

THE HARVARD FOREST 1994 - 95

Harvard University



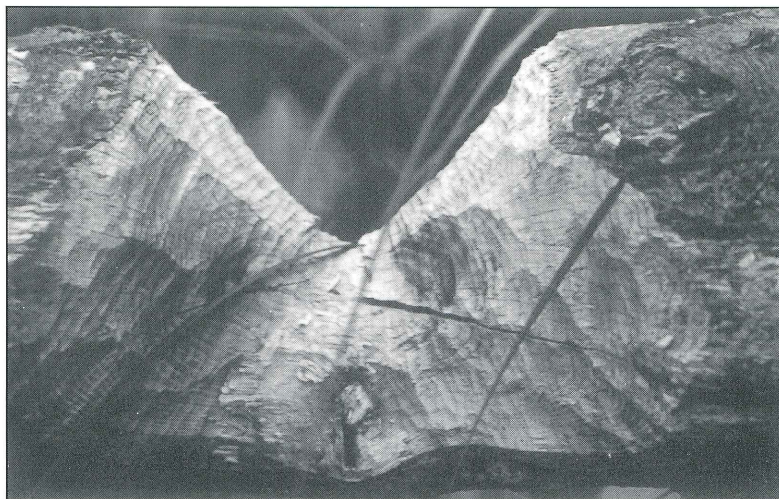
Cover photograph

Harvard Pond after a summer of drought

ANNUAL REPORT OF THE HARVARD FOREST 1994-1995

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Photography by Laura Wulf

PERSONNEL AT THE HARVARD FOREST 1994-95

Arthur Allen	Research Assistant	David B. Kittredge, Jr.	Charles Bullard Fellow
Michael Binford	Associate	Gong Wooi Khoon	Charles Bullard Fellow
Richard D. Boone	Soil Ecologist	Joan Kraemer	Clerk Typist
Emery R. Boose	Computer Scientist	Christopher Kruegler	Administrator
Richard D. Bowden	REU Coordinator	Oscar P. Lacwasan	Custodian
Jeannette M. Bowlen	Accountant	Sharachchandra Lele	Charles Bullard Fellow
David M. Bowman	Charles Bullard Fellow	Richard A. Lent	Data Manager
Jana D. Canary	Research Assistant	Anita Locke	Summer Cook
Kristen Chamberlin	Research Assistant	Catherine M. Mabry	Research Assistant
Jana Compton	Research Associate	Jason McLachlan	Research Assistant
John F. Connolly	Charles Bullard Fellow	Daniel Manter	Research Assistant
Sarah Cooper-Ellis	Research Assistant	Patricia Micks	Research Assistant
Evan H. DeLucia	Charles Bullard Fellow	Ellen G. Moriarty	Graphic Artist
Sean M. Divoll	Woods Crew	Glenn H. Motzkin	Research Assistant
Kathleen Donohue	Research Associate	John F. O'Keefe	Museum Coordinator
Elaine D. Doughty	Laboratory Assistant	David Orwig	Research Associate
Natalie Drake	Palynologist	Hugh M. Raup	Charles Bullard Professor, <i>Emeritus</i>
John A. Edwards	Forest Manager	Emily Russell	Visiting Scholar
Marcheterre Fluet	Research Assistant	Timothy W. Sipe	Charles Bullard Fellow
Barbara J. Flye	Librarian/Secretary	Dorothy R. Smith	Secretary
E. David Ford	Charles Bullard Fellow	Charles C. Spooner	Woods Crew
Charles H. W. Foster	Associate	Mark Thibault	Woods Crew
David R. Foster	Director	P. Barry Tomlinson	E. C. Jeffrey Professor of Biology
Lisa George	PhD Candidate, OEB	Carlos Vazquez-Yanes	Charles Bullard Fellow
David Godbold	Charles Bullard Fellow	Robert Waide	Charles Bullard Fellow
Alisa Golodetz	Research Assistant	Jacob Weiner	Charles Bullard Fellow
Julian L. Hadley	Research Associate	Paul S. Wilson	Research Associate
Donald E. Hesselton	Woods Crew	Benjamin Wisnewski	Woods Crew
Steven Holmes	Woods Crew	John S. Wisnewski	Woods Crew
Camilla J. Hughes	Visiting Scholar	Steven C. Wofsy	Associate
Guy D'Oyly Hughes	MFS Candidate		
David P. Janos	Charles Bullard Fellow		



