THE HARVARD FOREST 1995-96
Harvard University

ANNUAL REPORT OF THE HARVARD FOREST 1995-1996

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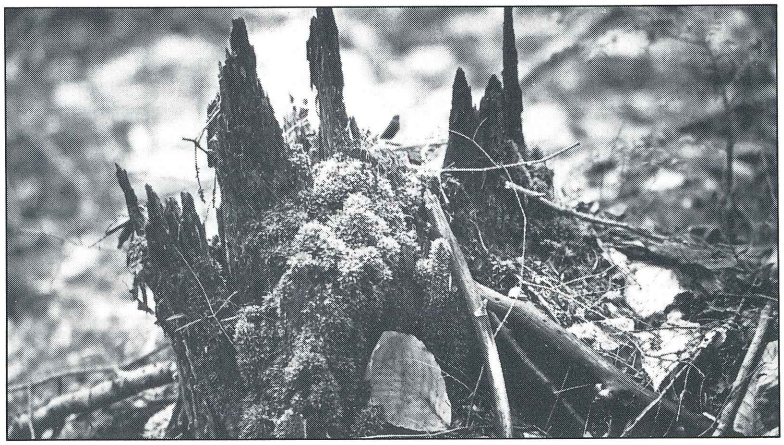
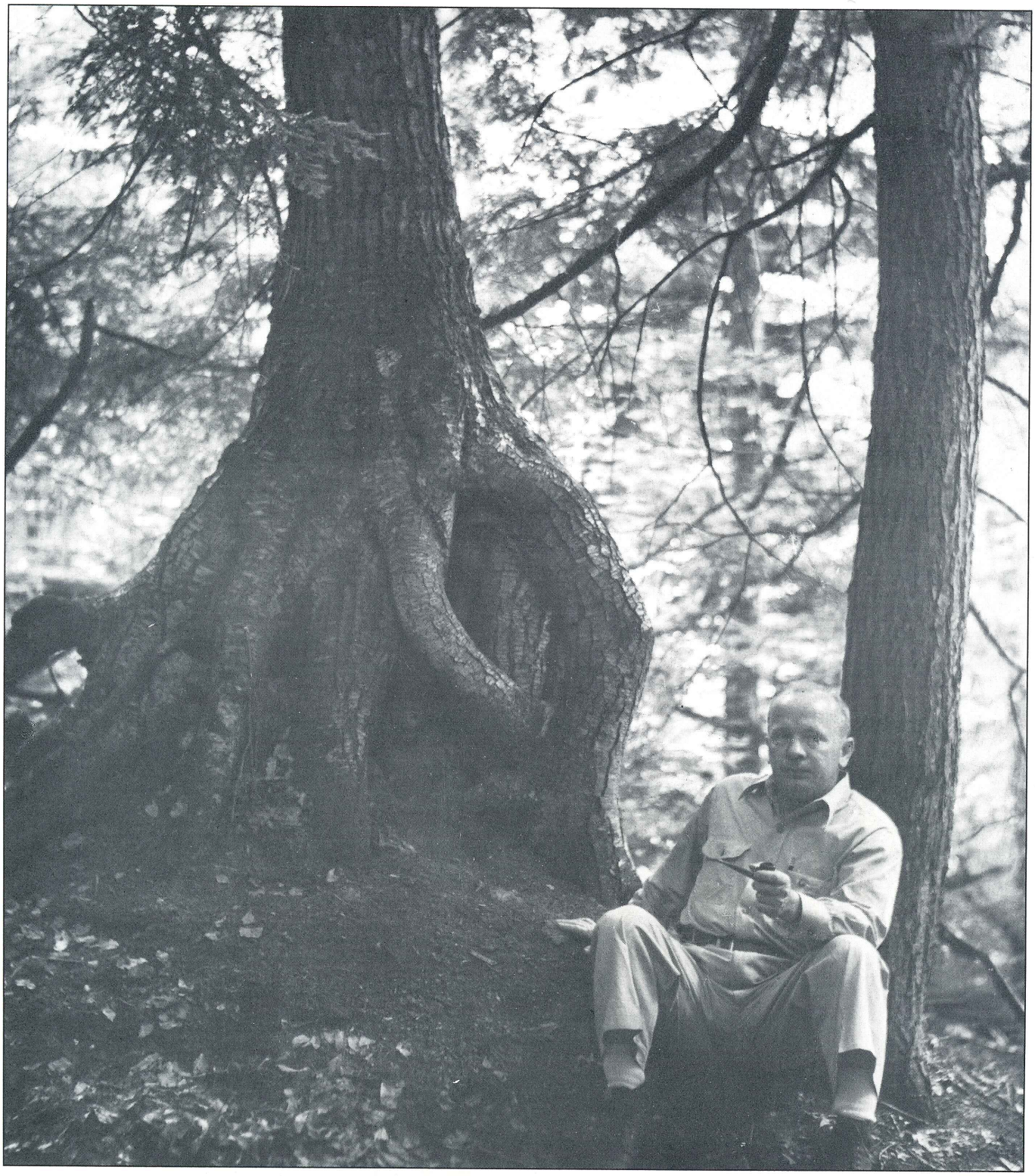


Photography by Laura Wulf



HUGH MILLER RAUP

1901 - 1995

"The ideas of community structure and the expression of dominance, that of biological succession, and finally that of climax, are based largely upon the assumption of long-term stability in the physical habitat. Remove this assumption and the entire theoretical structure becomes a shambles. This is precisely what has happened in all of the [following] cases. In the tundra the disturbing agent is frost in the soil. In the New England forests, both before and after the coming of Europeans, it has been fire and windthrow. In Central America man himself seems to have been a singularly efficient disturber of the tropical forests for at least two millennia. In the little shore communities at Lake Athabaska merely a periodic high water level in the lake was sufficient to undo the theoretical sequence of events. In all of these cases the disturbances have been so frequent and so generally effective that the expected "climaxes," or "equilibria," recede into pure speculation. Natural successions either do not occur at all or are limited to such incomplete fragments as can be accomplished between upheavals.

When I look at these botanical phenomena naively, without benefit of preconceived notions derived from projections of theory beyond the facts, I see the plant community as a relatively loose aggregation of species, visible in the landscape, but not precisely definable in space or time."

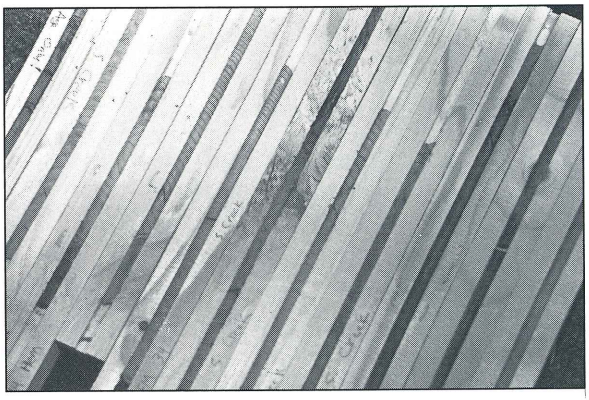
Hugh M. Raup. 1957. Vegetational adjustment to the instability of the site.

Hugh Raup's interests and knowledge were immense. Noted as an ecologist, conservationist and botanist, he preferred to be called a geographer. Hugh's life spanned the entire history of the Harvard Forest and his research activity, inspirational leadership and wise guidance to students and staff directed it on a course that naturally linked its early history with its current direction. His Harvard University appointments at the Arnold Arboretum (1932-38), as professor in biology (1938-1967), and as Director of the Harvard Forest (1946-1967) led him to develop, conduct and supervise seminal studies on land-use history at the Arboretum, Harvard Forest, and the Black Rock Forest in Cornwall on Hudson and on post-glacial climate, vegetation history, and disturbance processes in New England forests. Fascinated by the interplay of geological, hydrological and biological forces in boreal, subarctic and Arctic ecosystems he initiated a course of research that led him, his wife Lucy, family and colleagues on a life-long series of trips to northern Canada, Alaska and Greenland. His remarkable ability to identify the common ecological characteristics among tropical, temperate and northern ecosystems enabled him to critique existing theories on succession and climax communities and to make lasting contributions to the fields of forestry, ecology, conservation and geography. His paper interpreting the history of John Sanderson's farm at the Harvard Forest remains the most widely sought reprint at the Fisher Museum, continues to provide the inspiration for our interpretive tours, and generates ideas for research on the impact of land-use history on our modern forest ecosystems.

The photograph on the accompanying page provides a metaphor for Hugh Raup's role as a scientist and mentor. Taken in the old hemlock wood-lot adjacent to Harvard Pond, the picture includes a large overstory black birch propped up by roots on an old soil mound and Dr. Raup sitting against a smaller hemlock. Both trees were subsequently aged by Earl Stephens in his doctoral thesis work and the birch was shown to have established as a seedling on the root mound of a tree windthrown by a powerful storm. Hugh served as advisor on the study and subsequently cited the results as major evidence of the role of natural disturbance processes in maintaining the dynamics, diversity and productivity of New England forests. At the Harvard Forest, the legacy of research and education developed by Hugh Raup underlies and continues to inspire our new programs and current activity.

PERSONNEL AT THE HARVARD FOREST 1995-96

Arthur Allen	Research Assistant
Michael Binford	Associate
Emery Boose	Computer Scientist
Jeannette M. Bowlen	Accountant
Jeanne Boutelle	Custodial Assistant
David M. Bowman	Charles Bullard Fellow
Grace Brush	Charles Bullard Fellow
Kristen Chamberlin	Research Assistant
Susan L. Clayden	Research Assistant
Willard Cole	Woods Crew
Jana Compton	Research Associate
John F. Connolly	Charles Bullard Fellow
Sarah Cooper-Ellis	Research Assistant
Kathleen Donohue	Research Associate
Guy D'oyly Hughes	MFS Candidate
Elaine D. Doughty	Laboratory Assistant
Natalie Drake	Palynologist
John A. Edwards	Forest Manager
Barbara J. Flye	Librarian/Secretary
Charles H. W. Foster	Associate
David R. Foster	Director
Janice Fuller	Research Associate
Balachander Ganesan	Charles Bullard Fellow
David Godbold	Charles Bullard Fellow
Julian Hadley	Research Associate
Jeffrey D. Herrick	Research Assistant
Donald E. Hesselton	Woods Crew
Kenneth Holmberg	Research Assistant
Camilla Hughes	Visiting Scholar
David P. Janos	Charles Bullard Fellow
Dennis H. Knight	Charles Bullard Fellow
Joan Kraemer	Clerk Typist
Christopher Kruegler	Administrator
Oscar P. Lacwasan	Custodian
Richard A. Lent	Data Manager
Anita Lockesmith	Summer Cook
Jason McLachlan	Research Assistant
Patricia Micks	Research Assistant
Ellen G. Moriarty	Graphic Artist
Glenn Motzkin	Research Assistant
John F. O'Keefe	Museum Coordinator
David Orwig	Research Associate
Hugh M. Raup	Charles Bullard Fellow, *Emeritus*
Emily Russell	Visiting Scholar
Benjamin Slater	Research Assistant
Dorothy Recos-Smith	Secretary
Charles C. Spooner	Woods Crew
P. Barry Tomlinson	E. C. Jeffrey Professor of Biology
Robert B. Waide	Charles Bullard Fellow
Thompson Webb III	Charles Bullard Fellow
Alan S. White	Charles Bullard Fellow
John Wisnewski	Woods Crew
Steven C. Wofsy	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 central New England 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 a 90-acre 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. An additional nine houses provide accommodation for staff, visiting researchers, and students. Extensive records including long-term data sets, historical information, original field notes, maps and ground-based aerial photography 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, with the Director reporting to the Dean of FAS. The Harvard Forest administers the Graduate Program in Forestry that awards a Masters degree in Forest Science. Faculty at the Forest offer courses through the Department of Organismic and Evolutionary Biology (OEB), which awards the PhD degree, and through the Freshman Seminar Program. Close association is maintained with the Department of Earth and Planetary Sciences (EPS), Kennedy School of Government (KSG) 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 (Marine Biological Laboratory, 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 provides for an infusion of outside perspectives. Forest management and physical plant activities are undertaken by our three-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 University support, whereas research activities are conducted with grants primarily from the federal government. Major research support comes from the National Science Foundation, Department of Energy (National Institute for Global Environmental Change), the U.S. Department of Agriculture, 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 of Harvard Forest.

NEW STAFF

The research staff was greatly strengthened in the areas of paleoecology and geographic information systems during the past year with the additions of Dr. Janice Fuller, Susan Clayden and Ben Slater. Janice comes from Ireland via the University of Cambridge where she received her PhD in Botany and Susan recently completed her MS degree at the University of New Brunswick. Ben received a BA degree from Virginia Polytechnic and State University in 1995. All three individuals are working with David Foster on aspects of forest and landscape dynamics in central New England.

RESEARCH ACTIVITIES

Land-use History and Forest Ecosystem Dynamics

New England is highly varied physiographically, environmentally and biologically. However, despite substantial sub-regional variation, much of the area went through a similar, remarkable transformation as a result of European land use. From a nearly completely forested condition that supported relatively low Indian populations, the landscape was rapidly and extensively deforested by European settlers for agriculture, which peaked from the late 18th C through mid-19th C. As a consequence of industrialization and the development of productive Midwestern farmlands, the rural population declined markedly beginning in 1860. Farmland was abandoned on a broad-scale, and forests re-established naturally. Thus, in the span of 250 years, the region has changed from having been entirely forested to approximately 20-35% forested, and then again to 65-80% forested. Major changes in plant and animal abundance and distribution have accompanied these vegetation dynamics. Understanding these changes is essential for any study of modern ecological processes and for land-management and conservation planning.

