 symposium is shown on the following page.

National Institute for Global Environmental Change (NIGEC)

Harvard University is the Northeastern Regional Center for the NIGEC program sponsored by the Department of Energy. NIGEC research seeks to improve the understanding of mechanisms of global environmental change, to develop experimental and observational programs that enhance the understanding of ecosystem and regional scale processes contributing to global change, and to provide educational opportunities in global environmental change research. The Division of Applied Sciences administers the Center and large portions of the field studies are conducted at the Harvard Forest. Researchers include many of the LTER scientists in addition to faculty from the University of New Hampshire (P. Crill, R. Harris, R. Talbot), State University of New York (D. Fitzjarrald, K. Moore) and Woods Hole Research Center (E. Davidson), University of Virginia (J. Moody), University of California (S. Trumbore), U.S. Geological Survey (E. Sundquist) and Harvard Forest (J. Hadley).

Fifty-year log decomposition study

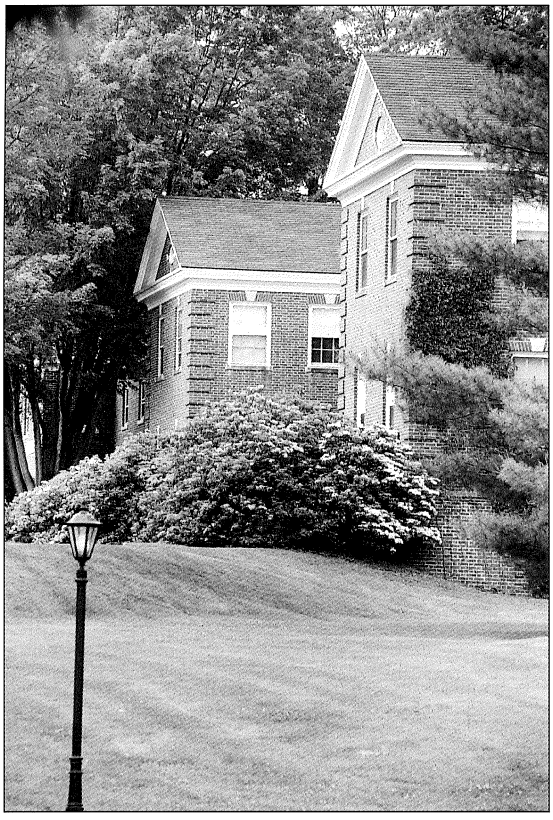


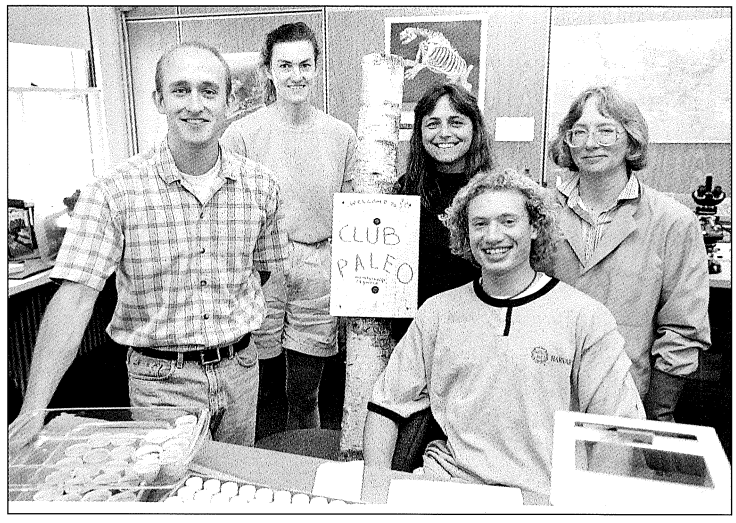
Measuring atmosphere-biosphere exchange

Harvard Forest Ecology Symposium 1999

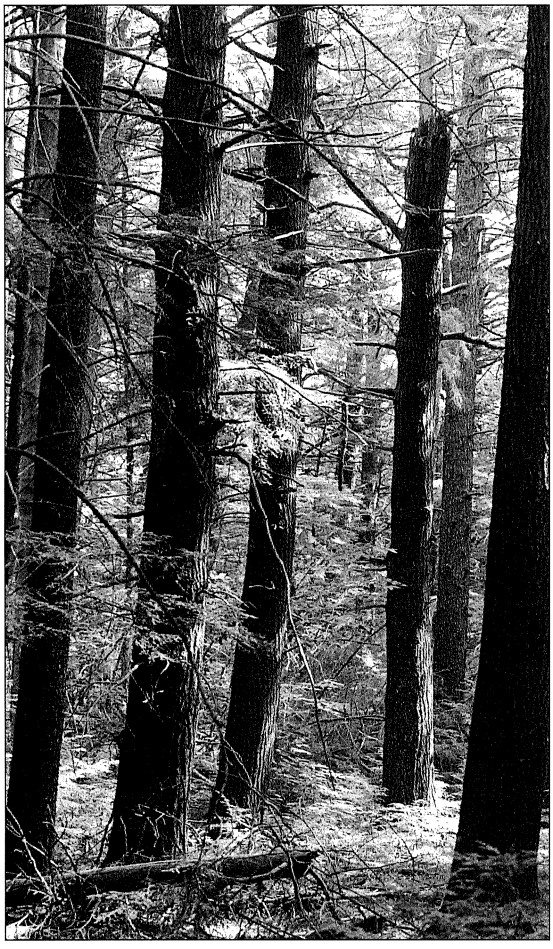
Titles of Abstracts and Presentations

Aitkenhead, J. and *W. McDowell.* Litter Manipulation: Effects on Soil Solution Chemistry
Barford, C., E. Pyle, K. Bagstad, J. Munger and S. Wofsy. Net Ecosystem Exchange of Carbon -1998
Barker-Plotkin, A., D. Foster, E. Boose and *S. Cooper-Ellis.* Hurricane Disturbance and Silviculture
Barker-Plotkin, A., D. Orwig and *D. Foster.* Long-term Dynamics and Disturbance in a Hemlock Woodlot
Barnes, D. and *S. Wofsy.* Evaluation of Greenhouse and Ozone-Depleting Gases in Rural New England
Berntson, G., J. Aber and *A. Magill.* Canopy Physiology in Nitrogen-saturated Forests
Berntson, G. and *J. Aber.* The Importance of Fast Nitrate Immobilization in N Saturated Forest Soils
Boose, E., K. Chamberlin and *D. Foster.* Landscape and Regional Impacts of New England Hurricanes
Bowden, R., C. McClaugherty, T. Sipe and *the CRUI Student Team.* Land-use Legacies and Forests
Bürgi, M. and *E. Russell.* Post-settlement Vegetation and Land-use History in the Northeastern USA
Burk, J. Archive and Record Management at the Harvard Forest 1998-99
Catovsky, S. and *F. Bazzaz.* Environmental Conditions and Patterns of Seedling Regeneration
Catovsky, S., N. Holbrook and *F. Bazzaz.* Seasonal Patterns of Whole-tree Transpiration
Clayden, S., D. Foster, D. Orwig, N. Drake and *E. Doughty.* Long-term Vegetation Dynamics
Dria, K., D. Dail, J. Chorover, E. Davidson and *P. Hatcher.* Solid State ^{13}C NMR Studies of Forest Soils
Eberhardt, R., D. Foster, G. Motzkin and *B. Hall.* Vegetation Dynamics on Outer Cape Cod
Field, R.. Nest Predation in Eastern Oak Forest: Variations with Nest Height
Fitzjarrald, D., K. Moore, R. Sakai, J. Freedman, O. Acevedo, and *R. Staebler.* Forest-Atmosphere Exchange
Foster, D., G. Motzkin and *B. Hall.* Historical Influences on the Landscape of Martha's Vineyard
Foster, D., G. Motzkin, B. Hall, T. Parshall, and *R. Eberhardt.* An Historical Approach for the Conservation of Species, Communities and Landscapes: Application to Cape Cod, The Islands and Long Island