INTRODUCTION TO THE HARVARD FOREST

Since its establishment in 1907 the Harvard Forest has served as a base 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 and 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. 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, 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 conifer plantations; and the 90-acre Tall Timbers Forest in Royalston, Massachusetts. In Petersham a complex of buildings that includes Shaler Hall, the Fisher Museum, and the John G. Torrey Laboratories provides office and laboratory space, computer and greenhouse facilities, and a lecture room and lodging for seminars and conferences. An additional six houses and apartments provide housing for staff, visiting researchers, and students. Extensive records of plant research, long-term data sets, and historical information 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) 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 of approximately 50 work collaboratively to achieve the research, educational and management objectives of the Harvard Forest. A sub-group of researchers meet monthly to discuss current activities and to plan future programs. Regular meetings with the HF LTER science team and with the Harvard Forest Advisory Committee provide 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 base operation and staff at the Harvard Forest is derived from endowments, whereas research activities are supported 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 Northeastern Consortium for Undergraduate Science Education (Pew Charitable Trust), the A. W. Mellon Foundation, and the R. T. Fisher Fund of Harvard Forest.

NEW STAFF

Recent additions to staff include Emily Russell, who comes to us as a Visiting Scholar from the faculty of Rutgers University; Kathleen Donohue and David Orwig, new Research Associates from Brown and Pennsylvania State universities respectively; Research Assistants Kristen Chamberlin, Sarah Cooper-Ellis, and Jason McLachlan; and Christopher Kruegler, who provides additional personnel, financial, and planning support in the newly created position of department Administrator. Finally, Charles H. W. Foster, Research Fellow and Lecturer at the John F. Kennedy School of Government's Center for Science and International Affairs, joins us as a faculty Associate in the area of environmental policy.

RESEARCH ACTIVITIES

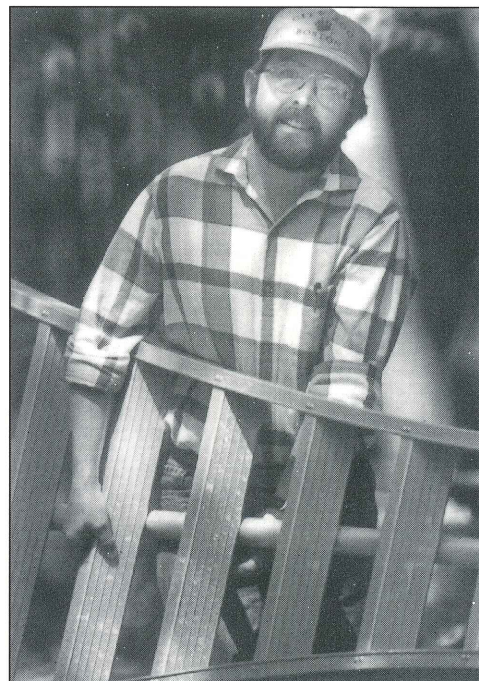
Land-use History and Forest Ecosystem Dynamics

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 low aboriginal populations, the landscape was rapidly and extensively deforested by European settlers for commercial 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 70-85% forested at present. 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

Basic questions surrounding the impact of land-use history on New England vegetation include: What was the original vegetation of the region? How



Chris Kruegler

was it changed temporally and spatially as a result of varied land-use practices? To what extent does the modern vegetation resemble that of the past? In order to address these questions we have developed paleoecological studies that examine the pollen content of lake sediments and soils across the region.