For nearly 90 years Harvard Forest researchers have been documenting and interpreting the consequences of human history on forest ecosystems and land-use studies continue to form a core research program at the Forest. The current effort is strongly interdisciplinary and is evaluating land-use effects across regional cultural and environmental gradients. Geographically, studies are organized within a spatial hierarchy: region (1000 km) - all of New England and adjacent New York, New Jersey and Pennsylvania; sub-region (100 km) - Central Massachusetts from the Connecticut River Valley to the Boston Lowland; landscape (10 km) - the township of Petersham; stand (1 km) - intensive study sites in the Harvard Forest.

Paleoecological Studies

A number of basic questions drive the paleoecological studies that use the stratigraphic record of pollen and other fossils in lakes, wetlands and soils to reconstruct vegetation and environmental history at the regional, sub-regional, and stand scales. These questions include: What is the impact of New England land-use history of deforestation, agriculture, reforestation, logging and population growth on the composition and structure of the vegetation? At what rates does the vegetation and environment change as the type, intensity and scale of disturbance varies through time? To what extent have the forests that developed following agricultural abandonment come to resemble the original pre-European vegetation of New England?

Across New England and adjoining states, Emily Russell, in collaboration with D. Foster, J. Fuller, J. McLachlan and R. Lent, has been analyzing the results of pollen analysis of sediments from over 75 lakes to develop a regional picture of historical vegetation change. Initial maps of species abundances through time exhibit at least two major patterns of change from pre-colonial to modern times: (1) a major change in

Susan Clayden

species abundance with little change in the pattern of abundance; and (2) a pronounced change in both the magnitude and pattern of abundance. The first pattern is represented by hemlock and beech, which declined rather uniformly across the region, whereas the second pattern is followed by birch species, which increased by very different amounts in different parts of New England. In general, the modern samples are distinct from precolonial samples, suggesting that the modern forest vegetation has not recovered compositionally and that it has no analogues in the era before European land-use.

In central Massachusetts, Janice Fuller is coordinating the paleoecological research in collaboration with David Foster, Jason McLachlan, Mike Binford, Natalie Drake and Elaine Doughty, while David, Ben Slater and Glenn Motzkin are undertaking an analysis of historical changes across the same study area. Initial results of multivariate analyses by Janice indicate a marked change in forest composition after European colonization. However, reforestation following agricultural abandonment has not resulted in a return to the pre-European forest conditions despite the elapse of 100-150 years. Janice is currently analyzing the rates and geographic patterns of vegetation change across the transect of sites in central Massachusetts in order to interpret the factors responsible for these changes. The transect of sites crosses environmental and land-use gradients and during the next year the paleoecological analysis will be directly compared to those emerging from the historical studies in the same study area. In conjunction with this project Mitch Mulholland, Joannah Whitney, and Mary Ann Levine (UMASS) have been synthesizing the archaeological records for over 800 sites across central Massachusetts to obtain information on prehistorical human densities and cultures. The archaeological information will strengthen substantially the interpretation of pre-European fire history and vegetation dynamics.

At the community level Jason McLachlan worked with David and Fabian Menalled to investigate the post-settlement dynamics of four older-growth hemlock stands in the Harvard Forest that are among the least disturbed parts of the central Massachusetts landscape. To interpret stand history Jason has analyzed pollen in humus soils, studied the dendroecological (tree-ring) records of age and growth of trees in the stands, reviewed the stand histories in the Harvard Forest Archives and sampled the modern vegetation. Pollen records from humus accumulating at these sites suggests that the pre-European forest composition at each of these sites was distinctive and that no site contained the hemlock-dominated assemblage seen today. The complementary techniques of tree-ring analysis and stand-level pollen analysis reveal that the subsequent 300 years were punctuated by disturbances including logging, hurricane damage, fire and pathogens resulting in profound changes in stand structure and composition. Ultimately, these changes produced the modern forest dominated by large hemlocks whose stature and late-successional status mask the dynamic developmental history of these stands.

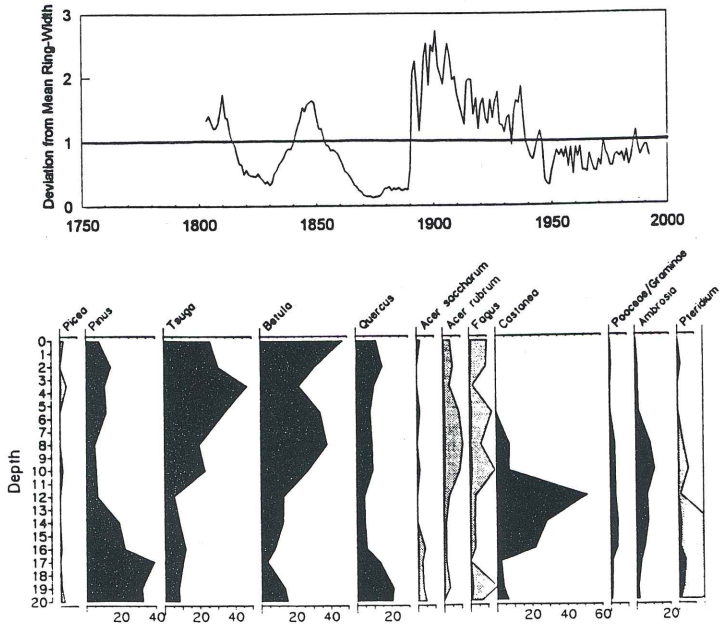


Figure 1. Forest dynamics of an old-growth stand comprised of hemlock (*Tsuga canadensis*), beech (*Fagus grandifolia*), birch (*Betula papyrifera, B. lenta*), maple (*Acer rubrum*), oak (*Quercus rubra*) and ash (*Fraxinus americana*). The figure shows changes in growth as recorded in tree rings and changes in composition from the pre-settlement period to today as recorded in pollen content of humus soils. Human disturbances through cutting occurred in 1800, 1830 and 1890 resulting in increased growth in remaining trees and marked changes in the forest composition especially in chestnut (*Castanea*). Although the forest appears mature and unchanging today, its history has been highly dynamic.

Historical Study of Cultural and Biological Change for the 50 Township Study Area in Central Massachusetts

David Foster, Ben Slater and Glenn Motzkin completed the collection of data from town halls, historical societies, archives and state agencies in order to use all available historical data to reconstruct the history of human and vegetation change across the region. Material collected and analyzed includes: population, agricultural, and industrial statistics (1780 to present), forest structure and composition data (ca. 1760, late 1800's, early 1900's), and modern, regional logging activity and forest maps (1830, 1937, 1951, 1971, 1985). The data document striking patterns of variation in forest composition at the time of European settlement from the Connecticut River Valley to the Eastern Lowlands near Boston and a decrease in regional variation in vegetation in the modern landscape. Interestingly, the study suggests that one factor that is restricting the compositional recovery of the forest vegetation in the region is ongoing disturbance by logging. From the mid 19th C through the 1930's forests were cut for fuelwood and building materials at a very small size. Although the rate of cutting has lessened, a project by David Kittredge and David Foster that inventoried all cutting activity in north central Massachusetts over the last 10 years indicates that more than 18% of the forest area was included in forest cutting operations during that time period (Fig. 2).

Community Ecology and Conservation Biology

Although there is increasing conservation interest in protecting uncommon plant communities, little is known about changes in the landscape distribution and dynamics of these communities over time. In areas such as New England that have a long history of human modification of the landscape, combining a landscape and historical approach may be particularly important in order to interpret modern community patterns, to identify appropriate conservation objectives, and to develop management strategies for achieving those objectives. Together with Bill Patterson from the University of Massachusetts, Glenn Motzkin and David Foster are investigating landscape level historical changes in the distribution and dynamics of pitch pine-scrub oak (PPSO) communities throughout the Connecticut Valley of Massachusetts. PPSO communities are priorities for conservation because they are uncommon, support several rare plant and animal species, and are threatened by industrial, commercial and residential development.

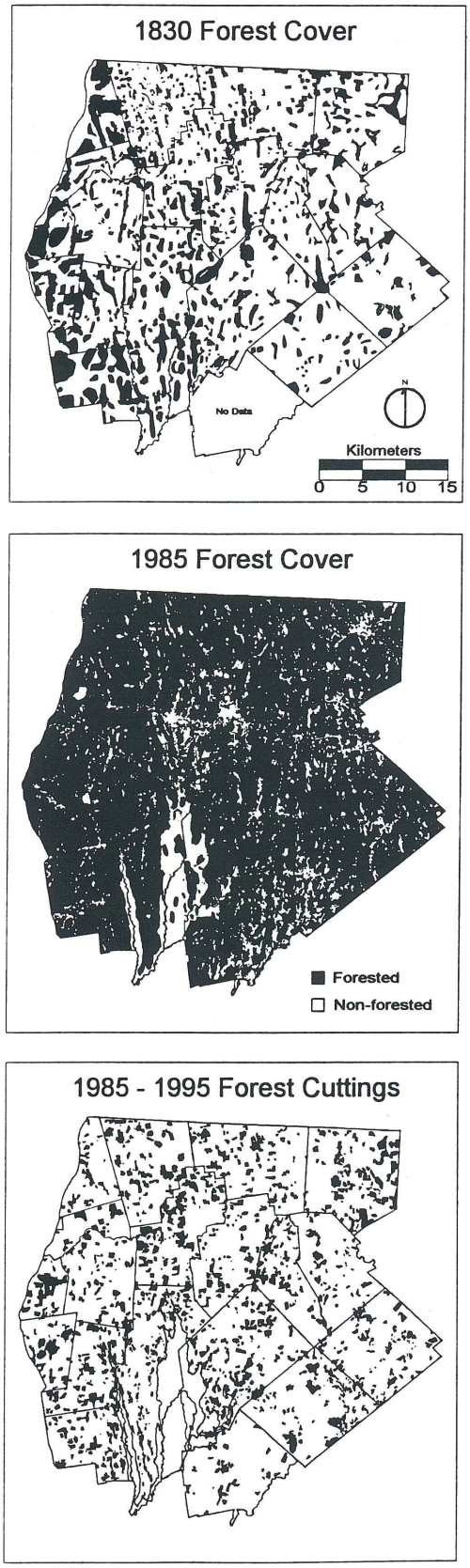


Figure 2. Changes in forest cover and forest cutting in the North Quabbin region of Massachusetts. The abandonment of agricultural activity in the mid 19th C allowed massive reforestastion and a complete change from an open agrarian to a heavily forested landscape. Over the past 10 years the region has been extensively cut for a variety of wood products.

Historical sources indicate that pine plains were widespread on xeric outwash deposits throughout the Connecticut Valley at the time of European settlement, with large pitch and white pines that were highly valued by European settlers for a variety of forest products. The pine plains were widely cleared for agriculture in the second half of the 19th C and nearly all modern pitch pine stands in the Valley developed on old fields after agricultural abandonment (Fig. 3). Modern species composition strongly reflects land-use history, and several species that we suspect were formerly wide-spread have not successfully re-colonized these sites even 50 to >100 years after agricultural abandonment. Modern distribution of PPSO communities throughout the Connecticut Valley is largely controlled by patterns of urban and suburban development, and many of the historical pine plains have been eliminated or highly degraded by development. Although modern community patterns and dynamics differ substantially from historical ones, immediate conservation efforts are required in order to prevent the complete elimination of these formerly widespread communities.

Sarah Cooper-Ellis is working under a grant from Massachusetts Natural Heritage Program and The Nature Conservancy to produce a checklist of bryophyte species for the state. The work involves compiling a county by county list of moss species and state-wide list of liverwort species from existing records, updating nomenclature for species of record, adding confirmed new reports, and identifying species of interest and concern through research on species distribution and consultation with knowledgeable individuals.

Soil and Ecosystem Response to Land Use

Human land-use activities such as deforestation, land clearance and plowing often accelerate the rates of nitrogen mineralization and nitrification in soils, yet the duration of these disturbance effects, especially following the subsequent abandonment of agriculture and reforestation, is not well known. The duration and intensity of the land-use activity may strongly affect subsequent changes in N availability as a site is reforested. Understanding these effects is important because nitrogen is a limiting nutrient in most forests and many forests in the eastern U.S. occupy sites that were previously in agriculture. Ongoing work by Jana Compton in the Prospect Hill tract of Harvard Forest, with help from summer students Adrien Elseroad and Erica Cline, reveals that sites which were cleared of forest and then plowed during the 19th C have higher nitrification rates than sites that remained continuously in forest. Ratios of carbon to nitrogen were lower in the plowed soils and a study using the nitrogen-15 isotope revealed that the rates of nitrogen cycling are strongly affected by land-use history and vegetation types.