Francis, D., D. Foster, E. Doughty, J. Garrett and *N. Drake.* Land-use impacts on Lake Ecosystems
Francis, D., A. Wolfe and *E. Doughty.* Long-term Climate Dynamics in the Canadian Arctic
Frolking, S. Modeling the Ecosystem Carbon Balance of Northeastern Forests with a Focus on the Soil
Fuller, J., D. Francis, D. Foster, B. Wolfe. Human Disturbance in the Context of Environmental Change
Hadley, J. and *E. Goss.* Effect of Seed Production on C Balance of an Old-growth Hemlock Stand
Horii, C., J. Munger, S. Wofsy and *M. Zahniser.* Atmospheric Reactive Nitrogen Budgets
Kern, R., D. Foster and *G. Motzkin.* Life History Analysis of Plant Distribution in Relation to Land-use
Kern, R., G. Motzkin and *D. Foster.* The Effects of Land-use History on Tree and Shrub Distributions
Langtimm, C. Vertical Distributions of Small Mammals in Oak Forest
Lawrence, D. and *D. Foster.* Nutrient Cycling During Recovery of Dry Tropical Forests in Yucatan
Lee, D., J. O'Keefe, T. Feild and *N. Holbrook.* Why Do Leaves Turn Red in the Autumn?
Lin, J., S. Trumbore and *S. Wofsy.* Quantification of Fossil CO_2 Using Radiocarbon
Magill, A., J. Aber, W. McDowell and *R. Minocha.* Indicators of Nitrogen Saturation in Two Forest Stands
Micks, P., K. Nadelhoffer, J. Canary, R. Boone, and *K. May.* Forest Soil Respiration Response to Litter Inputs
Minocha, R., J. Aber, S. Long, A. Magill, and *W. McDowell.* Effects of Chronic N on Polyamine Metabolism
Muth, C. and *F. Bazzaz.* Canopy Asymmetry in a Deciduous Forest
Nadelhoffer, K. and *W. Currie.* Long-term Responses of Forest C Balances to N Deposition
Newkirk, K., C. Catricala, J. Melillo and *P. Steudler.* Soil Warming — 1998 Update
O'Keefe, J. Woody Species Phenology, Prospect Hill Tract, Harvard Forest — 1998
O'Keefe, J. and *T. Cooper.* Regeneration Following Clearcutting of Red Pine Overstory — Year 9
Orwig, D., M. Kizlinski and *D. Foster.* Ecosystem Analyses of Hemlock Woolly Adelgid Outbreaks
Orwig, D., D. Foster and *J. O'Keefe.* Vegetation Dynamics of Old-growth Forests on Wachusett Mt
Orwig, D., D. Mausel and *D. Foster.* Landscape-Level Analyses of Hemlock Woolly Adelgid Outbreaks
Perez-Salicrup, D. and *D. Foster.* Forest Recovery Following Slash and Burn Agriculture in the Yucatan
Russell, E. Five Hundred Years of Vegetation Change in the Northeastern United States
Savage, K. and *E. Davidson.* Modeling Soil Respiration rates in a Temperate Forest Soil
Trumbore, S., J. Gaudinski, E. Davidson. Drainage Control of Soil C Storage, Accumulation, and Turnover
Zwieniecki, M., L. Hutyra and *N. Holbrook.* Dynamic Changes in Petiole Specific Conductivity



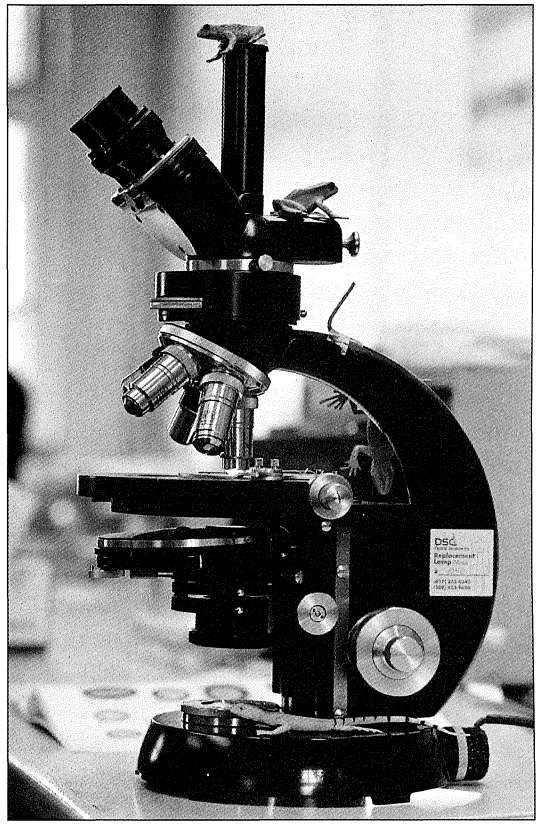


Tim Parshall, Susan Clayden, Donna Francis,
Jason Murnock and Elaine Doughty



Steve Currie and Richard Cobb

Brian Hall and Emery Boose



BULLARD FELLOWS

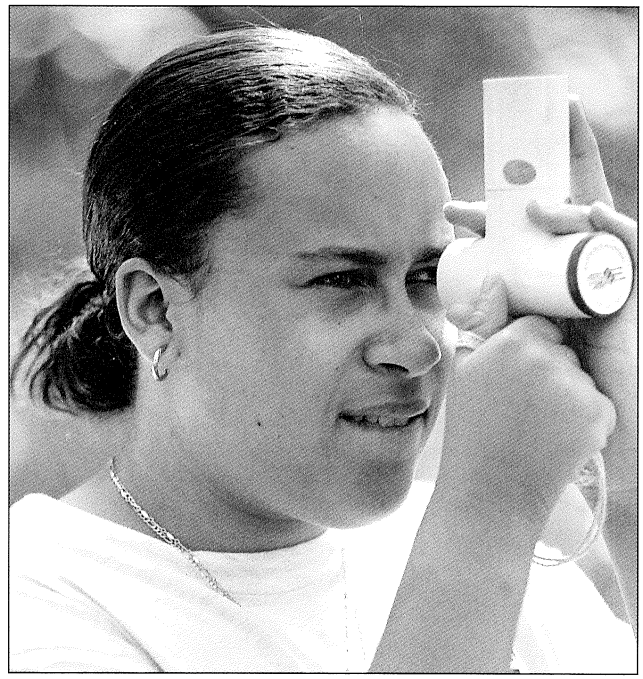
Alexander Golub (Moscow School of Economics) spent the year collaborating with Jeffrey Vincent at the Harvard Institute for International Development. Alexander was researching and developing models of carbon sequestration in Russia and other parts of the world. Results from his efforts were presented at numerous symposia including a Kennedy School of Government workshop "Estimating the costs of biological carbon sequestration."