Emily Russell collaborates on paleoecological studies at the regional scale. Working with David Foster, Jason McLachlan, and Rich Lent, Emily has developed a pollen database from 100 sites across New England that were compiled in collaboration with Ron Davis at the University of Maine. A similar dataset is being developed by David, Jason, Natalie Drake, Elaine Doughty, and Mike Binford for the central Massachusetts region. In both studies 500-2000 year-old records of vegetation change, fire history, and lake history will be compared and related to detailed land-use histories derived from census data, historical maps, and archives. In conjunction with this project Mitch Mulholland, Joannah Whitney, and Mary Ann Levine (UMASS) have been synthesizing the archaeological records for over 650 sites across central Massachusetts to obtain information on prehistorical human densities and cultures. The synthesis of paleoecological and archaeological data will greatly strengthen our interpretation of pre-European fire history and vegetation dynamics. Dating of materials for paleoecological studies is being accomplished through the analysis of two natural isotopes: Pb-210, which can be assessed in our new paleoecology laboratory and C-14, which is analyzed at outside laboratories.

At the stand scale Jason McLachlan, summer student Fabian Menalled, and David Foster are examining the forest dynamics of hemlock stands from pre-settlement time to the present. Hemlock forests are particularly interesting because they represent one of the least disturbed and oldest forest types in the New England landscape. Thus, the record of change in these stands represents a conservative estimate of the rate and extent of forest change resulting from human impacts. At four sites in the Prospect Hill and Slab City tracts, samples of the deep (~20 cm) organic soil are being analyzed for pollen and plant macrofossils. Fabian and Jason are sampling the modern vegetation and are analyzing tree rings from more than 400 trees to provide additional information on forest development. Results will be compared to prior studies in the Prospect Hill tract and form part of a large project examining the role and dynamics of old-growth hemlock forests in New England.

Community Ecology and Conservation Biology

It is clear that the structure and composition of New England forests are strongly linked to past human activity. However, due to variation in intensity, timing, and type of land-use and the confounding interaction between land-use and site conditions these relationships are often complex. A group including Glenn Motzkin, Art Allen, and David Foster have developed a series of studies to interpret these relationships and to apply this information to the conservation of natural areas. In 1994 we concluded a study of vegeta-

tion patterns, soils, and disturbance history of a large sand plain in the Connecticut Valley. At this site, where soils and environmental variation were minimal, the vegetation:land-use relationships were distinct and very long-lasting for particular species. For example, we found that land use, soils morphology (presence/absence of a plow layer), and vegetation changed abruptly at many ownership boundaries and that certain plant species are highly restricted in their distribution to either plowed or unplowed sites.

On the much more varied uplands of Petersham, plant and land-use relationships are less clear due to the substantial environmental heterogeneity. In order to unravel the complex interactions between land-use, soils, and modern community composition an analysis of vegetation, physical, and historical data collected from 269 plots on Prospect Hill is being completed by Glenn, Art, and David. With Paul Wilson, Glenn also sampled bryophytes on 105 of these plots to enable a comparison of vascular and non-vascular species response to similar environmental conditions and land-use history.

In related studies, Glenn is completing a study of distribution, composition, and history of pitch pine-scrub oak communities throughout the Connecticut Valley with David and Bill Patterson (UMASS). He also completed an inventory of uncommon plant communities throughout western Massachusetts for the Massachusetts Natural Heritage and Endangered Species Program. Inventory efforts focused on calcareous wetlands, floodplain forests, and sand plain communities.