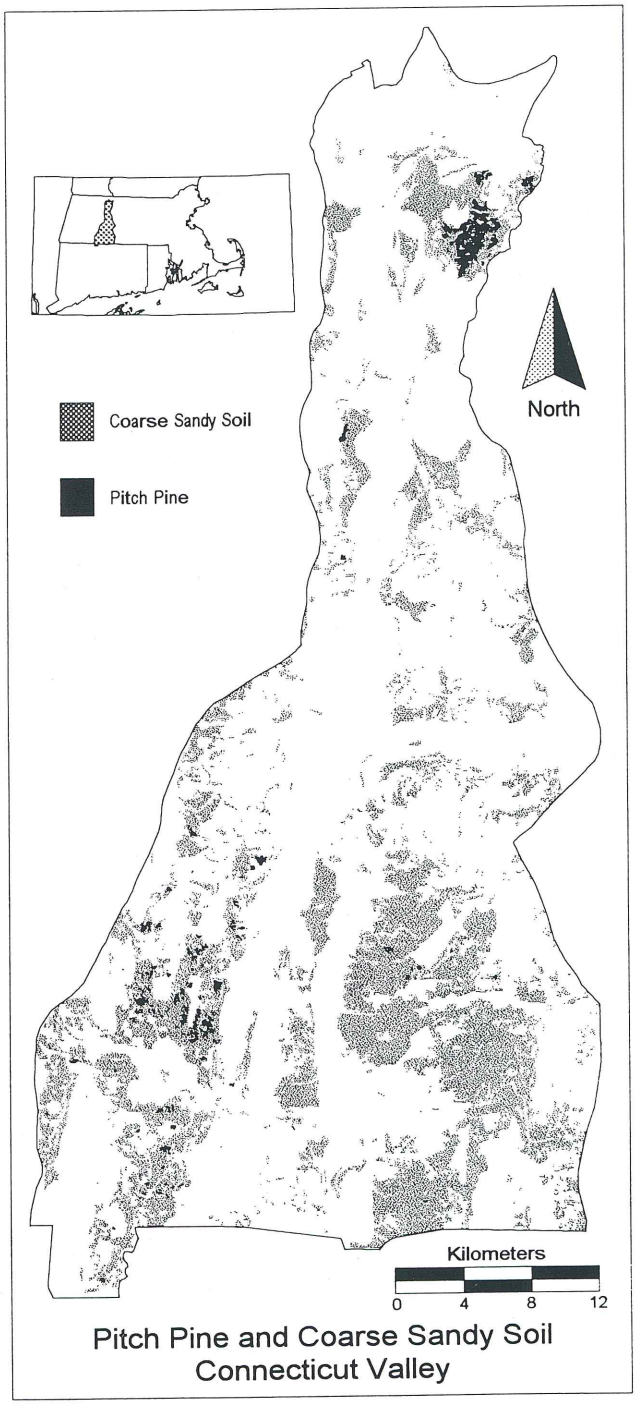


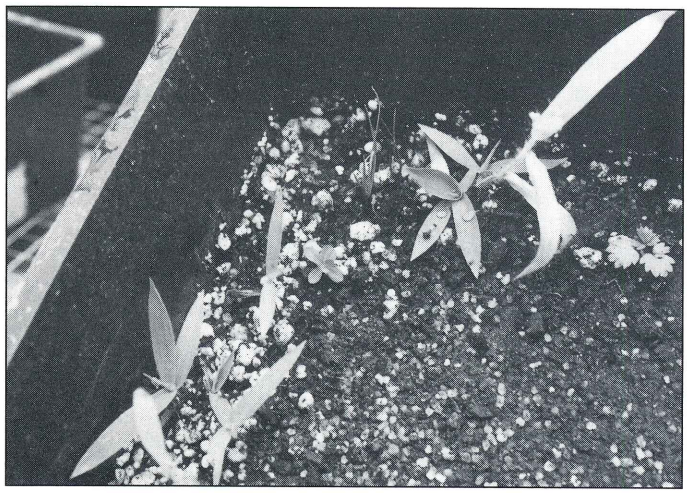
Figure 3. Distribution of dry, sandy soils and pitch pine stands in the Connecticut Valley of Massachusetts. Although extensive pine plains formerly occurred across the sandy soil deposits, today most stands are small and threatened by industrial, commercial, or residential development.

Jana is collaborating with Eric Davidson of Woods Hole Research Center and Sue Trumbore of the University of California, Irvine to examine the impact of land-use on soil C and N accumulation by soil depth. Soil pits were excavated in four sites (two plowed, one pastured and a permanent hardwood woodlot) and total soil carbon and nitrogen were determined. In addition, summer student Laurel Schaider is determining total phosphorus for these soils. Preliminary results indicate that most pronounced land-use effects are observed in the deeper soils (20-90 cm), suggesting that the long-term absence of root inputs may be the largest difference in soil carbon storage between plowed and unplowed sites. Soil C and N concentrations were slightly higher in the plow layer (the uppermost layer of mineral soil) of the most recently abandoned site; however, below 20 cm, soil carbon and nitrogen were higher in the permanent woodlot. Soil total C to N ratio showed the most dramatic differences between sites, with the plowed sites having a much lower C to N ratio, especially below the plow layer. Thus the most dramatic effects of agriculture on soil C and N storage is not associated with the plow layer or plowing per se, but with processes occurring below the plow layer. Eric and Sue are working to model carbon fluxes within the soil, isolating organic matter decomposition and root respiration and turnover using ^{14}C techniques.

Buried seed pools: a legacy of land-use

When the current vegetation of a site is studied we seldom give adequate regard to the living seeds that are stored in the soil and which may germinate as time passes or when disturbance and changes in the soil environment occur. Consequently, the total diversity of the vegetation is seldom sampled completely and we have only a partial understanding of the potential range of plant species that may appear shortly after cutting or natural disturbance such as fire or windstorm. In New England, where many of our forests occupy former agricultural sites and locations in which the structure and composition of the vegetation has changed dramatically over the past 100 years, there is a great possibility that the buried seed flora is substantially different than the current vegetation on the site. In order to assess the importance of this little studied component of the vegetation, we undertook a buried seed study and began to investigate our major experimental disturbances for evidence that buried seeds are important in revegetation.

Sarah Cooper Ellis, with Harvard student Annabel Bradford, worked to develop the methodology for assessing the viable seedbank in plots with varying land-use histories. Soil monoliths were taken from previously plowed, previously pastured, and permanent woodlot plots controlled for dominant vegetation, soil type, and drainage. Soil was held in the greenhouse to germinate, and extracted seeds were examined microscopically. Germinants were primarily species of *Rubus, Betula, Carex,* and *Panicum.* On the experimental pull-down a suite of species that were rare before the disturbance appeared on the site immediately after the manipulation. These species were especially common on upturned root mounds and other areas of soil disturbance.



Rubus, Betula, Carex and *Panicum*

Plant Populations

Kathleen Donohue conducted research comparing demographic properties of populations of *Gaultheria procumbens* growing in areas with different land-use histories in order to address the mechanisms of distributional patterns in relation to previous land-use. In addition, she conducted a study of four ericaceous species that grow in abundance on the Montague sand plain in order to compare germination behavior and establishment success of these species under different natural and experimental conditions. Three summer students working with Kathleen, E. Zacharias, L. Williams and S. Maliakal participated in the demographic study of *Gaultheria* and conducted independent studies on species distributional patterns along former plow boundaries, on below-ground morphology and growth patterns of *Gaultheria*, and on mycorrhizal associations with *Gaultheria* in areas with different land-use histories.

Gaultheria and other plant species have distinctive patterns of distribution associated with land-use variation across the plain, which is otherwise homogeneous with regards to soils and other site conditions. The work that Kathleen is undertaking is designed to identify the factors controlling these distributional pat-

terns. Possible mechanisms include: modification of soils by land-use activity or biological constraints including limitations in dispersal, germination, establishment or growth on areas in which the natural vegetation was formerly removed by plowing.

Soil-plant-atmopshere interactions

The Collaborative Research for Undergraduate Institutions (CRUI) program funded by the National Science Foundation, and coordinated by Timothy Sipe, Gustavus Adolphus College, Richard Bowden, Allegheny College, and Charles McClaugherty, Mount Union College, began at the Harvard Forest this summer. Over the next three years this program will enable 27 students from the three colleges to conduct a multidisciplinary study of the impact of human land-use legacies on soil-plant-atmosphere (SPA) interactions in forested ecosystems. There is at present a lack of data on (1) how long the impacts of land uses may persist in modern forests (land-use "legacies"); (2) the mechanisms whereby these legacies regulate the current function of ecosystems; and (3) the influence they will have on the future forest. Studies will be conducted on forested sites with three types of land use legacies (logged, pastured, plowed). Students and faculty from the three colleges will work at the Harvard Forest each summer along with Rachel Clark, a year round research assistant, to measure carbon and nitrogen cycling, trace gas fluxes, forest productivity, litter chemistry, microclimatology, sapling ecophysiology and growth, plant population distributions, and plant community patterns. This research should tie in well with established Harvard Forest and LTER studies and will help to clarify the impact of land-use legacies in central New England.

Natural Disturbance in Forested Landscapes

Hurricane Impacts to New England and Puerto Rico

The impacts of past hurricanes on the forested landscapes of New England and Puerto Rico are being investigated by Emery Boose, Kris Chamberlin, and David Foster. Important hurricanes in each region since European settlement are reconstructed with a simple meteorological model using meteorological and damage data from the National Oceanographic and Atmospheric Administration (NOAA) and historical sources. Long-term impacts across the two regions are assessed by compiling the results of the reconstructions of individual storms. The effects of topography on wind damage on a particular landscape are estimated with a simple topographic exposure model.

During the past year efforts focused on collecting and analyzing data for the 61 most powerful hurricanes in New England since 1635. Modeling techniques were refined through detailed studies of six recent storms (1938, 1944, 1954, 1960, 1985 and 1991), for which data were most abundant and reliable. For these storms the predicted wind conditions were compared to actual observations across New England, New

Rachel Clark, Jennifer Dean and Shana Stewart sample for target herb species in a plowed site

and New Jersey, while predicted regional damage was compared with actual damage compiled from newspaper and other contemporary reports. Results suggested that is it possible to model wind damage reasonably well on a regional scale using only hurricane track and maximum wind speed as input variables. These techniques are now being applied to reconstruct all 61 past hurricanes and to create maps of long-term hurricane frequency and intensity across New England.

The second phase of the project will study the hurricane history of Puerto Rico and will involve collection of historical data and modification of the meteorological model for the warm Caribbean climate, mountainous topography, and tropical forests of Puerto Rico. Laura Hoffman, a summer student is beginning this work with detailed studies of the major hurricanes to impact Puerto Rico in the 20th C.

In a project that integrates paleoecological and hurricane modeling studies, David Foster and Tom Webb (Brown University) received funding from the Bermuda Biological Station for research to undertake an assessment of the long-term impacts of hurricanes to the landscape of New England. The project is underwritten by the re-insurance industry, which is seeking longer baseline information on the frequency of extremely powerful hurricanes in the region from New York City through Boston. Researchers will examine salt water marshes and lakes on transects across Massachusetts and from coastal Rhode Island and Connecticut inland, and will use stratigraphic and pollen analysis to identify evidence for historically important storms in 1635, 1815 and 1938. If adequate resolution of these impacts can be established, then subsequent work will involve searching for similar events during the millennia before European settlement.

Experimental Hurricane Manipulation

In the hurricane experiment a 75 x 125 m area of forest was pulled over with a winch in order to simulate the impact of a severe hurricane like the one that struck New England in 1938. The study was initiated in 1990 as part of the Harvard Forest LTER program and comprehensive sampling of soils, microenvironment, plant and forest response have been studied in the experimental and control areas since.

In 1995, students Jacqueline Bartee and Sarah Neelon working with Elaine Doughty and Sarah Cooper-Ellis undertook the fifth year of annual survey of tree leafout and sprouting on the hurricane experiment. The major objective in this portion of the study is to answer the questions: How long do trees survive and continue to leaf out after uprooting and other severe damage from a hurricane? and, How important is vegetative reproduction and sprouting as a mechanism for survival and revegetation? Nearly 70% of the damaged trees continue to survive on the site by basal sprouting, leafing or both (Fig. 4). Jacqueline, Sarah Neelon and Elaine also analyzed the herbaceous and shrub vegetation in transect plots in the control, pulldown and clearcut. We analyzed trends of cover and height (shrubs) in these areas over the five year period following the experiment and found that species' relative importance remains stable, although *Dennstaedtia punctilobula* increased in the pulldown, height and cover of shrubs such as *Amelanchier canadensis*, *Corylus cornuta*, and *Viburnum cassinoides* increased sharply in the clearcut and less dramatically in the pulldown, and *Rubus spp.* have appeared and become increasingly important in the pulldown and clearcut. Analysis of cover by lifeform categories shows sharp increases in sapling cover in the pulldown between years two and five post-experiment.