Neil Enright (University of Melbourne, Australia) completed five papers, presented a research seminar on serotiny, ran a laboratory group meeting about his New Caledonian conifer ecology project, and assisted David Orwig in organizing a special laboratory group meeting on multivariate methods for vegetation analysis. He presented invited lectures at McGill University, York University (Toronto), the University of Northern Illinois, and Fairchild Tropical Gardens. Ideas and methodologies developed through collaboration with Harvard Forest researchers will be used in a new project on the impacts of mining, timber harvesting, grazing and fire on the box-ironbark ecosystem of central Victoria, southeastern Australia. This will represent a new direction for his research, and one that is at present only poorly developed in Australia.

Roger Kitching (Griffith University, Australia) made extensive use of the library facilities at Harvard while working on the book *Container Habitats and Foodwebs* (1999, Cambridge University Press), a manual on biodiversity survey techniques for studies in Australia and Southeast Asia, and papers on arthropod surveys in Australia. New research on aquatic origins in insects was begun in collaboration with Dr. Brian Farrell of the MCZ. Roger delivered seminars at the Harvard Forest, in OEB, at the University of Tennessee, at Queen's University, to the Cambridge Entomological Society, and was an invited speaker at a DIWPA symposium in Japan.

Dr. Takashi Kohyama (Hokkaido University, Japan), joined Peter Ashton's and Fakhri Bazzaz's research groups in Cambridge while frequenting seminars at the Forest and Princeton University. He presented a paper in Japan at the symposium commemorating Professor Otto Solbrig's International Prize in Biology for 1998. Dr. Kohyama centered his research on the functional understanding of species-rich mixed dipterocarp forests of south-east Asia and analyzed data from two permanent forest plots established in West Kalimantan.

In addition to pursuing his interests in anthocyanin, Dr. David Lee (Florida International University) wrote up two articles on Malaysian rainforest tree seedlings and gave seminars at the Forest and in Cambridge.



Tana Collazo

Edythe Ellin

Summer Reseach Assistants

Top: Steve Currie, Ana Laborde, Barbara Munoz, Andy Finley, Tana Collazo, Jason Eaton

Bottom: Shira Bell, Jason Murnock, Emily Huhn, Saskia van de Gevel, Sarah Cook, Henry Schumacher

EDUCATIONAL ACTIVITIES

Henry and David Foster taught Using History to Inform Policy: Lessons from the Massachusetts Forest (ENR 225: Topics in Natural Resource Policy) to eighteen students in the Kennedy School of Government. In addition to normal class activities, the course hosted nineteen outside lecturers, undertook an extensive fieldtrip to the Harvard Forest and Quabbin Reservoir watershed, and hosted a special colloquium of national forest history experts.

David Foster served as undergraduate thesis advisor for Mary Berlik, a concentrator in Environmental Studies and Public Policy, who produced a thesis The Illusion of Conservation: An Environmental Argument for Forest Cutting in Massachusetts. David served on the graduate committees of Sebastian Catovsky and Christine Muth (Organismic and Evolutionary Biology), Anna Hersperger (Graduate School of Design), and Julie Richburg (University of Massachusetts).

Rob Eberhardt, MFS student, pursued initial field studies on Cape Cod and developed a comprehensive research proposal to investigate vegetation patterns on the Cape Cod National Seashore. Rob took two courses in Cambridge: "Conservation, Ecology and Environment" in the History of Science Department, and "Introduction to Probability" in the Statistics Department. In March Rob was awarded a NSF Graduate Research Fellowship.

Summer Research Program

The Harvard Forest Summer Student Research program, coordinated by Chris Kruegler and Edythe Ellin and assisted by Thia Cooper, attracted a diverse group of students to receive training in scientific investigations, and experience in ecological research. Students work closely with faculty and scientists, and many conduct their own independent studies. The program includes weekly seminars from resident and visiting scientists, discussions on career issues in science (e.g. career decisions, ethics in science), and field trips on soils, land-use history, and plant identification. An annual field trip is made to the Institute of Ecosystem Studies (Millbrook, NY) to participate in a Forum on Jobs in Ecology. At the Annual Summer Student Research Symposium students present major results of their work.

Summer Students 1999

Shira Bell	Oregon State University
Raoul Blackman	University of Edinburgh
Tana Collazo	Virginia Polytechnic
Sarah Cook	Hamilton College
Autumn Bryant	Oregon State University
Steven Currie	State Univ. of New York
Jason Eaton	University of Idaho
Andrew Finley	Pennsylvania State
Emily Huhn	Bowdoin College
Ana Laborde	Harvard University
Erin Largay	Connecticut College
Barbara Munoz	Oberlin College
Jason Murnock	Gannon University
David Patterson	Tufts University
Max Ranall	Reed College
Larissa Read	University of Virginia
Henry Schumacher	Tulane University
Kelly Seary	Radcliffe College
Jessica Sisco	Univ. California, Berkeley
Saskia van de Gevel	Pennsylvania State Univ.
Karen Vitkay	University of Michigan
Sadhna Vora	Radcliffe College
Heidi Wasson	University of Maine
Georgine Yorkey	Swarthmore College

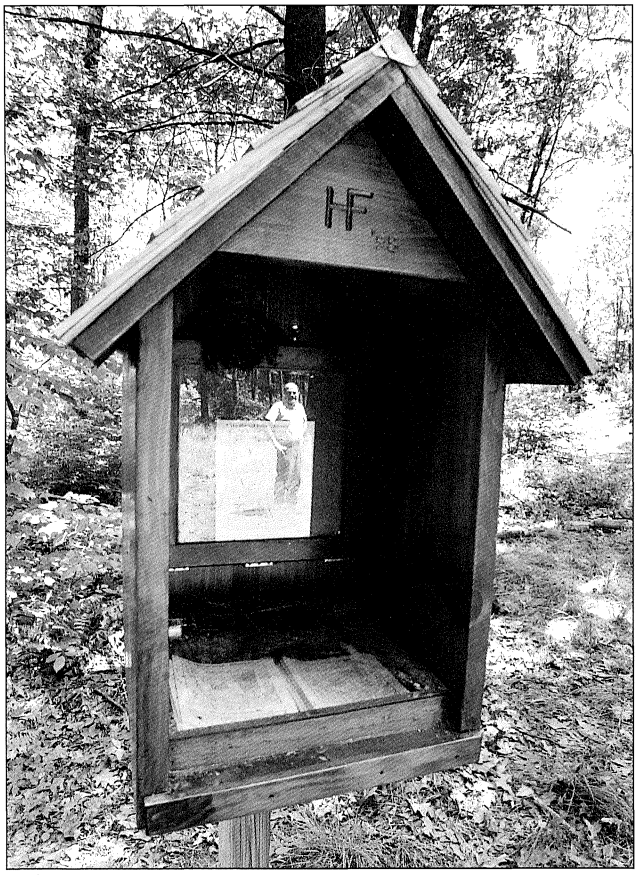
ACTIVITIES OF THE FISHER MUSEUM

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 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.