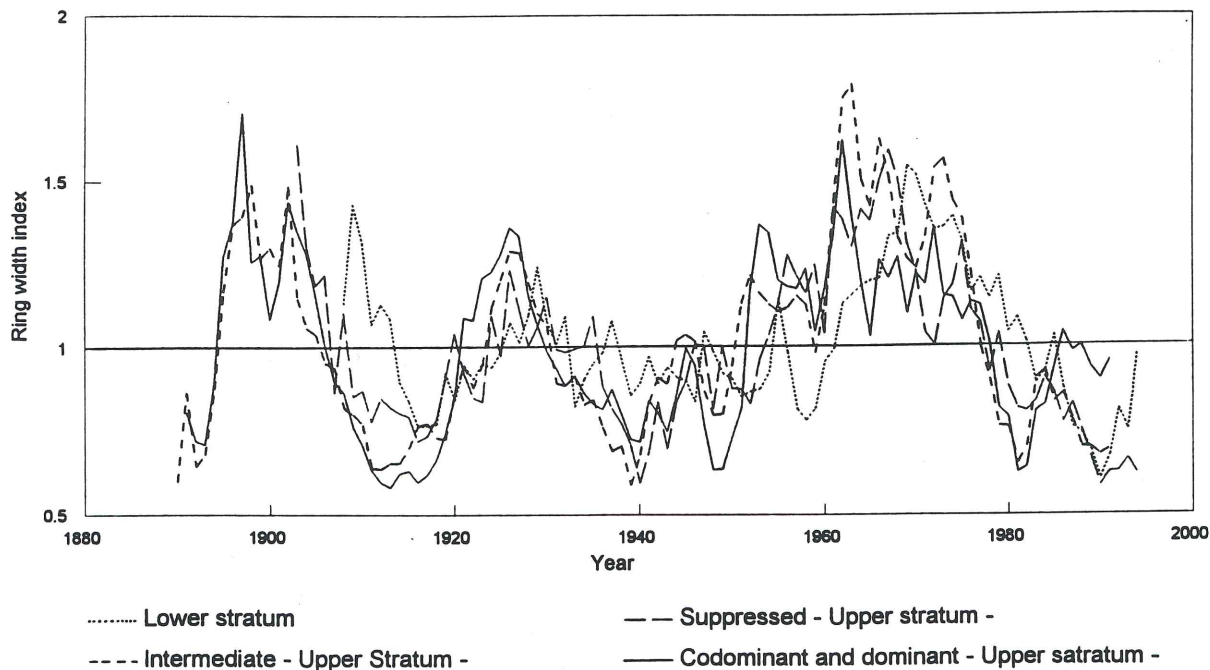


Figure 1. Tree ring analysis from an old hemlock stand on Prospect Hill. The ring width of trees shows considerable variation between years but remarkable similarity for trees in different layers (strata) of the forest canopy. Periods of fast growth were stimulated by increased light resulting from canopy openings produced by: heavy logging (1890-1905), mortality of chestnut from blight (1918-1930) and selective removal of hardwood trees (1960-1975).

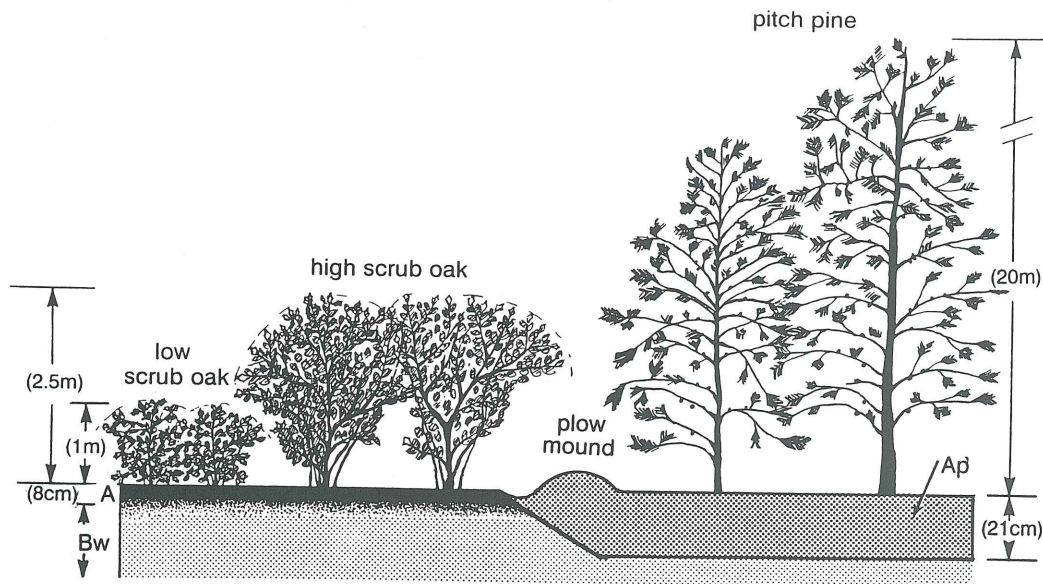


Figure 2. Cross-sectional diagram across the major land-use, vegetation, and soils boundary at the Montague sand plain. Unplowed sites (left) support scrub oak on soils that exhibit a dark and shallow A horizon and gradual transition to B horizon below. In contrast, sites plowed for agriculture (right) support pitch pine, which seeded into abandoned agricultural fields. Even after 75-100 years of forest growth the soils on the plowed sites exhibit a deep and light-colored A horizon, separated by a sharp transition from the underlying B horizon.