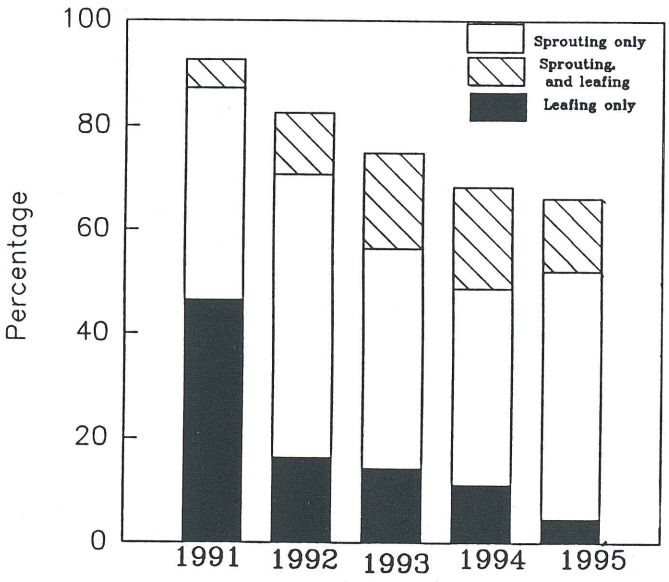
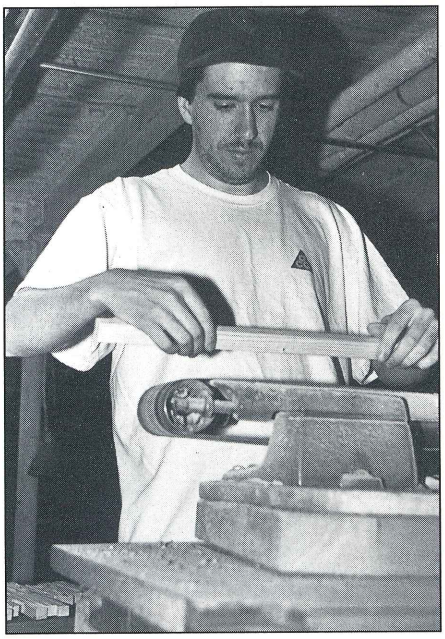


Figure 4. Survival of trees for the five years following the experimental hurricane pulldown on the Tom Swamp tract. The majority of these trees were uprooted or broken but were able to survive through sprouting of new branches and shoots or continued leaf-out of the now-prostrate tree crown. The remarkable and unexpectedly high rate of survival has moderated the changes in composition, environmental conditions and ecosystem processes. The important role that surviving trees and vegetation reproduction by sprouting play in forest recovery from major disturbance is one strong argument against the salvage logging that is a prevalent human response to natural disturbance.

Hemlock Woolly Adelgid

Since 1985, the hemlock woolly adelgid (HWA), an Asian insect, has been infesting hemlock forests across southern New England. The introduction of this pest has the potential to reduce or substantially eliminate hemlock throughout its range. Thus, evaluation of the HWA's ecology and impact is of great interest to landowners, forest managers, and ecologists. In 1995 the Harvard Forest initiated a program to study the HWA in order to evaluate its ecological consequences in southern Connecticut at a stand, landscape and regional scale (Fig. 5). Hemlock's importance lies not only in the fact that it is a major constituent of old-growth forests. It also frequently occupies riparian areas and wetlands where its rapid demise may result in major environmental changes that may affect aquatic ecosystems and water quality. The HWA study therefore forms part of a large Harvard Forest program evaluating the history and ecology of hemlock in New England. The research approach that Dave Orwig and David Foster developed includes: mapping of hemlock distribution and HWA impacts across the region from aerial photographs and remote sensing, analysis of the relationship between landscape features and the spread of the infestation, and quantification of stand response and environmental change following HWA impact. Working with summer student Jamie DeNormandie and MFS student Guy Hughes, Dave established a series of permanent plots on state and private lands for long-term studies. The extent of the impact of the adelgid and associated eastern hemlock looper can be extreme: on one study site over 100 acres of nearly pure hemlock has been entirely killed within the past two years. The subsequent regeneration of birch and change in environmental conditions are remarkable.

In 1996 David Orwig, working with summer students Kevin Dodds and Chris Lawinski, continued to develop the stand-level and regional study of infestation and impacts from the hemlock woolly adelgid (HWA) on hemlock forests in south-central Connecticut. Preliminary results from permanent plots established in eight forest stands during 1995 indicate that a wide range of hemlock damage and mortality have already occurred ranging from relatively unaffected stands to areas with greater than 95% hemlock mortality. The initial response of understory vegetation to canopy openings created by dying hemlock has been a dramatic increase in black birch seedlings. Multiple regression results suggest that increased light and humus depth are the most important factors affecting new birch establishment. We are currently examining the age-structure and developmental history of these forests using tree cores. In addition, we will continue a long-term evaluation of damage, mortality, and vegetational changes in these and other hemlock-dominated sites. At the landscape level we have initiated a project mapping the pre-HWA distribution of hemlock throughout a band of Connecticut forest stretching from Long Island Sound to the Massachusetts border. This map will be used to analyze the size distribution, patch characteristics, and spatial distribution of hemlock stands and to assess these distributions in relation to physiographic features, soils, and landscape position. This information will be useful in elucidating what factors control the pattern of HWA spread and damage.



Kevin Dodds

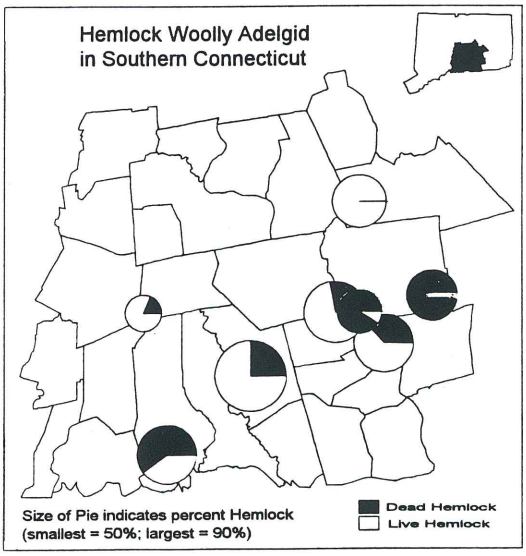


Figure 5. Results of the hemlock woolly adelgid study in southern Connecticut. At each of the sites sampled the relative abundance of hemlock in the forest is indicated by the size of the circle, whereas the blackened area within the circle represents the percentage of hemlock killed by the adelgid. Although the current impact of the adelgid is patchy, the prognosis is troubling. Mortality rates range to 99% and stands many hundreds of acres have been destroyed.

Old-growth forest dynamics at Wachusett Mountain

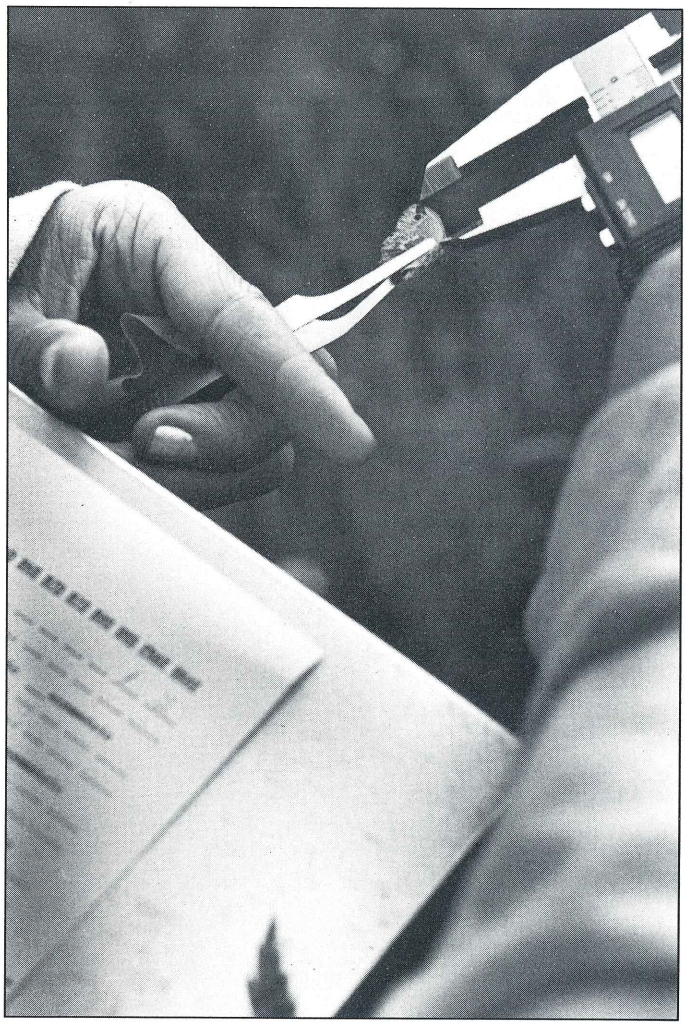
The discovery of stands of old-growth forest on the steep, upper slopes of Wachusett Mountain in Princeton and Westminster, Massachusetts has provided the opportunity to characterize the composition, structure and dynamics of vegetation in central Massachusetts that has not been directly impacted by humans. Researchers at the Harvard Forest including David Foster, Dave Orwig and John O'Keefe were requested by the Massachusetts Department of Environmental Management (DEM) to conduct field studies in order to document the extent and characteristics of these forests, which are located on land owned and managed by DEM. A final report was submitted that identified an old-growth forest area exceeding 100 acres and described the age-structure and composition of these stands. This Harvard Forest research effort follows an initial reconnaissance by Dr. Charlie Cogbill of Plainfield, Vermont, and was led by Dave Orwig who determined that trees exceeded 250 years in age, with the oldest tree aged a red oak 307 years old. This project is continuing as Dave, with Kevin Dodds and Chris Lawinski, establish permanent plots and undertake additional sampling. This information will be extremely valuable for increasing our understanding of the historical and ongoing dynamics of these forests and for guiding future protection and management efforts. This study also has a very interesting historical context as two of the earliest descriptions of this forest area come from an excursion by Henry Thoreau to Mount Wachusett in the 1850s and a field survey conducted in the early 1900s for the state of Massachusetts by Richard T. Fisher, first director of the Harvard Forest.

Ecophysiology of red spruce and eastern hemlock

Julian Hadley continued his studies of red spruce cold tolerance, microclimate and freezing injury in western Massachusetts and northern New York State, assisted by Jeff Herrick. Extensive red spruce winter injury occurred in southern New England in the winter of 1995-96, including severe injury to some trees at high-elevation research sites on Mt. Greylock, Massachusetts. Microclimatic measurements of red spruce were made at this site before, during, and after injury development. These are the first such data ever collected during a red spruce winter injury episode, and a comparison of temperature patterns in winter-killed and undamaged foliage during the period of injury development may finally allow identification of the weather conditions leading to injury. In June, 1996 Julian began studies of CO_2 exchange and environmental conditions in eastern hemlock forests on the Prospect Hill tract. This research will describe the gas exchange ecophysiology of eastern hemlock, determine the contribution of eastern hemlock to the total ecosystem CO_2 exchange currently being measured at the Harvard Forest, and also indicate how ecosystem gas exchange can be expected to change if hemlock in this area is killed by the hemlock woolly adelgid which is spreading northward from Connecticut.

Animal Ecology

Richard Lent and summer student Catherine Mendenhall continued studies of butterfly ecology in the Petersham area and Massachusetts landscape. Catherine conducted a mark-recapture study of butterflies in several Petersham grasslands to determine individual survival, phenotypic variation and habitat relationships. In addition, she used several Internet data sources and a GIS to compile a land use-land cover map of Massachusetts, with which she examined patterns of bird and butterfly diversity in relation to landscape variation.



Catherine-Astrid Mendenhall collects butterfly specimens

Post Glacial Vegetation and Climate History

Jason McLachlan and David Foster collaborated with K. Pregitzer, D. Reed, G. Mroz, and T. Bornhorst from Michigan Technical University in analyzing the stand-level pollen and macrofossil assemblages from a white spruce stand buried intact by glacial outwash near Marquette, Michigan 11,000 years ago. This unusual fossil assemblage consists of an intact forest complete with standing trees and forest floor. The assemblage is of great interest for its remarkable state of preservation as well as for its age; at the time that this forest was buried the environment and vegetation were changing at a very rapid rate from lake glacial conditions. Pollen from humus accumulations in the stand indicate that, although the stand was predominantly composed of white spruce, a taxon that had dominated late-glacial forests in the Midwest but was in regional decline, taxa such as jack pine, elm and oak which had migrated to the area from southern refugia were locally present as well. Macrofossil remains of the moss *Drepanocladus uncinatus* and the pollen of several understory species suggest that this site was a moist open woodland. Overall, the site seems to have been a local remnant of spruce forest which was actively changing in response to new post-glacial conditions. Analyses of the annual growth rings from the spruce in the stand suggest that the trees declined in growth and then died as the area was flooded by meltwater.

Reproductive Biology

Barry Tomlinson continued his field research in September-November in New Zealand and Australia on the reproductive biology of southern conifers, with support from the National Geographic Society. Research associates also involved were from the University of Auckland, University of Waikato and University of New South Wales. This phase of research has demonstrated that coniferous taxa respond differently to pollen. In conifers there is no apparent pre-zygotic selection process, but some of their pollen capture mechanisms may work to reject some kinds of pollen. Research is now focussing on the mechanism by which the pollination drop, characteristic of pollen capture in gymnosperms, is produced and resorbed. Observations were continued in Spring, 1996, with emphasis on the collections of the Arnold Arboretum and natural populations at Harvard Forest.

Harvard Forest LTER Program

The Harvard Forest is one of eighteen sites forming the Long Term ecological Research (LTER) program sponsored by the National Science Foundation. Each site addresses ecological questions of a long-term nature; collectively the sites undertake comparative studies across ecosystems. Representatives from the LTER sites and NSF meet twice annually to develop the collaborative studies. The central theme of the Harvard Forest LTER is a comparison of historically-important, physical disturbances and modern, chemical disturbance in terms of their effects on forest ecosystem structure and function. One fundamental question is whether chronic, low-level additions of pollutants can result in more long-lasting alterations of ecosystem functions than does the natural regime of disturbance. A second major focus of the Harvard Forest LTER program is an evaluation of the long-term legacies of human land-use activities on modern forest structure, composition and function.