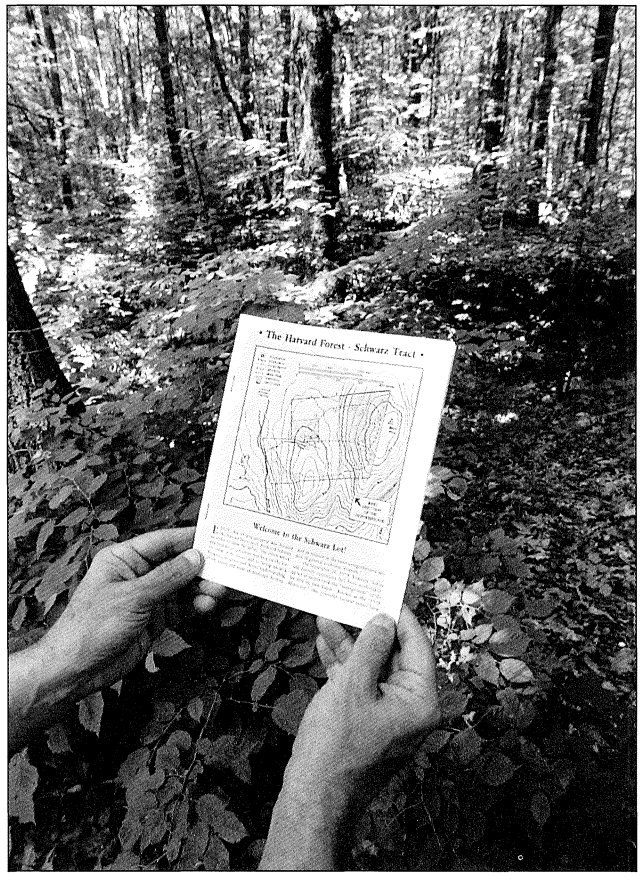
Thanks to the ongoing efforts of our enthusiastic and committed volunteers the Museum enjoyed yet another very successful weekend schedule, welcoming well over a thousand visitors on Saturday and Sunday afternoons, May through October. In November, the Eighth Annual Volunteer Recognition Dinner provided an opportunity to review the season's activities while sharing good food and companionship. Mary Ann Walker received special recognition for her enthusiastic work as volunteer coordinator and for being one of the most active volunteers, an honor she shared with Bob Lane and Martha Siccardi. On a more solemn note, over the winter the volunteer group was deeply saddened by the deaths of Rosalie Fiske and Polly Riley, both volunteers since the group's inception.

In the spring the woods crew began construction of a seven hundred-foot long boardwalk through the Black Gum Swamp that will become a part of the Black Gum Trail. The boardwalk is constructed from larch grown on the Forest and will provide visitors with an outstanding opportunity for close-up examination and interpretation of this fascinating habitat while minimizing environmental impacts.

In October the Museum hosted a meeting of the Ameriflux Network, a group of scientists at sites throughout North America who are investigating carbon exchange between the atmosphere and biosphere using the eddy-correlation method, pioneered by Steve Wofsy and his group at the EMS tower at Harvard Forest. In early November, the Museum hosted more than a hundred scientists and policy makers at the fifth annual Eastern Old-Growth Conference. After a day and a half of presentations on the latest research on old-growth forests throughout the east, the group toured the old-growth areas at Wachusett Mountain that are being studied by Harvard Forest researchers.



New trail map shelter on Schwarz Tract



Interpretive trail guide on Schwarz Tract

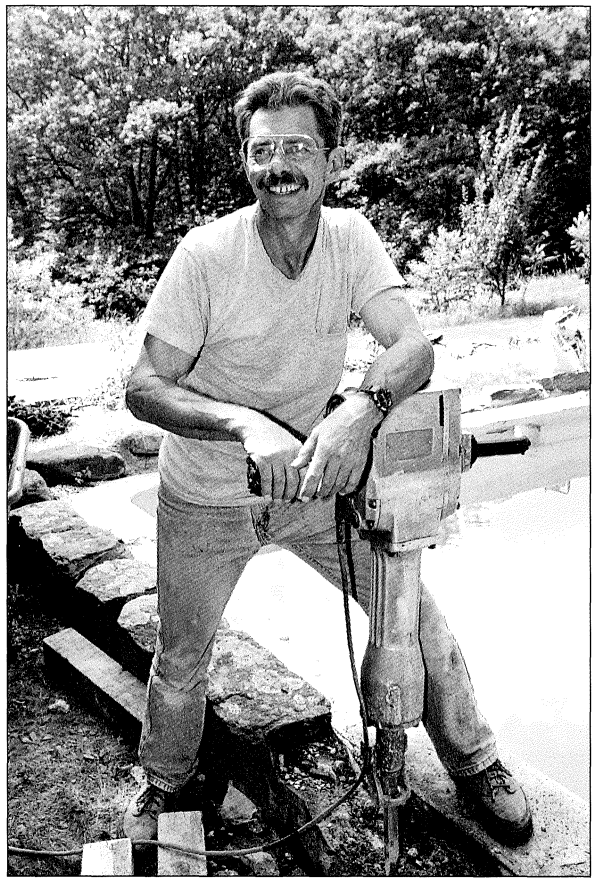
Meetings, Conferences, Seminars

Other meetings at Harvard Forest included the monthly meetings of the Athol Bird and Nature Club, eight weekly meetings of the Butterfly Institute – a program to teach identification of our local butterflies, the Massachusetts Department of Environmental Protection Soils Workshop, Massachusetts Department of Environmental Management OSHA Workshop, National Park Service Rivers and Trails Program, North Quabbin Regional Landscape Partnership, Massachusetts Extension Service Coverts Project, Massachusetts Extension Service Wetlands Workshop, Millers River Watershed Basin Team, Mount Grace Land Conservation Trust, New England Chapter of the Wildlife Society, CommonWealth/ Common Ground, Massachusetts Association of Social Studies Teachers, and meetings of staff from the U.S. Forest Service and Massachusetts Department of Environmental Management.