Plant Populations

In order to understand the biological mechanisms underlying the land-use:vegetation patterns documented in the studies described above, Kathleen Donohue has initiated population studies of species that show distinct distributional patterns related to land-use history. In particular the Connecticut Valley sand plain offers a system that minimizes the complex interactions between land-use and edaphic factors and Kathleen is using this site to investigate how land-use influences population demography of restricted species, and how population dynamics influences their distributional patterns.

The main question that Kathleen would like to address is whether the distribution of the restricted species is due to dispersal limitation, differences in environmental factors on formerly plowed versus unplowed sites that cause performance differences, or intrinsic life history properties of the species that make them poor at colonization or establishment after agricultural abandonment. To address this question, she is conducting comparative, observational demographic studies and initiating transplant experiments on wintergreen (*Gaultheria procumbens*).

Three summer students assist Kathleen on the project. Lonnie Williams III is investigating how species presence and abundance change as a function of distance from the boundary between plowed and unplowed sites, and how time since agricultural aban-



Kathleen Donohue sampling population dynamics in the forest herb layer

donment and overstory composition influence species distributions. Elizabeth Zacharias is examining how variable the morphological structure and growing patterns of wintergreen are in the two land-use types, and Satya Maliakal is investigating mycorrhizal associations with wintergreen, huckleberry, and two species of blueberry growing in the two land-use types.

An additional, though quite invisible legacy of past land-use is the retention of viable buried seeds from species that have been more abundant on a site during the past ten to over one hundred years. Following a disturbance such as wind damage, an array of new species frequently germinate and establish from the buried seed pool. In order to evaluate the composition of buried seeds and to relate it to contrasting site histories, Sarah Cooper-Ellis and David Foster designed a study of forest seed banks on Prospect Hill, comparing permanently forested sites to those that have been pastured and tilled. With summer student Annabel Bradford, Sarah began sampling soils, extracting and identifying seeds, and germinating buried seeds in the newly renovated greenhouse.



Sarah Cooper-Ellis and summer student Annabel Bradford

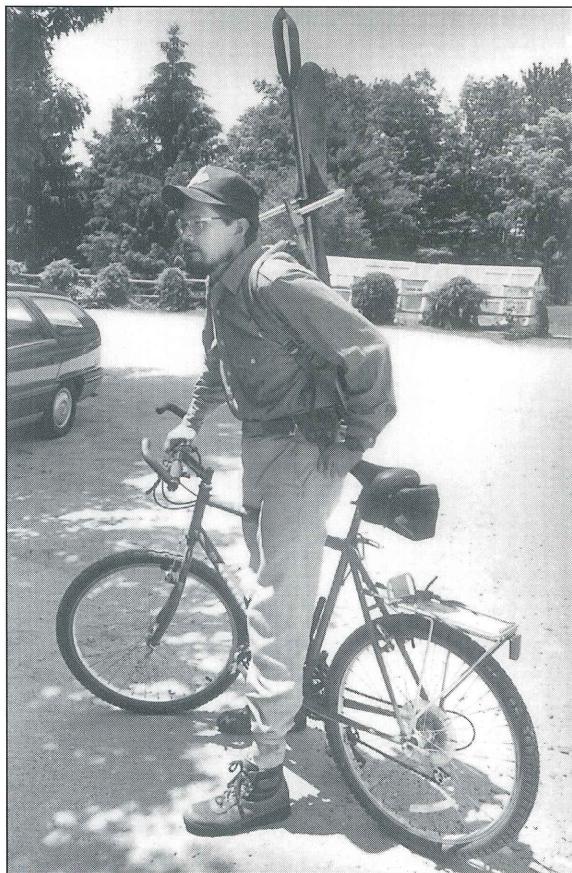
Soil and Ecosystem Response to Land Use

In addition to long-term impacts on vegetation, land-use may create legacies in terms of the morphological, biogeochemical, and functional aspects of soils. Important ecological questions that emerge and are being addressed by Harvard Forest soil scientists include: What is the nature of these impacts? How do they compare to natural variation in soils resulting from environmental differences? How long do these effects persist following land-use abandonment and reforestation?