The research project involves soil scientists, atmospheric chemists, and ecologists studying physiological, population, community and ecosystem processes. Principal investigators represent the Departments of Biology (F. Bazzaz), Earth and Planetary Sciences (S. Wofsy), Graduate School of Design (M. Binford), and Harvard Forest (D. Foster, E. Boose, R. Lent) 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), Mt. Union College (C. McClaugherty), Rutgers University (E. Russell), and the University of Massachusetts (M. Mulholland). The research is organized to maximize the interactions and exchanges among scientists from different disciplines. Four core experiments include: (1) re-creation of physical disturbances, including catastrophic hurricane blowdown and smaller windthrows; (2) simulation of chronic chemical disturbance by altering inputs of important pollutants; (3) interactions between physical and chemical disturbances; and (4) repetition of treatments to assess the range of variation in response.

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 1996 Symposium is shown on the following page.

National Institute for Global Environmental Change (NIGEC)

Harvard University serves as the Northeastern Regional Center for the NIGEC program sponsored by the Department of Energy. The purpose of NIGEC research is to improve the understanding of mechanisms of global environmental change, to develop innovative 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 Center is administered by the Division of Applied Sciences and a large proportion of the field studies are conducted at the Harvard Forest. Researchers include many of the LTER scientists (Bazzaz, Melillo, Nadelhoffer, Wofsy) 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), and U.S. Geological Survey (E. Sundquist).

LTER collaborators John Aber and Fakhri Bazzaz compare notes at the Annual Ecology Symposium

Harvard Forest Ecology Symposium 1996

Titles of Abstracts and Presentations

Aber, J., A. Magill, S. McNulty, R. Boone, K. Nadelhoffer, M. Downs and R. Hallett. Forest Biogeochemistry and Primary Production Altered by Nitrogen Saturation

Berntson, G. and F. Bazzaz. Nitrogen Cycling in Microcosms of Yellow Birch Exposed to Elevated CO_2

Boose, E., E. F. Boose and A. Lezberg. A Practical Method for Mapping Trees Using Interpoint Distances

Boose, E., K. Chamberlin and D. Foster. Landscape and Regional Impacts of New England Hurricanes

Boose, E., M. Feldberg and K. Chamberlin. Reconstructing the 1635 New England Hurricane

Brush, G. Land-water Interactions: Paleoecological Approaches and Results

Catricala, C., K. Newkirk and J. Melillo. Effects of Temperature on Soil Respiration and Nitrogen-Availability

Cavender-Bares, J. and F. Bazzaz. Ontogenetic Differences in Physiology of *Quercus rubra* in Response to Drought.

Compton, J., A. Elseroad, E. Cline and R. Boone. The Role of of History and Vegetation in Soil Nitrification

Compton, J., R. Boone, D. Foster and E. Davidson. Impact of Land-use History on Soil Carbon and Nitrogen Storage

Cooper-Ellis, S. and D. Foster. Understory Vegetation Response to a Simulated Hurricane

Crill, P. and K. Bartlett. Diurnal to Interannual Scales of Variability in Ambient Methane at Harvard Forest

Currie, W., C. Driscoll and J. Aber. Cation and Anion Leaching From the Forest Floor Under Chronic Nitrogen Additions

Davidson, E., E. Belk and J. Reynolds. Controls on Soil Carbon Storage and Soil CO_2 Fluxes

Donohue, K. Seed and Fruit Characters of Three Ericaceous Species on the Montague Sand Plain

Donohue, K. Below Ground Growth Patterns and Vegetative Growth Rates of *Gaultheria procumbens*

Donohue, K., L. Williams III and G. Motzkin. Seedling Establishment Versus Vegetation Expansion in Ericaceous Species

Donohue, K. and E. Zacharias. Demographic and Morphological Variation in *Gaultheria procumbens*

Fitzjarrald, D., K. Moore, R. Sakai and J. Freedman. Forest-Atmosphere Exchange Processes in Central New England

Foster, D., B. Slater and G. Motzkin. Regional Analysis of Historical Landscape Dynamics in Massachusetts

Foster, D., G. Motzkin, J. O'Keefe, J. Carlson and D. Strauss. The Past and Present Distribution of White Pine and Hemlock

Fuller, J., D. Foster, J. McLachlan, M. Binford, N. Drake and E. Doughty. Vegetation Responses to Human Disturbance

Gardner, A. and J. O'Keefe. Influence of Microhabitat on Seedling Establishment After the 1938 Hurricane

Godbold, D., G. Berntson and F. Bazzaz. Root Growth and Mycorrhizae in Response to Elevated CO_2

Hadley, J., J. Herrick and D. Manter. A Comparison of Red Sprue Canopies in Massachusetts

Hughes, G. Forest Structure, Disturbance, and Alien Plant Invasion in the Hawaiian Islands

King, K. and C. McClaugherty. Five Years of Decay in Red Pine and Red Maple Twigs

Kittredge, D. and D. Foster. Timber Harvesting Patterns in the North Quabbin Region of Massachusetts

Knight, D. Detecting the Effect of Wood on Mineral Soil Organic Matter

Lefer, B. and R. Talbot. Dry Deposition of Atmospheric Nitrogen in a Forest Setting

Lent, R. and S. Buchanan. Use of Clearcuts by Early-Successional Bird Species in New England

Li, A., D, Godbold, G. Berntson and F. Bazzaz. Root Growth of Birch Seedlings in Response to CO_2 and Aluminum

Magill, A. and J. Aber. Plant and Soil Response of Red Pine and Mixed Hardwood Stands to Chronic Nitrogen

S. Maliakal and K. Donohue. The Effect of Land Use History on the Abundance of Ericoid Mycorrhizae

McLachlan, J., D. Foster and F. Menalled. Post-Settlement History of Harvard Forest Woodlots

Melillo, J., K. Newkirk, C. Catricala, P. Steudler, J. Aber, K. Nadelhoffer and R. Boone. Soil Warming - 1995

Moody, J., J. Munger and A. Goldstein. Regional-scale Pollution Sources Contributing to Harvard Forest

Motzkin, G., D. Foster, P. Wilson and A. Allen. Modern Vegetation Patterns: Historical and Environmental Factors

Munger, J., M. Goulden, P. Czepiel, M. Potosnak, D. Sutton and S. Wofsy. Seasonal Variation in Rates of Regional Nitrogen Oxidation and Deposition

Nadelhoffer, K., R. Boone and J. Canary. Carbon Turnover in Forest Soils

Nadelhoffer, K., M. Downs, P. Micks and K. Kim. Litter Decomposition and Chronic Nitrogen Additions

O'Keefe, J. and A. Gardner. Woody Species Phenology on the Prospect Hill Tract, Harvard Forest - 1995

O'Keefe, J. and A. Gardner. Regeneration Following Clearcutting of Red Pine Overstory - Year 6

Orwig, D. and D. Foster. Forest Ecosystem Response to Hemlock Woolly Adelgid Outbreak in Connecticut

Patterson, W., G. Motzkin, D. Foster and A. Stevens. Pitch Pine Communities in the Connecticut Valley

Pregitzer, K., D. Reed, G. Mroz and T. Bornhorst, D. Foster and J. McLachlan. Stand Characteristics and Dynamics of a Late-Glacial Spruce Forest, Upper Peninsula, Michigan

Rainey, S., M. Downs and K. Nadelhoffer. Effects of Chronic N Additions on Understory Communities

Russell, E., D. Foster, J. McLachlan, J. Fuller and R. Lent. Regional Vegetational Change in Northeastern U.S.

White, A. Spatial and Temporal Patterns of Stand Development in an Old-Growth Forest

White, A. Effects of Land-use, Climate, and Soil Drainage on Radial Growth Patterns in an Oak-Pine Forest

BULLARD FELLOWS

David Bowman spent the second half of his fellowship revising manuscripts and writing a book on environmental controls of Australian rainforests. He gave a number of seminars in Cambridge (Herbarium, Bazzaz Laboratory, Peabody Museum) and at the Harvard Forest. He also presented seminars on sustainable forestry at the University of Washington and the Australian National University at Canberra, Australia.

Grace Brush spent the year compiling and analyzing modern and paleoecological data that she and her students have collected over the past decade on the Chesapeake Bay watershed and estuary into an interpretative monograph of the dynamics and interactions among terrestrial and estuarine systems. Grace gave talks at Harvard Forest, Graduate School of Design, Department of Earth and Planetary Sciences, and the Herbarium at Harvard University, and at the University of Massachusetts and the New York State Museum. She organized a symposium with Alan Covich to be presented at the 1996 Ecological Society of America meetings in August.

Balachander Ganesan completed a paper on the Ecology and Economics of Protected Areas in India. He collaborated with Ricardo Godoy of Harvard Institute for International Development on the determinants of household income in a protected area in India and on the impact of economic activities on the conservation of biodiversity. Balachander initiated a book on non-timber forest products, especially on the role that sustainable extraction could play in conserving biodiversity while improving livelihoods for local peoples.

Douglas Godbold has been investigating the effects of elevated levels of CO_2 on root growth of four species of tree seedlings. After collecting naturally established saplings of *Tsuga canadensis, Acer rubrum, Betula papyrifera* and *Pinus strobus* from the Harvard Forest, the saplings were grown in rhizotrons for 6-8 months in a controlled environment glasshouse at the laboratory of Fakhri Bazzaz. At the end of the growth period the biomass allocation, degree of mycorrhization, and assemblage of mycorrhizal and morphotypes colonizing the roots were investigated. In collaboration with Glenn Bernston, Doug looked at the effect of mycorrhizal species assemblage on Nitrogen uptake. Doug gave a seminar at the University of Maine, Orono and at the Harvard University Herbaria. He visited M.I.T. to discuss research work into heavy metal toxicity, and he gave guest lectures in Introductory Biology at Harvard.

Dennis Knight spent much of his time starting a new study on the effects of wood on the development of mineral soil organic matter. This topic is relevant to sustainable forest management, as excessive timber harvesting could lead to declines in soil organic matter. Unlike natural disturbances such as wind storms and fire, timber harvesting removes bolewood from an eco-

Janice Fuller, Grace Brush, Jana Compton, and Alan White (left to right)

Bullard Fellow Dennis Knight (middle) enjoys a moment with Glenn Motzkin and Kristen Chamberlin

system before it can contribute to soil development. For millennia the residuals of bolewood and rootwood decomposition have contributed in various ways to the accumulation of soil organic matter, which is important for nutrient storage, nitrogen-fixation, the formation of ectomycorrhizae, soil permeability, and resistance to erosion. In collaboration with Jana Compton, Dennis did a pilot study on the *in situ* effects of wood on the soil of the Pisgah and Prospect Hill tracts of Harvard Forest. He also developed a successful research proposal on this topic to the U. S. Department of Agriculture. In addition, he worked on two manuscripts pertaining to fire ecology in the Rocky Mountain region and, with David Foster, started a new manuscript comparing patterns of undisturbed vegetation distribution following fires, floods, wind-storms and volcanic eruptions. During the year he gave lectures at the Ecosystems Center (MBL), Harvard Forest, Harvard University Herbaria, Rutgers University, University of Massachusetts, and the National Center for Ecological Analysis and Synthesis.

Robert Waide spent a summer at Harvard Forest interacting with David Foster and Emery Boose on a joint project to determine the relative impact of historical land use and hurricane impacts on forest vegetation in the Luquillo Experimental Forest of Puerto Rico. Bob's project was designed to focus on the area around the El Verde Field Station, which is one of the principal research sites of the Luquillo LTER program. The area around the station was exposed to a variety of anthropogenic influences which can be examined with the seven available sets of aerial photography. This analysis is complemented by detailed ground surveys mapping and measuring every tree in a 16 hectare plot.

Tom Webb's paleoecological and global change research focused on using pollen data to check global biome models, record the incidence of species-wide disease outbreaks in trees, and check the results of global circulation models. He started a research project with David Foster to use evidence of forest disturbance in identifying the frequency of major hurricanes in New England during the last 2000 years and completed five manuscripts. Tom is serving as an editor for a volume of papers in Quaternary Science Reviews that presents and tests climate modeling results for the last 21,000 years. Tom attended several meetings including presentations on paleovegetation mapping at the Conference of French-speaking Palynologists in Paris, the first Science Conference of GAIM in Garmisch-Parkenkirchen, the American Geophysical Union in San Francisco, and the International Palynological Conference in Houston. He was also invited to describe the pollen evidence for the chestnut blight and for the hemlock decline 5400 years ago at a forestry conference in Portland, OR concerned with the import of raw logs from Asia. He was helped in his presentation by David Orwig's research on the hemlock woolly adelgid attack and by Janice Fuller's detailed study of the hemlock decline.

Alan White's research focused on old-growth forests, dendrochronology, diversity, and forest stand development. He prepared five manuscripts, with several coauthors, on the definition of old-growth stands, relationships between species richness and biomass, the effects of strip clearcutting on regeneration, the age structure and growth of sugar maple seedlings three years after partial cutting of a northern hardwood stand, and factors influencing the distribution of pitch pine/ scrub oak community types on a sandy outwash plain in southern Maine. Alan used Harvard Forest's tree-ring measurement system to analyze many red oak and white pine increment cores from coastal Maine to determine if soil drainage class affects response of the two species to climate. He presented seminars at the University of Maine, participated in the Society of American Foresters' (SAF) Silviculture Instructors' Tour, and attended the SAF National Convention in Portland, Maine. Bullard Fellows for 1996-97 include Drs. John Aber, University of New Hampshire; Eldon Franz, Washington State University; Keith Kirby, Nature Conservancy Council, United Kingdom; Earl Saxon, Wet Tropic Management Authority, Australia; Kerry Woods, Bennington College, Vermont; and Mr. Harri Lorenzi, Editora Plantarum, Brazil, South America.