Speakers in the Harvard Forest Seminar series included:

Xiaoming Zou	University of Puerto Rico
Gerhard Glatzel	Institute of Forest, Ecology, Vienna, Austria
Janine Bolliger	Swiss Institute for Forest and Landscape Research
Deborah Lawrence	Harvard Forest
David Lee	Florida International Univ.
Brian Donahue	Brandeis University
Neal Enright	University of Melbourne
Bill Leak	U.S. Forest Service
Steve Anderson	Forest History Society
Paul Barten	UMASS, Amherst
Matthew Kelty	UMASS, Amherst
Takashi Kohyama	HokkaidoUniversity
Roger Kitching	Griffith University
Jim Fownes	UMASS, Amherst
Ruth Kern	Harvard Forest
Peter Del Tredici	Arnold Arboretum
Bill Patterson	UMASS, Amherst
Robin Harrington	UMASS, Amherst
Renate Gebauer	Keene State College
Dave Kittredge	UMASS, Amherst
Campbell Webb	Harvard University
Robert Seymour	University of Maine
Alexander Golub	School of Economics, Moscow
Anna Hersperger	Harvard University
Kevin McGarigal	UMASS, Amherst
Paul Schaberg	U.S. Forest Service
Janneke HilleRisLambers	Duke University
Timothy Parshall	Harvard Forest

Boardwalk along the Black Gum Swamp nature and interpretive trail



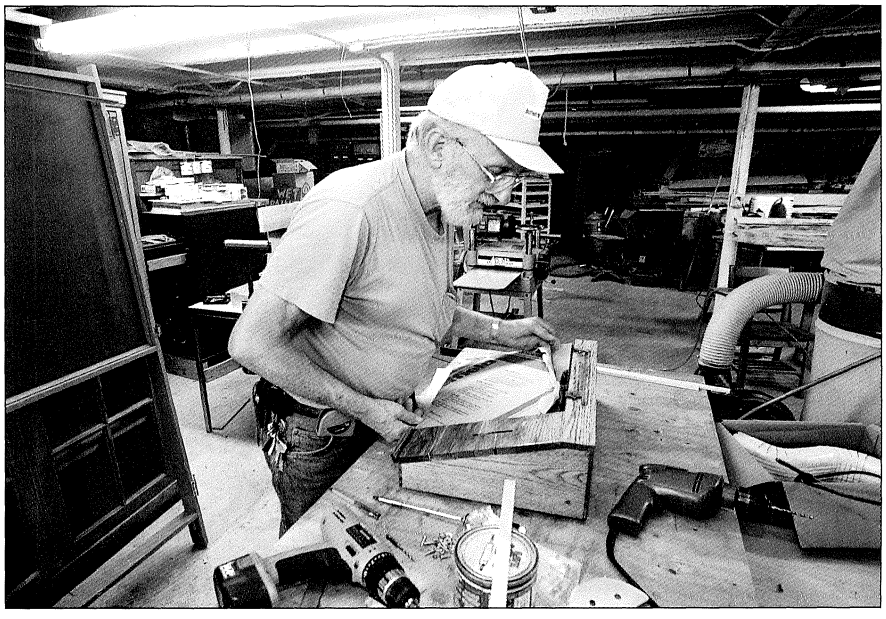
Woody Cole

FOREST MANAGEMENT/MAINTENANCE

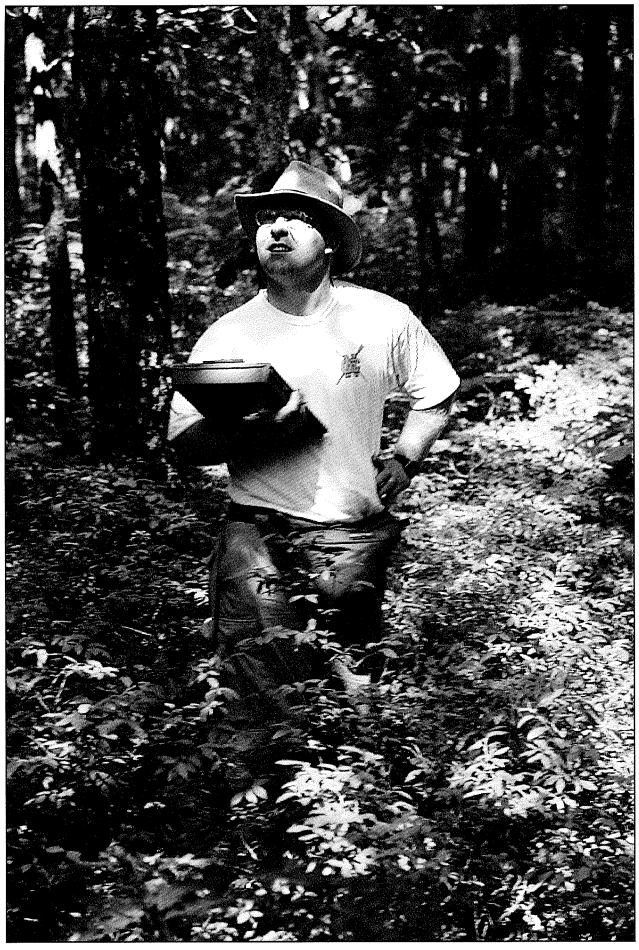
In early winter work began to upgrade existing laboratory and office space in Shaler Hall. What started as an effort to remove asbestos floor tile developed into a major effort and a completely new look in the basement. Improved lighting and new walls and floors created an inviting expansive area. Redesigned space in the computer lab enhanced the use of our new computer facilities as well.

Other building maintenance activities include the de-leading and restoration of the Benson House and conversion of many of the bedrooms in Shaler Hall into offices. With support from the Massachusetts Department of Environmental Management work is nearing completion on an elevated walkway that will give visitors to the Black Gum Swamp access to a 700-foot walk through part of the swamp. Forestry activities have focused on the west side of Harvard Pond where we have cut over 90,000 board feet of softwood and 280 cords of firewood in the process of converting conifer plantations to natural stands. We have received numerous favorable comments regarding our cutting activity at the pond and have created new walking trails and vistas for visitors to explore.