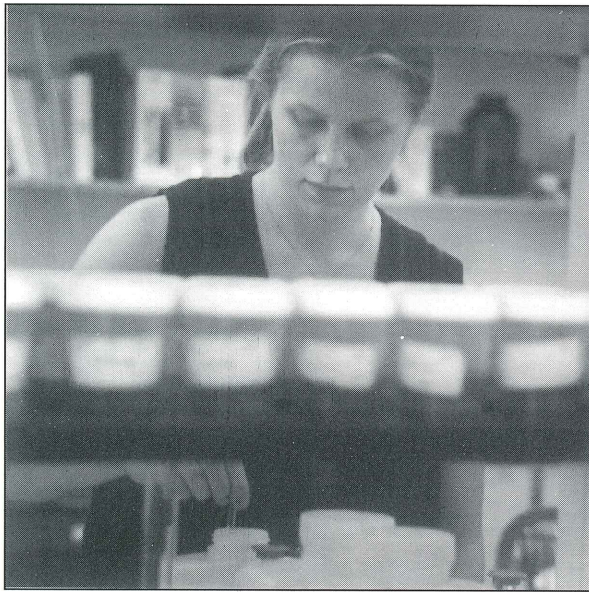
In order to develop a comprehensive baseline of land-use and soils information, Art Allen initiated an evaluation of Prospect Hill land-use maps based on field verification of soil and physiographic indicators. He updated the soil surveys for all Harvard Forest tracts, incorporating modern soil taxonomy and recent soil investigation results. This work and associated soil analyses form a basis for vegetation:land-use studies and site selection for studies of ecosystem processes. As an outgrowth of this activity Art is publishing a paper describing the significance of soil science and survey work at Harvard Forest since its inception in 1907.

The past clearance and agricultural use of presently forested land in New England may have resulted in very long-lasting changes in the amounts and availability of soil carbon and nitrogen. This potential land-use legacy is being examined by Jana Compton in a project coordinated by David Foster and Rich Boone on the loamy till soils of Prospect Hill and in the sandy outwash soils in the Connecticut River Valley. With Art Allen and Glenn Motzkin, sites were selected which were formerly plowed, pastured, or permanent woodlots, across a range of present vegetation types.

Several interesting findings have emerged for Prospect Hill: (1) higher net nitrogen mineralization in permanent woodlot soils than in formerly plowed or



Art Allen heading out for a day of soil sampling



Jana Compton

pastured soils; (2) significantly higher net nitrification in the formerly plowed soils; and (3) microbial nitrogen content decreased in the order woodlot>pastured>plowed. In contrast, the sandy Connecticut Valley soils showed no long-lasting imprint of former land use on nitrogen cycling rates; present-day vegetation and perhaps fire seemed to exert a stronger control. This work suggests that at Prospect Hill, where cultivation spanned many decades, nitrogen cycling rates did not recover to pre-disturbance levels despite nearly 100 years of reforestation. Changes in soil carbon due to cultivation are being measured in conjunction with Eric Davidson of the Woods Hole Research Center.