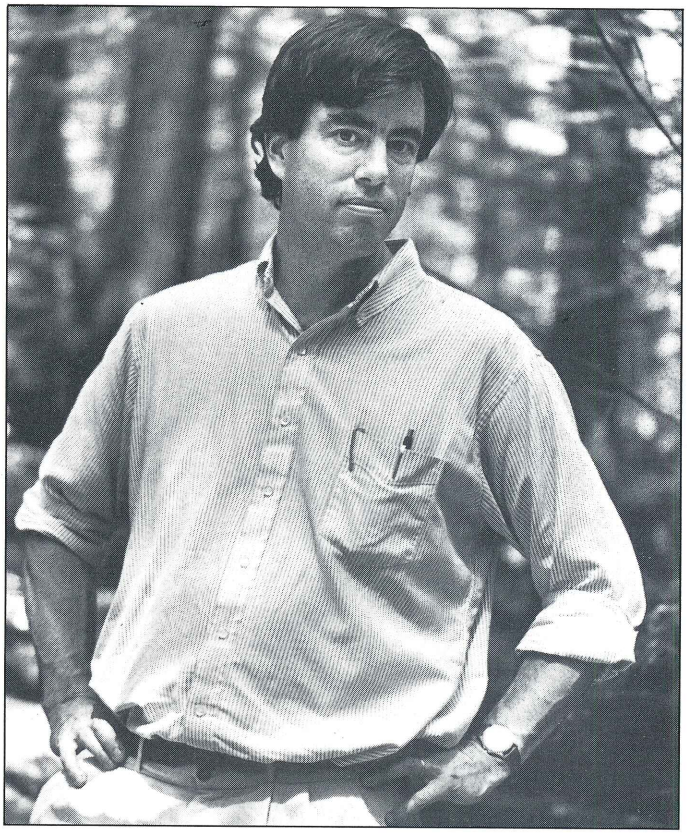
EDUCATIONAL ACTIVITIES

In the fall David Foster taught ENR 522 (*Topics in Environmental Policy: Biosphere Reserves in Concept and Practice*) with C. H. W. Foster in the Kennedy School of Government. This graduate course focused on an evaluation of the Biosphere Reserve program managed by UNESCO's Man and the Biosphere program and included lectures, discussion and a field trip to the Quabbin Reservoir, which is managed by the Metropolitan District Commission. The highlight of the class was a one-day colloquium in which managers, scientists and administrators associated with Biosphere Reserves from across the U.S. evaluated the strengths, limitations and history of reserves. In the spring term David joined with Barry Tomlinson in leading the Harvard Forest Freshman Seminar, which is in its 24th year. In this course 11 students spend four weekends at the Harvard Forest becoming exposed to the history, biology and environment of forests and ultimately conducting an independent project on the last weekend.

At the Graduate School of Design, David participated as a project reviewer for GSD Studio 1212 (*Planning and Design of Landscapes*), he served on the doctoral committee of Kristiina Hill, and he was a member of the search committee for a faculty position in aquatic ecology. David continues to serve as Director of the Graduate Program in Forestry and is advisor of Guy Hughes, a MFS student working on the role of non-native plant species in the vegetation of Hawaii. In his capacity as an adjunct faculty member in the Department of Forestry and Wildlife at the University of Massachusetts, David served on the PhD committee of Andrea Stevens and collaborated with Professors David Kittredge and William Patterson on research projects in central Massachusetts.

Barry Tomlinson taught Biology 102 (*Evolution and Biology of the* Seed) in Cambridge and Biology S-105 (*Biodiversity of Tropical Plants*) at Fairchild Tropical Garden, Miami Florida under the auspices of the Harvard Summer School. With graduate student Russell Spangler in a Biology 309 project, the complex interlocking vasculature of the palm leaf sheath was explored, based on sections prepared for the extensive series of papers on the palm *Rhapis excelsa* in 1960-1970. This is a difficult structure to understand developmentally since vascular bundles not only contra-rotate along a shallow helix, but also interweave.

Julian Hadley taught *Winter Survival: Biological Adaptations to Seasonally Frozen Environments,* at Harvard which covered both plant and animal adaptations for winter survival. Glenn Motzkin led educational programs and field walks for the Nature Conservancy (floodplain forest) and the New England Wildflower Society staff (with John O'Keefe).



David Foster

Summer Research Programs

The Harvard Forest Summer Student Research program attracted a diverse group of students to receive hands-on training in scientific investigations, and to gain experience in working on long-term ecological research. The program, coordinated by Chris Kruegler, Administrator at the Harvard Forest, was supported by NSF Research Experience for Undergraduates program, Collaborative Research for Undergraduate Institutions, National Institute for Global Environmental Change, Mellon Foundation, and the Harvard Forest. Students work closely with faculty and scientists, and many conduct their own independent research studies. The program includes weekly seminars from resident and visiting scientists, weekly discussions on issues pertinent to careers in science (e.g. career decisions, diversity in the scientific community, ethics in science), and field trips on soils, land-use history and vegetation of the forest. An annual field trip is made to the Institute of Ecosystem Studies (Millbrook, NY) to participate in a Forum on Jobs in Ecology, which includes discussion of environmental occupations with students and professionals employed in the field. The summer program culminates in the Annual Summer Student Research Symposium, in which students present major results of their summer work. This year the summer program welcomed the addition of the Collaborative Research for Undergraduate Institutions (CRUI) program with nine students and three faculty from Mount Union College, Allegheny College and Gustavus Adolphus College.

Summer Students, 1996

Sara Chun	Harvard University
Karli Clark	Mt. Union College
Jennifer Dean	Gustavus Adolphus College
Kevin Dodds	Frostburg State University
Scott Heath	Gustavus Adolphus College
Laura Hoffman	Princeton University
Vickie Hunker	Allegheny College
Sujay Kaushal	Cornell University
Melissa Kibler	Mt. Union College
Christopher Lawinski	Oberlin College
Michael Leneway	Michigan Technological University
Dana MacDonald	University of Michigan
Kristin D. McCarthy	University of Massachusetts
Catherine-A.Mendenhall	Amherst College
Sarah Neelon	Smith College
Chad Nielsen	Harvard University
Mark Norris	Allegheny College
Derek Pelletier	Boston University
Kevin Puls	Mt. Union College
Jessica Rigelman	Gustavus Adolphus College
Gregg Saunders	University of Denver
Laurel Schaider	Massachsuetts Institute of Technology
Shana Stewart	Allegheny College
Katariina Tuovinen	Cornell University
Alexandria Wolf	University of Wisconsin
Christopher Wurster	SUNY, Syracuse

Master student Guy Hughes in paleo lab with summer intern Sujay Kaushal and Associate Mike Binford

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 information related to research in forest biology and management. The Museum also provides a unique setting for conferences 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 dedication and enthusiasm of our Museum volunteers, we enjoyed another very successful weekend schedule during the summer and fall of 1995, welcoming about one thousand visitors. In November the Fifth Annual Volunteer Recognition Dinner continued the tradition of reviewing the season's accomplishments while sharing good food and fellowship. Bob Lane shared most active volunteer honors (his third time) with Rosalie Fiske and Dick Sherwood. Helen Gronich received recognition for her continuing work as volunteer coordinator.

The new exhibit greeting visitors using the Shaler Hall entrance to the Museum, and seen by all as they view the dioramas, was dedicated at Friends' Day in September and has been very well received. A central, floor to ceiling mural, enlarged from a close up photo of a portion of one of the dioramas, is flanked by four panels explaining the history, development and current research activities at Harvard Forest. This exhibit was developed and produced in collaboration with the exhibit design staff of the Harvard Peabody Museum of Anthropology.

Continuing the Museum's collaboration with the Petersham Craft Center, John O'Keefe led a family nature walk in July and a workshop on tree architecture in April. Harvard Forest again hosted the Rainforest Collaboration middle and high school students in September. This joint UMASS-Boston Public Schools program is now in its sixth year. As part of her work as a research assistant with John O'Keefe, Amanda Gardner, a graduate student at Antioch New England Graduate School, developed a self-guided interpretive nature trail for the Schwarz lot. The trail describes the history, ecology and woodlot management of this 45-acre forest, about half of which was thinned during the summer of 1995.

Meetings, Seminars, Conferences

In July, Harvard Forest hosted an aerial-photography interpretation and training workshop for a group of students from the University of Puerto Rico. Dennis Swartwout from the Cartographic Services Office at the University of Massachusetts assisted David Foster, John O'Keefe and Emery Boose from the Forest and Bob Waide and John Thomlinson from the University of Puerto Rico in explaining the use of historical and recent aerial photographs to study land-use and disturbance history. These students will work with the Luquillo LTER site in Puerto Rico to examine how past land-use in Puerto Rico, surprisingly similar to that in central Massachusetts, may have influenced present forest species distribution, and ecosystem functioning.

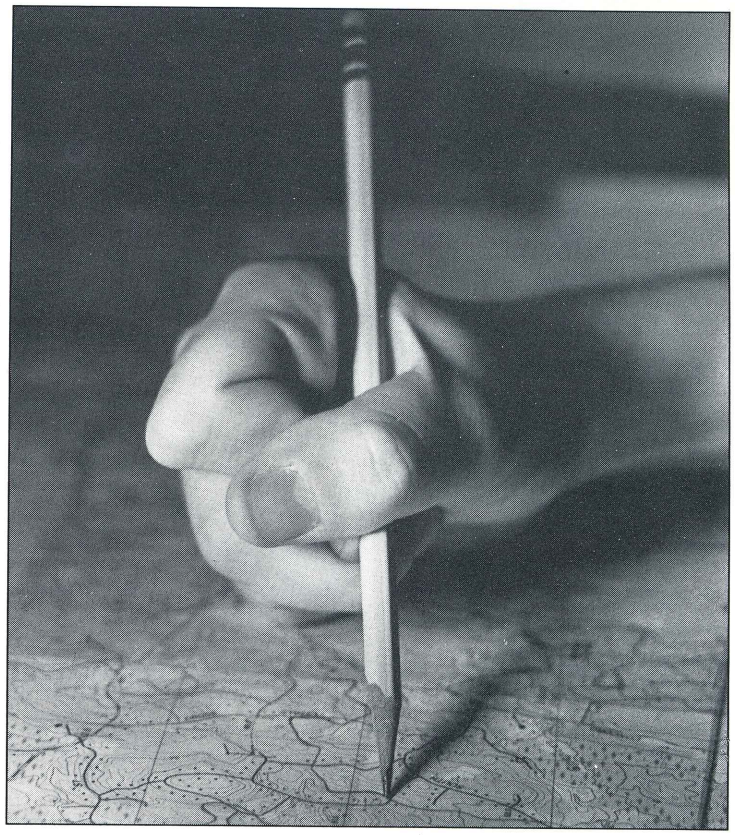
Other meetings at Harvard Forest included the New England Wildflower Society, Millers River Watershed Council, Massachusetts Cooperative Extension Service Coverts Project, New England Chapter of the Wildlife Society, Massachusetts Department of Environmental Management Chapter 132 (Forest Practices Act) revisions public information session, meetings of staff from the U. S. Forest Service and the Metropolitan District Commission and the Harvard University Organismic and Evolutionary Biology Department Faculty Retreat.

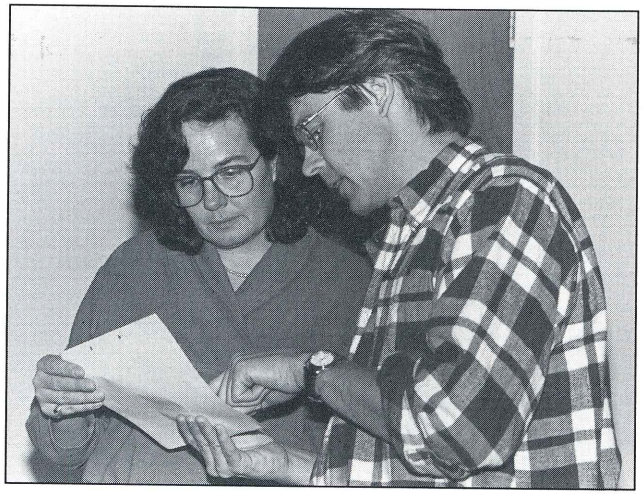
The Fisher Museum continued to host the monthly meetings of the Athol Bird and Nature Club. These meetings have included presentations about research on a variety of native wildlife species including peregrine falcons, porcupines and fishers as well as slide presentations on more exotic species. In August, for the fourth year, we hosted a group of Spanish environmental scientists attending Real Collegio Complutense, a collaborative program between Spanish universities and Harvard. In September the new graduate students from the Landscape Architecture Department of the Rhode Island School of Design were introduced to the Harvard Forest by John O'Keefe and David Foster for the fifth year. In October we hosted Fellows from the Switzer Environmental Foundation and a field trip for environmental journalists who were attending the National Environmental Journalists Conference in Boston. During the morning John O'Keefe and the Harvard Forest staff explained our research to the group and during the afternoon the group organized a panel discussion addressing important environmental issues.