Pete Spooner



Don Hesselton



Jon Harrod

John Burk and Alexis Calvi

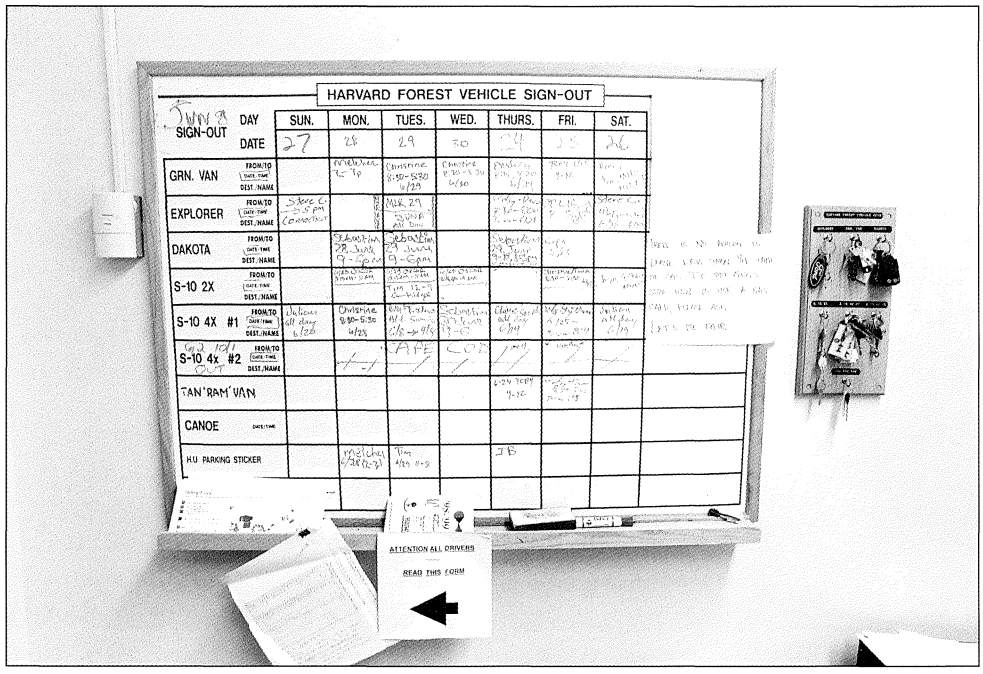
Harvard Forest Archives

In its second year of operation, over 500 visitors used the new archives. In addition to its value for Forest and outside researchers, the facility continued to be an important resource for the local community, as area scholars, farmers, foresters, surveyors, landowners, and planners used items for various projects. John Burk completed the development of the soil and sample archive, which currently holds over 200 boxes of soil, litter, and tree core specimens, all of which were inventoried, assigned an accession number, and entered into a database. Major new additions to the document archive include the Central Massachusetts vegetation survey, historical wildlife notes, 100 maps from the Massachusetts 1830 series, a library of over 160 antique books, and a Massachusetts state information section consisting of historical forest and soil surveys, census and tax data, and archaeological information. During this process, a large number of surplus reprints and notes were sorted and donated to several institutions, including the Hugh Raup collection at the University of Alberta, the Black Rock Forest Consortium, the University of Southern Maine, and the Arnold Arboretum. The Harvard Forest reprint collection of over 8,000 holdings was inventoried, and the database updated.

Computers

Major renovations to our computer facilities were begun this year with support from NSF, FAS, and the Forest. Additional work area was created in the Computer Lab and in the Shaler Hall Vault, which now serves as a computer and telecommunications "nerve center" for the Forest. Five new computers were installed in the Lab and fourteen new computers were installed for individual staff, while two new laser printers (one color) are now accessible over the network. The new computers run Windows NT, which provides improved support for networking and security.

The following improvements are planned for the coming year, using NSF grant funds: (1) the network connection from the Forest to Harvard University will be upgraded from 56 kbps to T1 (1.5 mbps), (2) the Fisher and Raup buildings will be wired for data and connected via optical fiber to Shaler Hall, (3) a high speed network connection will be established between the EMS Tower and Shaler Hall, and (4) NT servers will be installed to enhance connectivity and to host the Harvard Forest web page.



ACTIVITIES OF HARVARD FOREST STAFF

Audrey Barker Plotkin coordinated the 1998–1999 seminar series, and presented a talk at the North American Forest Ecology Workshop in Orono, Maine. Emery Boose completed 10 years of service at the Harvard Forest and he gave talks on hurricane research at the Ecological Society of America (ESA) meeting in Baltimore and at the Ecosystems Center in Woods Hole. Emery attended the LTER Data Managers meeting and the LTER Technology Committee meeting. He served on a NSF panel for the new KDI (Knowledge and Distributed Intelligence) program, and serves on the LTER Climate Committee and as the Forest's Information Technology contact for FAS.

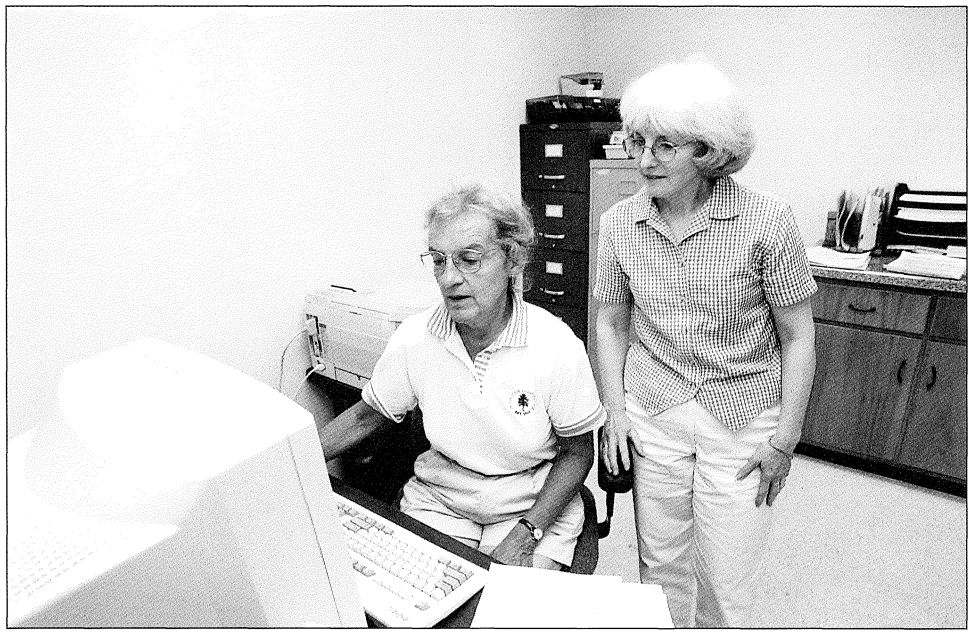
John Burk presented a paper on water supply management in Massachusetts to the Water Supply Citizen's Advisory Committee, and led two discussion groups at Harvard Forest on the subject. He volunteered for Cathy Langtimm and Becky Field on their project, and had a series of nature photographs published in the *Athol Daily News.* He met with curators at the Arnold Arboretum and Harvard University Preservation Center and researched historical proprietor records at the New Hampshire State library.

David Foster gave talks at the Vineyard Conservation Society in Martha's Vineyard, New England Botanical Club centennial symposium, Bennington College, and the keynote address at the symposium Sustainable Management of Hemlock Forests in Eastern North America at the University of New Hampshire. In conjunction with the publication of *Thoreau's Country* he gave talks at the Harvard University Natural History Museum and Bennington College, was interviewed on the radio shows "Here and Now" (WBUR), "The Connection" (WBUR), and "Walden's Pond" (WBAI), and wrote an op-ed piece for the *New York Times.* David completed his final year as a member of the Executive Committee of the Long Term Ecological Research program by participating in the National Advisory Board meeting in Albuquerque.

Donna Francis gave talks at the International Society of Limnology, Dublin, Ireland and Harvard Forest Summer series, and led a Spring Hike at Pisgah State Park, NH. She supervised summer student Eron Drew of the University of Wisconsin.