Comparative Studies in New England and Puerto Rico

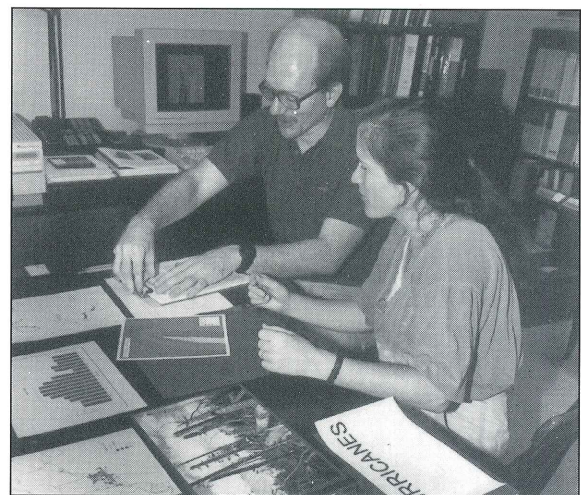
Despite tremendous differences in climate, vegetation, and physiography the landscape of Puerto Rico and New England share many similarities, notably their history of deforestation, agriculture, and reforestation. David Foster, Emery Boose, and others at the Harvard Forest are investigating the patterns of land-use history, revegetation, and forest dynamics of the Luquillo Experimental Forest as part of an inter-LTER project. Collaborations with Bob Waide, John Thomlinson, and Jesse Zimmerman at the University of Puerto Rico were strengthened this year through new funding from the NSF LTER programs and NASA. The current studies in Puerto Rico rely on the interpretation of aerial photographs (1936-1989), archival research, and hurricane exposure models to understand the relative importance of natural and anthropogenic factors in controlling vegetation patterns and change. The resulting analysis suggests that the dominant factor determining 20th C forest patterns is land-use. However, as forest cover and forest height increase due to farmland abandonment in the early to mid 20th C the relative importance of natural disturbance and environment will continue to increase.

Natural Disturbance in New England Forests

Hurricane Disturbance to New England Forests

The impacts of past hurricanes on New England forests, from the Great Colonial Hurricane (1635) to Hurricane Bob (1991), are being investigated by Emery Boose, Kris Chamberlin and David Foster, through a combination of computer modeling and historical studies. During the past year efforts focused on data collection, detailed analyses of six modern hurricanes (1938, 1944, Carol, Donna, Gloria and Bob), and refinement of modeling techniques. Data from these storms led to several improvements in the ability to reconstruct wind conditions using the HURRECON model. Emery and Kris also worked on adapting the Fujita scale of wind damage to classify damage reports from historical hurricanes. This scale, developed by T. Fujita at the University of Chicago, is widely used to characterize tornado damage. The HURRECON model was extended to predict Fujita damage values directly, and results to-date suggest that it may be possible to predict regional wind damage given summary meteorological data on a hurricane's track, size, and intensity.

The next phase of the project will involve reconstructing hurricanes of the more distant past. As a start in this direction, summer students working with Emery and Kris have been studying the 1815 and 1635 hurricanes. Last summer Sherry Baker collected damage and wind reports from 1815 for nearly 130 towns across southern and central New England, enough data to reconstruct the storm with reasonable accuracy. This summer Melissa Feldberg collected reports from 1635 for the early settlements along the New England coast. Though the data are sketchy, it is possible to draw conclusions about the track, intensity, and damage patterns even for this early storm.



**Emery Boose and Kris Chamberlin
preparing a poster on hurricane modeling**



Elaine Doughty and Jackie Bartee compare notes on the hurricane blowdown

Experimental Hurricane Manipulation

Sarah Cooper-Ellis and David Foster developed a plan for long-term sampling of vegetation dynamics in permanent plots at the Tom Swamp pulldown. With Elaine Doughty and summer students Jacqueline Bartee and Sarah Neelon, Sarah monitored leaf-out and sprouting and censused understory vegetation on transect plots. This group also analyzed rates of tree mortality and survival by sprouting over the five years since the pulldown, and spatial patterning in the understory vegetation in response to overstory disturbance and changing light regimes. As part of the LTER project evaluating the interactions of natural physical disturbance with modern climatic and chemical stress, results from the experimental pulldown and 1938 hurricane were incorporated into a manuscript by David, John Aber (UNH), Jerry Melillo (MBL), Rich Bowden (Allegheny College), and Fakhri Bazzaz (Harvard).