Volunteers Dorothy Andrews and Bob Reed enjoy a beautiful afternoon beside the new Fisher Museum sign

Speakers in the Harvard Forest Seminar series included:

John Aber	University of New Hampshire
Marc Abrams	Pennsylvania State University
Peter Alpert	University of Massachusetts
David Bowman	Bullard Fellow
Grace Brush	Bullard Fellow
Jeff Clark	Johns Hopkins University
Rachel Clark	Gustavus Adolphus College
Jana Comptòn	Harvard Forest
Peter DelTredici	Arnold Arboretum
Mike Flannigan	Petawawa For. Inst., Ontario
David Foster	Harvard Forest
Donna Francis	University of Michigan
Janice Fuller	Harvard Forest
Balachander Ganesan	Bullard Fellow
Douglas Godbold	Bullard Fellow
Matt Hickler	University of Massachusetts
Camilla Hughes	Harvard Forest
Ruth Kern	Duke University
Dave Kicklighter	Marine Biological Laboratory
Dennis Knight	Bullard Fellow
Cecelia Link	Tom Snyder Productions
Richard Lent	Harvard Forest
Charles McClaugherty	Mount Union College
Kathy Newkirk	Marine Biological Laboratory
Dorothy Peteet	Columbia, Lamont-Doherty
Tim Perkins	University of Vermont
Charlotte Pyle	University of Connecticut
Ed Rastetter	MBL, Woods Hole
Timothy Sipe	Gustavus Adolphus College
Dennis Souto	U.S. Forest Service
Julian Szeicz	Queens University, Ontario
Barry Tomlinson	Harvard Forest
Thompson Webb III	Bullard Fellow
Alan White	Bullard Fellow





Kathy Newkirk and Per Gunderson

FOREST MANAGEMENT AND MAINTENANCE

In a continuing effort to expand open space and to recreate the historical landscape around the main Harvard Forest buildings, a three-acre field and orchard were created adjacent to the Community House and a five-acre field was developed at the northern and eastern edges of the Forest Cottage under the supervision of John Edwards. Of the 56,000 board feet harvested from the second operation most was sold as logs to a local mill. We have almost completed fencing the area to accommodate 6-10 cows that we plan to rotate among our three fields in order to maintain pasture, minimize mowing and to add some agricultural realism to the walking tours of the Fisher Museum.

The Torrey Laboratories renovations were completed with landscaping, new sidewalks and a handicapped access ramp. Additional sidewalks, stone retaining walls, and plantings were added to initiate the the conversion of the driveway and lawn areas between Shaler Hall, the Torrey Laboratories, and new Harvard Forest Archives into an open, grassy quadrangle. New lighting, landscaping and sub-surface drainage will be added later this year. An initial assessment of renovation needs and projected construction activities at the Fisher House, was completed by John Edwards.

Harvard Forest Archives

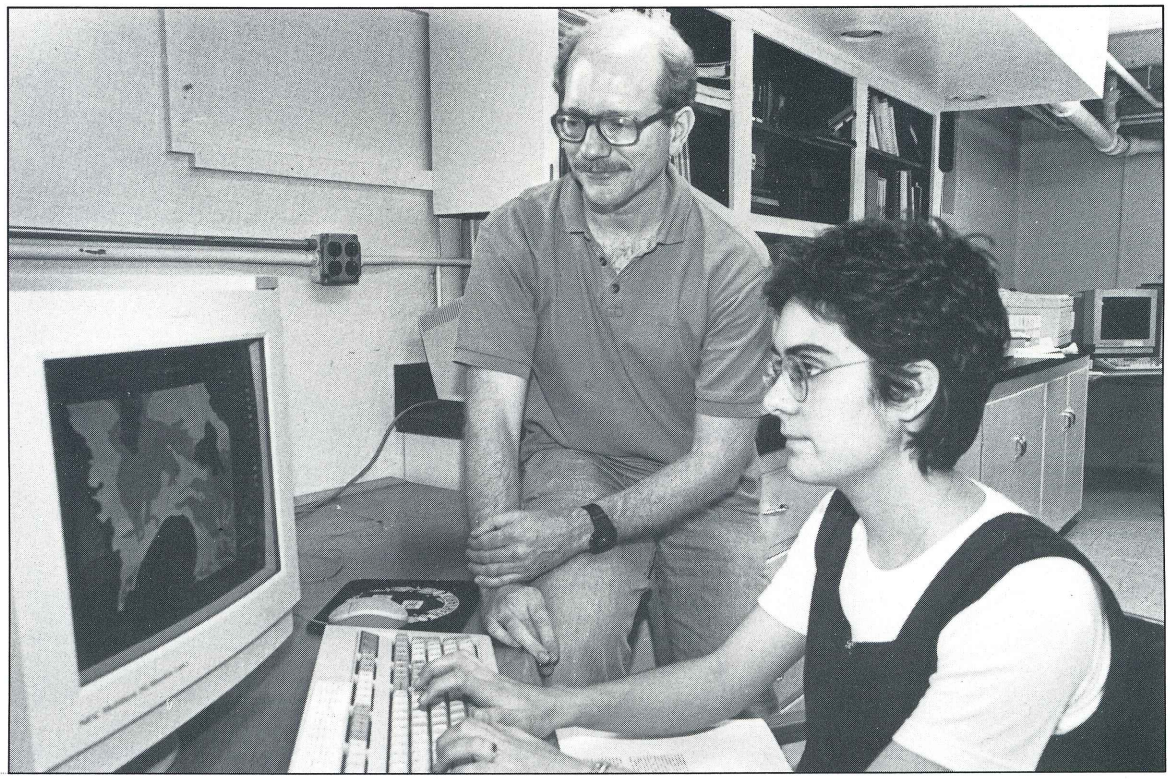
The conversion of Shaler Garage into a new archive facility was completed in June. In the front of the building three rooms provide 1200 square feet of space for historical archives, photographs, cartographic materials, and equipment including stereoscope and zoom transfer scope for air photo analysis, light table and computer with electronic data bases. In the rear of the building we have created a soil and sample archive (350 square feet) and a cold storage facility (two walk-in refrigerators and freezers) for plant, tissue, water and paleoecological samples.

Computer

In October the Forest joined the Harvard University Faculty of Arts and Sciences (FAS) computer network. All office and lab computers at the Forest (currently 35) are now fully connected to the University and to the Internet via a high-speed leased telephone line (56 kbps) from Petersham to Cambridge and via network cable that extends from the electronic "nerve center" in the Shaler Hall vault to offices and labs in all three Forest buildings. Harvard Forest faculty and staff now have direct access to both electronic mail and the World Wide Web from their own desktop computers. Electronic mail accounts are provided by FAS on the computer systems in the Science Center on the main campus. Technical support for the network connection is provided by FAS Network personnel in Cambridge and locally by Emery Boose and Rich Lent. Funding for the connection was provided by FAS, Harvard Forest and the National Science Foundation.

Funding from Harvard Forest and NSF also permitted substantial improvements to data storage and archiving capabilities at the Forest. New acquisitions over the past year included nine new computers, memory and hard disk upgrades and CD-ROM drives for the Computer Lab, 35 Conner tape drives, a CD-Recordable drive for creating CD's, an HP DeskJet 1200C color printer, and a Microtek ScanMaker III color scanner. The scanner can be used with character recognition software to convert old typescripts in the Harvard Forest Archives into machine readable form.

Rich Lent and Barbara Flye enter materials into new Harvard Forest Archives



Emery Boose and Laura Hoffman prepare ESA presentation on the hurricane project

ACTIVITIES OF THE HARVARD FOREST STAFF

Emery Boose, Kris Chamberlin and David Foster presented a poster on their hurricane research at the Ecological Society of America (ESA) meeting, Snowbird, Utah. Emery gave a lecture at UMASS and continued to serve on the LTER Climate Committee. He served as the Forest's IT (Information Technology) contact for FAS and attended a workshop on computer and network security offered by FAS Network personnel. Jana Compton presented the findings of her work on land-use history at the ESA, and at the Forestry Department at UMASS. She spent December and January working on a nitrogen tracer study in the rain-forests of Chiloe Island in southern Chile. Sarah Cooper-Ellis presented a poster entitled "Mosses and liverworts in old-growth forests of western Massachusetts" at ESA.

David Foster was an invited participant in a number of academic and professional conferences including *Ecological Role of Large-scale, Infrequent Disturbances* (National Center for Ecological Analysis and Synthesis, Santa Barbara), *Biodiversity and Ecosystem Function* (LTER, Cedar Creek, Minnesota), *Establishment of a Program for Land-use History in North America* (National Biological Service, Patuxent, Maryland), *Forestry and Forest History in Massachusetts* (Mount Holyoke College), and *Natural Areas Conference on Old-Growth Forests* (Fayetteville, Arkansas). David continues to serve on the Executive Committee of the LTER program, and on boards of the Conservation and Research Foundation, Highstead Arboretum and Mount Grace Land Conservation Trust. At Harvard, he is on the executive committee of the National Institute for Global Environmental Change (DOE) and Executive Secretary of the Bullard Fellowship program. David and Marianne accompanied the Harvard Alumni Association tour to Costa Rica and the Panama Canal, where he served as trip lecturer.

David Foster and Jason McLachlan hosted a workshop for collaborators working on the Gribben Buried Forest, a 10,000 year-old conifer forest that was flooded and buried on the south shore of Lake Superior as the glaciers melted. Individuals attending included K. Pregitzer, D. Reed, G. Mroz, and T. Bornhorst from Michigan Technical University. David, Glenn Motzkin and John O'Keefe led an interpretive tour of the landscape history and conservation biology of the Connecticut River Valley and Central Uplands of Massachusetts in September for a Danish research and government group from Viborg County.

Dana MacDonald and Amy Wolf prepare for a day surveying regional vegetation

Janice Fuller attended the Annual Meeting of the American Association of Stratigraphic Palynologists and presented a paper titled: "The ecological im-pact of the mid-Holocene *Tsuga canadensis* decline in southern Ontario." Julian Hadley presented a talk on microclimatic conditions contributing to red spruce winter injury at the ESA meeting, and at the 14th North American Forest Biology Workshop in Quebec, Canada.

Richard Lent attended the annual LTER Data Manager's Meeting and served on the research committee of the Massachusetts Division of Fisheries and Wildlife Partners in Flight Working Group. He lectured on butterfly ecology to Massachusetts Audubon Society's Broad Meadow Brook Sanctuary, and on bird ecology at Manomet Observatory for Con-servation Science. He organized the 7th Annual Harvard Forest Ecology Symposium and edited the Proceedings (with D. Recos-Smith). Richard served on a PhD examination committee in the Department of Forestry and Wildlife Management, UMASS.

Glenn Motzkin gave a talk at the LTER meeting on Biodiversity held at Cedar Creek Natural History Area, Minnesota. David Orwig attended the First Annual Hemlock Woolly Adelgid Review meeting in Charlottesville, Virginia.

John O'Keefe helped organize the workshop on aerial photographic interpretation for the Puerto Rico collaborators in July and presented seminars on New England forest history at the Science Center of New Hampshire and the Barre Women's Club. He attended the National Society of American Foresters (SAF) Conference in Portland, Maine in October and the New England SAF Conference in Lowell in March. In June he presented with David Foster, a paper on the environmental history of Massachusetts forests at a workshop on Massachusetts Forest History. He accompanied the Rainforest Collaboration group on a trip to the UMASS Nantucket Field Station in April. John joined the board of the Mount Grace Land Conservation Trust in November and continues to serve on the boards of the Massachusetts Forestry Association and the Millers River Watershed Council.

Barry Tomlinson attended two bicentennial celebrations. In December he was an invited speaker at the two-hundredth anniversary celebration of the Palermo Botanic Gardens, Palermo, Sicily, serving also as an official representative of the Botanical Society of America. These celebrations were planned to coincide with the 90th annual meeting of the Italian Botanical

Society. Barry participated in a discussion of the projected status of botanical gardens in the next millennium and a symposium discussing research on palms.

In April Barry was the invited speaker at the 200th anniversary celebration of Botany at the University College, Dublin, Ireland, commemorating the first appointment of a professor of Botany. His topic was "Conifers in Irish Gardens, past, present and future." Although Ireland has only three native species of conifers, its climate is suited to their cultivation and over 200 species are planted. These form the materials for a developing plantation industry, based on exotic conifers, which is projected to turn Ireland into a timber-exporting country by the year 2020. In February, Barry was the convocation speaker at the University of Guelph, Ontario, Canada, at which ceremony he received the honorary degree of Doctor of Science, the first time botany has been so recognized at this function.

In Memorium

Ann Gould, long-time member of the Harvard Forest and Petersham communities with her husband Ernie, passed away in Largo, Florida, where she has been living for the past five years. Ann will always be remembered as a delightful hostess with a spontaneous and infectious sense of humor. Memorial gifts in Ann's name are being used to support the educational activities of the Gould Audiovisual Center in the Fisher Museum at the Harvard Forest. Catherine Danahar, business secretary at the Harvard Forest from 1969-1984 passed away in San Antonio, Texas, where she had resided for the past nine years. Staff at the Harvard Forest were also saddened to learn of the death of former staff member Craig Whiting. Craig served as a research assistant in soils, surveying, and graphic and architectural design.

Gifts and New Funding

The family of Richard T. Fisher, first director of the Harvard Forest, made a magnificent donation consisting of an early 19th C house (Fisher House) and cottage (the Schoolhouse), pool, outbuildings and five acres of land. The property abuts the Harvard Forest along Prospect Hill Road only 300 yards from Shaler Hall and, when renovated, it will serve as a residential and research center for visiting faculty and students. The National Science Foundation has awarded the Harvard Forest with a grant for $104,000 in order to undertake the renovations necessary to complete this important new facility.

Gifts from anonymous friends of the Harvard Forest enabled the acquisition of a 20-acre tract of land (the Lewis Lot) along Sunset Lane in the center of Petersham. The property abuts the Tom Swamp tract and will provide an important conservation buffer adjacent to major experimental areas of the LTER program.

Julian Hadley and David Foster were awarded a one-year grant for $67,000 from the Department of Energy National Institutes for Global Environmental Change to study photosynthesis and gas exchange in eastern hemlock. This project will erect a canopy access tower in an older growth hemlock forest in the Prospect Hill tract in order to conduct this study.