Julian Hadley presented portions of his hemlock carbon balance model at ESA and at a conference on forest canopy biology at the Selby Botanical Garden in Florida. He supervised Erica Goss and Raoul Blackman, a student at the University of Edinburgh. Raoul is working on a model of wood respiration in hemlock trees to present as his undergraduate thesis. Brian Hall took over the duties of official weather observer and data collector, an activity that the Harvard Forest has maintained for the National Weather Service for over 75 years.

Ruth Kern hosted four scientists from the Taiwan Long-Term Ecological Network. The two professors and two graduate students participated in the Taiwan–U.S. LTER exchange and were hosts to Ruth and 12 other U.S. scientists in June 1998. Ruth also



Dottie Smith and Linda Hampson

presented a research poster at ESA, and gave talks at Gustavus Adolphus College, Wheaton College, Eastern Illinois University and Humboldt State University. Ruth supervised summer students Clara Paynter from Colorado College and Joel Dunn from Evergreen State College. Matt Kizlinski presented a talk about HWA research at the tenth annual USDA Interagency Forum on Gypsy Moth and Other Forest Pests.

Glenn Motzkin and John O'Keefe led educational programs for students from Clark University, a field trip for forestry professionals on shrub identification and wildlife use, and a trip for Division of Fisheries and Wildlife staff on soils interpretation. Both attended the Old-growth Conference at Harvard Forest. Glenn presented a poster based on his work with Paul Wilson, David Foster, and Art Allen at ESA. Glenn served on the senior thesis committee of Danielle Piraino from Wesleyan University, who investigated the long-term history of Atlantic white cedar wetlands. Dave Orwig presented overviews of his research on hemlock woolly adelgid at ESA, the annual meetings of the Quabbin Science and Technical Advisory Committee, the Massachusetts Audubon Society Sanctuary Directors, the New England Society of American Foresters, the Northeast Forest Pest Council, and at the Sustainable Management of Hemlock Ecosystems in Eastern North America Symposium. Dave also spoke and led a field trip at the Eastern Old Growth Forest Symposium and participated in a panel discussion on old-growth forests with David Foster at a meeting of the Massachusetts Association of Professional Foresters.

John O'Keefe presented a poster at ESA based on Nicole Lavalle's summer work at Harvard Forest and her senior honors thesis at Mt. Holyoke College. He represented the Harvard Forest LTER at the spring LTER Coordinating Committee Meeting in Puerto Rico. He is working with the staff of Fruitlands Museums in Harvard, Massachusetts to develop interpretive materials and management plans for the more than 200 acres of historic landscape at their site. John presented talks on the history of Massachusetts forests to the Massachusetts Forestry Association, University of Massachusetts in Amherst and Boston and the Kennedy School of Government. John was a judge at the Mahar High School Science Fair in March, and serves on the boards of the Millers River Watershed Council and Mount Grace Land Conservation Trust, where he is currently the President, and on steering committees for the North Quabbin Regional Landscape Partnership and Massachusetts Project Learning Tree. He also serves on the Quabbin Science and Technical Advisory Committee and Secretary Durand's Advisory Group on Environmental Education.

Barry Tomlinson presented papers at the Royal Botanic Gardens, Kew, Linnean Society of London, the Royal Botanic Gardens, and University of New South Wales, Australia.

VISITING RESEARCH SCIENTISTS AT THE HARVARD FOREST 1998-99

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

John Aber	University of New Hampshire
Jeff Amthor	Lawrence Livermore Lab
Peter Bakwin	Harvard University
Carol Barford	Harvard University
Diana Barnes	Harvard University
Gutram Bauer	Harvard University
David Baum	Harvard University
Fakhri Bazzaz	Harvard University
Dennis Balocchi	NOAA/ARL/Oak Ridge, TN
Glenn Berntson	University of New Hampshire
K. Boering	Harvard Unversity
Richard Bowden	Allegheny College
Frank Bowles	Ecosystems Center – MBL
Sean Buirrows	University of Wisconsin
Sebastian Catovsky	Harvard University
Chris Catricala	Ecosystems Center – MBL
Chaur-Fong Chen	Oregon State University
Alan Coleman	Harvard University
Patrick Crill	University of New Hampshire
William Currie	Virginia Polytechnic Univ.
Peter Czepiel	Harvard University
David B. Dail	University of Georgia
Eric Davidson	Woods Hole Research Center
Peter Del Tredici	Arnold Arboretum
Michael Donoghue	Harvard University
Marty Downs	Ecosystems Center – MBL
Todd Drummey	Ecosystems Center – MBL
Bob Evans	U.S.D.A. Forest Service
Rebecca Field	University of Massachusetts
David Fizjarrald	SUNY, Albany
Son-Maio Fan	Harvard University
Richard Forman	Harvard University
Steven Frolking	University of New Hampshire
Julia Gaudinski	UCLA, Irvine
Robert Harriss	University of New Hampshire
Joseph Hendricks	University of New Hampshire
Michelle Holbrook	Harvard University
David Hollinger	U.S. Dept. of Agriculture
Lauren Interness	Woods Hole Research Ctr.
Daniel Jacob	Harvard University
Doug Karpa	Harvard University
Chris Kerfoot	Ecosystems Center – MBL
Melissa Kibler	Gustavus Adolphus College
David Kittredge	University of Massachuetts
Otto Klemm	Univ. of New Hampshire
Cathy Langtimm	U.S.G.S.; Holy Cross College
Barry Lefer	Univ. of New Hampshire
Manuel Lerdau	SUNY, Stony Brook
Alison Magill	Univ. of New Hampshire
Lynn Margulis	University of Massachsetts
Mary Martin	Univ. of New Hampshire
Charles McClaugherty	Mount Union College
Jerry Melillo	Ecosystems Center – MBL
Jennie Moody	University of Virginia
Kathleen Moore	SUNY, Albany
Mitch Mulholland	Univesity of Massachusetts
J. William Munger	Harvard University
Christine Muth	Harvard University
Knute Nadelhoffer	Ecosystems Center – MBL
Kathy Newkirk	Ecosystems Center – MBL
Jeffrey Parker	Smithsonian Environ. Res.
Marc Potosnak	Harvard University
Ronald Prinn	M.I.T.
Elizabeth Pyle	Harvard University
Michael Rogers	GA Institute of Technology
Kathleen Savage	Woods Hole Research Ctr.
Brian Shelley	College of the Holy Cross
Timothy Sipe	Franklin & Marshall College
Paul Steudler	Ecosystems Center – MBL
Britt Stephens	Harvard University
Eric Sundquist	U.S. Geological Survey
Robert Talbot	Univ. of New Hampshire
Matt Thompson	Harvard University
Susan Trumbore	University of California
Paul Wilson	Univ. California, Northridge
Greg Winston	U.S. Geological Survey

Publications

Berlik, M. 1999. The illusion of conservation: An environmental argument for forest cutting in Massachusetts. Honors Thesis. Harvard College.

Bürgii, M. Habitat alterations caused by Long-term changes in forest use in northeastern Switzerland. In: K. J. Kirby and C. Watkins (Eds.), *The Ecological History of European Forests.* CAB International.