David Foster and Thompson Webb III from Brown University received a one year grant for $80,000 from the Bermuda Biological Station for Research to conduct a paleoecological study of hurricane impacts to southern New England. As part of the Land Use History of North American program sponsored by the National Biological Service, David Foster was awarded a pilot grant of $15,000 in order to develop a series of land-use maps for central Massachusetts and New England.

A Research Experience for Undergraduate site grant for $149,386 was awarded from the National Science Foundation effective June 1, 1996 for a three-year period. This award provides major support for the Harvard Forest Summer Research Program for Undergraduates.

Work begins at the Fisher House
Chuck Hildreth, Jack Edwards and Pete Spooner (left to right)

VISITING RESEARCH SCIENTISTS AT THE HARVARD FOREST 1995-96

In addition to Harvard Forest researchers a large number of Harvard University and outside scientists made use of Harvard Forest facilities and research sites. Many of these scientists were involved in the Harvard Forest Long Term Ecological Research (LTER) program or in Harvard University's Northeast Regional Center of the National Institute for Global Environmental Change (NIGEC) project.

John Aber	University of New Hampshire
David Ackerly	Harvard University
Jeff Amthor	Lawrence Livermore Lab
Peter Bakwin	Harvard University
Dennis Baldocchi	NOAA/ARL, Oak Ridge, TN
Diana Barnes	Harvard University
Susan Bassow	Harvard University
Fakhri Bazzaz	Harvard University
Beth Belk	Woods Hole Research Center
Glenn Berntson	Harvard University
Mike Binford	Harvard University
K. Boering	Harvard University
Richard Boone	University of Alaska
Rich Bowden	Allegheny College
Frank Bowles	Ecosystems Center - MBL
Jennnifer Bravo	Brown University
Ted Bornhorst	Michigan Technical University
Sebastian Catovsky	Harvard University
Chris Catricala	Ecosystems Center - MBL
Jeannine Cavender-Bares	Harvard University
Chaur-Fong Chen	Oregon State University
Stephanie Ciccarello	Antioch New England
Rachel Clark	Gustavus Adolphus College
Alan Coleman	Harvard University
Patrick Crill	University of New Hampshire
William Currie	University of New Hampshire
Peter Czepiel	Harvard University
Eric Davidson	Woods Hole Research Center
Bruce Daube	Harvard University
Peter Del Tredici	Arnold Arboretum
Michael Donoghue	Harvard University
Marty Downs	Ecosystems Center - MBL
Todd Drummey	Ecosystems Center - MBL
Joseph Elkinton	University of Massachusetts
Elizabeth Farnsworth	Harvard University
David Fitzjarrald	SUNY. Albany
Son-Miao Fan	Harvard University
Richard Forman	Harvard University
Amanda Gardner	Antioch New England
Lisa George	Harvard University
Alan Goldstein	Harvard University
Michael Goulden	Harvard University
Dennis Gray	SUNY, Stony Brook
Robert Harriss	University of New Hampshire
Joseph Hendricks	University of New Hampshire
Kristiina Hill	Massachusetts Institute of Technology
Michelle Holbrook	Harvard University
David Hollinger	U.S. Department of Agriculture
Lauren Interness	Woods Hole Research
Daniel Jacob	Harvard University
Henry Jacoby	Massachusetts Institute of Technology
Doug Karpa	Harvard University
Shoichi Kawano	Kyoto University
Chris Kerfoot	Ecosystems Center - MBL
David Kicklighter	Ecosystems Center - MBL
Bruce Kindel	University of Colorado, Boulder
David Kittredge	University of Massachusetts
Otto Klemm	University of New Hampshire
Xuhui Lee	Yale University
Barry Lefer	University of New Hampshire
Manuel Lerdau	SUNY, Stony Brook
Sue Leschine	University of Massachusetts
Mary Ann Levine	University of Massachusetts
Alison Magill	University of New Hampshire
Mary Martin	University of New Hampshire
Charles McClaugherty	Mount Union College
Ernesto Medina	Centro de Ecologia y Ciencias Venezuela
Jerry Melillo	Ecosystems Center - MBL
Jennie Moody	University of Virginia
Kathleen Moore	SUNY. Albany
Glenn Mroz	Michigan Technical University
Mitch Mulholland	University of Massachusetts
J. William Munger	Harvard University
Knute Nadelhoffer	Ecosystems Center - MBL
Sarah Neelon	Smith College
Kathy Newkirk	Ecosystems Center - MBL
Fred Paillet	U.S. Geological Survey
William Patterson	University of Massachusetts
Bob Pearcy	University of California, Davis
Marc Potosnak	Harvard University
Ronald Prinn	Massachusetts Institute of Technology
Kurt Pregitzer	Michigan Technical University
David Reed	Michigan Technical University
Andrea Ricca	Ecosystems Center - MBL
Michael Rogers	GA Institute of Technology
Richard Rosen	AER, Inc.
Emily Russell	Rutgers University
Brian Shelley	College of the Holy Cross
Timothy Sipe	Gustavus Adolphus College
Paul Steudler	Ecosystem Center - MBL
Britt Stephens	U.S. Geological Survey
Peter Stone	Massachusetts Institute of Technology
Eric Sundquist	U.S. Geological Survey
Robert Talbot	University of New Hampshire
John Thomlinson	University of Puerto Rico
Susan Trumbore	UCLA, Irvine
Joannah Whitney	UMASS
Brayton Wilson	University of Massachusetts
Paul Wilson	University of California, Northridge
Greg Winston	U.S. Geological Survey
Richard Wilson	Harvard University

PUBLICATIONS

Aber, J. D., A. Magill, S. G. McNulty, R. Boone, K. J. Nadelhoffer, M. Downs and R. A. Hallett. 1995. Forest biogeochemistry and primary production altered by nitrogen saturation. Water, Air and Soil Pollution 85: 1665-1670.

Aber, J. D., P. B. Reich and M. L. Goulden. 1996. Extrapolating leaf CO_2 exchange to the canopy: a generalized model of forest photosynthesis validated by eddy correlation. Oecologia 106: 257-265.

Allen, A. 1995. Soil science and survey at Harvard Forest. Soil Survey Horizons 36: 133-142.

Bowman, D. M. J. S. 1995. Two examples of the role of ecological biogeography in Australian prehistory; The fire ecology of *Callitris intratropica* and the spatial pattern of stone tools in the Northern Territory. Australian Archaeology 41: 8-11.

Bowman, D. M. J. S. and I. Rainey. 1995. Tropical tree stand structures on a seasonally flooded elevation gradient in northern Australia. Australian Geographer 27: 31-37.

Bowman, D. 1995. Down in the forest something stirred. . . . New Scientist. December, p. 54.

Campbell, S. and D. B. Kittredge. 1996. Ecosystem-based management of multiple NIPF ownerships. Journal of Forestry 94: 24-29.

Castro, M. S., J. M. Melillo, J. D. Aber and R. D. Bowden. 1995. Soil moisture as a predictor of methane uptake by temperate forest soils. Canadian Journal of Forest Research 24: 1805-1810.

Castro, M. S., P. A. Steudler, J. M. Melillo, J. D. Aber and R. D. Bowden. 1995. Factors controlling atmospheric methane consumption by temperate forest soils. Global Biogeochemical Cycles 9: 1-10.

Cronk, Q. C. B. and J. L. Fuller. 1995. *Plant Invaders: The Threat to Natural Ecosystems*. Chapman & Hall, London.

Donohue, K. 1995. The spatial demography of mistletoe parasitism on a *Yemeni acacia*. International Journal of Plant Sciences 156: 816-823.

Dunwiddie, P., D. Foster, D. Leopold and R. Leverett. 1996. Old-growth forests of southern New England, New York and Pennsylvania. Pp. 126-143 (M. B. Davis, Ed.), *Eastern Old Growth Forests*. Island Press, Covelo, CA.

Foster, D. R. 1996. The Harvard Forest Long Term Ecological Research Program. LTER Bulletin 19: 6-7.

Foster, D. R., D. A. Orwig, and J. O'Keefe. 1996. Evaluation of the old-growth forest at Mount Wachusett, central Massachusetts. Report to the Department of Environmental Management, Commonwealth of Massachusetts. 9 pp.

Goldstein, A. H., B. C. Daube, J. W. Munger and S. C. Wofsy. 1995. Automated *in situ* monitoring of atmospheric non-methane hydrocarbon concentrations and gradients. Journal of Atmospheric Chemistry 21: 43-59.

Goldstein, A. H., S. C. Wofsy and C. M. Spivakovsky. 1995. Seasonal variations of non-methane hydrocarbons in rural New England: constraints on OH concentrations in northern midlatitudes. Journal Geophysical Research 100: 21023-21033.

Goldstein, A. H., S. -M. Fan, M. L. Goulden, J. W. Munger and S. C. Wofsy. 1996. Emsisions of ethene, propene and 1-butene by a midlatitude forest. Journal of Geophysical Research 102: 9149-9157.

Jacobson, H. A. and D. R. Foster. 1995. Development of raised bogs in central Sweden: geographical patterns and the role of climate change. Ecology 76: 2503-2516.

Kittredge, D. B. Jr., 1995. Logging & the protection of Rare Wetland Species Habitat. The Northern Logger & Timber Processor, October: 25-33.

Kittredge, D. B. Jr., and M. Parker. 1995. Massachusetts Forestry Best Management Practices Manual. Prepared for Massachusetts Department of Environmental Protection and U. S. Environmental Protection Agency. 56 pp.

Kittredge, D. B., Jr., M. J. Mauri and E. J. McGuire. 1996. Decreasing woodlot size and the future of timber sales in Massachusetts: When is an operation too small. Northern Journal of Applied Forestry 13: 96-101.

Lent, R. A. and D. E. Capen. 1995. Effects of small-scale habitat disturbance on the ecology of breedingbirds in a Vermont (USA) hardwood forest. Ecography 18:97-108.

Lent, R. A. and D. Recos-Smith (editors). 1996. Abstracts from the 7th Annual Harvard Forest Ecology Symposium. Harvard Forest, Petersham, MA.

Lewis, A. M. and E. R. Boose. 1995. Estimating volume flow rates through xylem conduits. American Journal of Botany 82(9): 1112-1116.

McLachlan, J. S. and L. B. Brubaker. 1995. Local and regional vegetation change on the northeastern Olympic Peninsula during the Holocene. Can. J. Bot. 73: 1618-1627.

Motzkin, G., D. Foster, A. Allen, J. Harrod and R. Boone. 1996. Controlling site to evaluate history: vegetation patterns of a New England sand plain. Ecological Monographs 66: 345-365.

Motzkin, G., W. A. Patterson III and N.E.R. Drake. 1996. Fire history and vegetation dynamics of a *Chamaecyparis thyoides* wetland on Cape Cod,

Massachusetts. Pp. 116-129 **In** F. B. Samson and F. L. Knopf (Eds.), *Ecosystem Management - Selected Readings*. Springer, New York (reprinted from Journal of Ecology 81: 391-402).

Munger, J. W., S. C. Wofsy, P. S. Bakwin, S.-M. Fan, M. L. Goulden, B. C. Daube and A. H. Goldstein. 1996. Atmospheric deposition of reactive nitrogen oxides and ozone in a temperate deciduous forest and a sub-arctic woodland. 1. Measurements and mechanisms. Journal Geophysical Research 101: 12639-12657.

Neelon, Sarah E. 1996. The Response of Understory Vegetation to Simulated Hurricane Disturbance. Honors Thesis, Smith College.

Orwig, D. A. and M .D. Abrams. 1995. Dendroecological and ecophysiological analysis of gap environments in mixed-oak understories of northern Virginia. Functional Ecology 9:799-806.

Schmid, B., F. A. Bazzaz and J. Weiner. 1995. Size dependence of sexual reproduction and of clonal growth in two perennial plants. Canadian Journal of Botany 73: 1831-1837.

Steudler, P. A., R. D. Jones, M. S. Castro, J. M. Melillo and D. L. Lewis. 1995. Microbial controls of methane oxidation in temperate forest and agricultural soils. NATO ASI Series, 139: 70-84.

Tomlinson, P. B. 1995. The leaf base in palms: structural and functional aspects. Giornale Botanico Italiano 129: 466-479

Tomlinson, P. B. 1996. Joinvilleaceae: In *The World of Plants."* Asahi Shimbun Press, Tokyo (In Japanese).

Vazquez-Yanes, C. 1994. La fisiologia ecologica de plantas en Mexico. Bol. Society of Botany, Mexico 55: 137-139.

Vazquez-Yanes, C. and A. Orozco-Segovia. 1996. Physiological ecology of seed dormancy and longevity. Pp. 535-558 **In** S. S. Mulkey, R. L. Chazdon and A. P. Smith (Eds.), *Tropical Forest Plant Ecophysiology*, Chapman & Hall, New York.

Wilson, P. 1995. Selection for pollination success and the mechanical fit of *Impatiens* flowers around bum-blebee bodies. Biological Journal of the Linnean Society 55: 355-383.

York, E. C. 1996. Fisher population dynamics in north-central Massachusetts. MS thesis, University of Massachusetts, Amherst.

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Massachusetts Natural Heritage and Endangered Species Program
A. W. Mellon Foundation
National Aeronautics and Space Adminsitration
National Biological Service
National Geographic Society
National Science Foundation
    Collaborative Research for Undergraduates
    Ecosystem Studies
    Long-term Studies
    Ecology Program
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