Compton, J. E., R. D. Boone, G. Motzkin, and D. R. Foster. 1998. Soil carbon and nitrogen in a pine-oak sand plain in central Massachusetts: Role of vegetation and land-use history. *Oecologia* 116:536–542.

Crampton, A. B., O. Stutter, K. J. Kirby and R. C. Welch. 1998. Changes in the composition of Monks Wood National Nature Reserve Cambridgeshire, 1964–1996. *Arboricultural Journal* 22: 229–245.

Foster, D. R. 1999. *Thoreau's Country: Journey Through a Transformed Landscape.* Harvard University Press. Cambridge.

Foster, D.R. 1999. Forests the Way They Used To Be. *New York Times.* June 26. C–4.

Foster, D. R. and G. Motzkin. 1999. Historical influences on the landscape of Martha's Vineyard: Perspectives on the management of the Manuel F. Correllus State Forest. Harvard Forest Paper No. 23.

Foster, D. R., M. Fluet and E. R. Boose. 1999. Human or natural disturbance: landscape-scale dynamics of the tropical forests of Puerto Rico. *Ecological Applications* 9: 555–572.

Foster, D. R., D. Knight and J. Franklin. 1998. Landscape patterns and legacies resulting from large infrequent forest disturbance. *Ecosystems* 1:497–510.

Foster, C. H. W. and D. R. Foster. 1999. Thinking in Forest Time: A vision for the Massachusetts Forest. Harvard Forest Paper No. 24.

Foster, D. R., J. Aber, J. Melillo, R. D. Bowden and Fakhri Bazzaz. 1998. Forest response to natural disturbance versus human-induced stresses. *Arnoldia* 58: 35–40.

Fuller, J. L. 1998. Ecological impact of the mid-holocene hemlock decline in southern Ontario, Canada. *Ecology* 79: 2337–2351.

Harrod, J. C., P. S. White, and M. E. Harmon. 1998. Changes in xeric forests in western Great Smoky Mountains National Park, 1936–1995. *Castanea* 63:346–360.

Harrod, J. C. and R. D. White. 1999. Age structure and radial growth in xeric pine-oak forests in western Great Smoky Mountains National Park. *Journal of the Torrey Botanical Society* 126:139–146.

Mabry, C. and T. Korsgren. 1998. A permanent plot study of vegetation and vegetation-site factors fifty-three years following disturbance in central New England, *U.S.A. Ecoscience* 5: 232–240.

Motzkin, G. and D. R. Foster. 1998. How land use determines vegetation: evidence from a New England sandplain. *Arnoldia* 58: 32–34.

Motzkin, G., W. A. Patterson III, and D. R. Foster. 1999. A historical perspective on pitch pine-scrub oak communities in the Connecticut Valley of Massachusetts. *Ecosystems* 3: 255–273.

O'Keefe, J. and D. R. Foster. 1998. An ecological history of Massachusetts forests. *Arnoldia* 58: 2–31.

Orwig, D. A. and D. R. Foster. 1998. Ecosystem response to an imported pathogen: the hemlock woolly adelgid. *Arnoldia* 58: 41–44.

Orwig, D. A. and M. D. Abrams. 1999. Impacts of early selective logging on the dendroecology of an old-growth, bottomland hemlock-white pine-northern hardwood forest on the Allegheny Plateau. *Journal of the Torrey Botanical Society* 126: 234–244.

Tomlinson, P. B. and T. Takaso. 1998. Hydrodynamics of pollen capture in conifers. Pp. 265–275 In: S. J. Owens and P. J. Rudall (Eds.), *Reproductive Biology in Systematics, Conservation and Economic Botany.* Royal Botanic Gardens, Kew, UK.

Zwieniecki, M. A. and N. M. Holbrook. 1998. Diurnal variation in xylem hydraulic conductivity in white ash (*Fraxinus americana* L.), red maple (*Acer rubrum* L.) and red spruce (*Picea rubens* Sarg.). *Plant, Cell and Environment* 21: 1173–1180.

Grants Received

R. Eberhardt. Ecological Studies on Cape Cod. National Science Foundation Graduate Research Fellowship $75,000.

D. R. Foster, J. L. Fuller, and D. R. Francis. Human disturbance in the context of environmental change: Re-evaluating the long-term dynamics of New England Forests. National Science Foundation. $370,000.

D. R. Foster and E. Boose. Enhancing data management and telecommunications at the Harvard Forest. National Science Foundation. $102,090.

D. R. Foster and E. Boose. Enhancing network connectivity at Harvard Forest. National Science Foundation. $232,834.

D. R. Foster and G. Motzkin. An Integrated Historical Approach for the Conservation of Species, Communities, and Landscapes: Application to Cape Cod, the Islands, and Long Island. The Nature Conservancy. $161,755.

D. R. Foster. Research Experience for Undergraduates (REU) Program in Forest Ecology at Harvard Forest. National Science Foundation. $102,090.

D. R. Foster, D. Lawrence, and D. Perez-Salicrup. Regional Historical Analysis of Forest Ecosystem Response to Disturbance: Comparative Study of Temperate and Tropical Landscapes. National Science Foundation. $37,200.

D. R. Foster and J. O'Keefe. Schoolyard LTER for the Harvard Forest. National Science Foundation. $30,000.

D. R. Foster and J. Hadley. A Physiological Model of CO2 Exchange by Hemlock Forests in Central New England. NIGEC – Department of Energy. $112,533.

D. R. Foster. A Temporal Framework for Interpreting Temperate and Tropical Forest Ecosystem Structure and Function. A. W. Mellon Foundation. $624,000.

D. Francis. Long-term climate dynamics in the Canadian Arctic: paleoclimate reconstructions using fossil midges. National Science Foundation International Fellowship. $20,000

ACKNOWLEDGMENT OF SUPPORT

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Friends of the Harvard Forest
Anonymous Donor
Commonwealth of Massachusetts
  Department of Environmental Management
  Division of Fisheries and Wildlife
  Ecological Restoration Program and
    Massachusetts Biodiversity Initiative
  Massachusetts Natural Heritage and
    Endangered Species Program
Andrew W. Mellon Foundation
National Aeronautics and Space Administration
National Geographic Society
National Science Foundation
  Biological Field Stations and Marine
    Laboratories
  Ecosystem Studies
  International Programs
  Long-term Studies
  Ecology Program
  Research Experience for Undergraduates
The Family of Richard Thornton Fisher
USDA, Competitive Research Grants, Forestry
Department of Energy – NIGEC

Gifts

The Harvard Forest Library would like to recognize the following donations of books and journals. Jim Baird of Petersham added bound volumes of *Bird Banding* and *Journal of Field Ornithology* to other bird journal collections that he has provided in the past. Five years of Soil Science Society of America journals were added to our shelves by Kathy Newkirk. Keith Kirby's gift of his book *The Ecological History of European Forests* was also a welcome addition. David Lee donated a 1998 edition of *Plant Biology* and David Orwig added to our Archives a copy of *History of Barre—Windows into the Past* published by the Barre Historical Commission.

David R. Foster
Director

Petersham, Massachusetts
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