Density and Basal Area Change at Pisgah 1907-1995

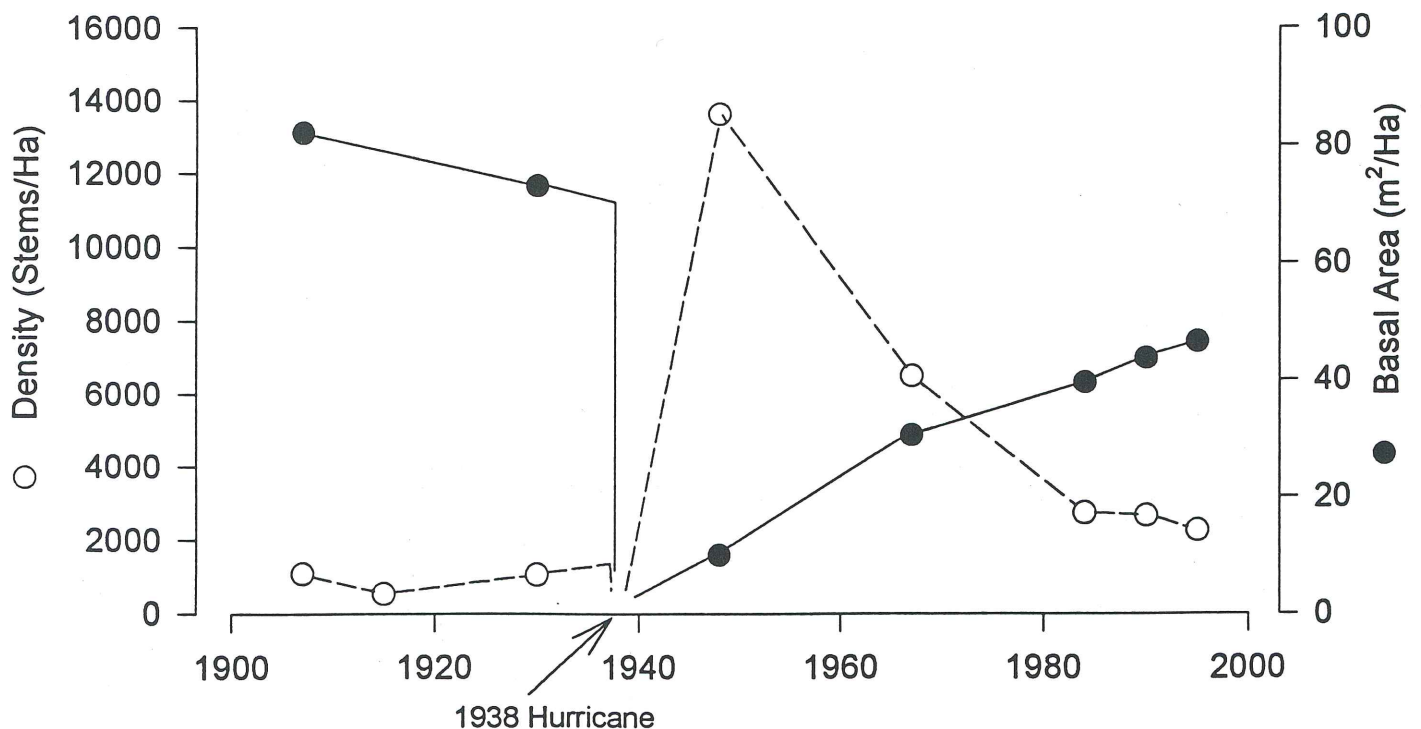


Figure 3. Long-term data from the Pisgah Forest in S. New Hampshire enable us to evaluate changes in composition and structure as the old-growth forest was catastrophically blown down by the 1938 hurricane. The original forest of few, large pines and hemlocks was replaced by suppressed hemlocks and beech and newly established birch and maple. Over the past 57 years this forest has grown in size and basal area as the density of trees has thinned substantially.

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. 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 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 Orwig has 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.

Hemlock importance lies not only in the fact that it is a major constituent of old-growth forests. It 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. Additional projects include: an assessment by Glenn Motzkin, John O'Keefe, and David Foster of the landscape-level dynamics of hemlock (1830 to present) in the town of Petersham; interpretation of the post-hurricane dynamics of the old-growth Pisgah Forest in southern New Hampshire by Jamie DeNormandie and David Foster; and ecophysiological studies by Julian Hadley. We plan to complement these studies with the addition of a soil ecologist examining carbon, nitrogen, and nutrient dynamics in hemlock forests.

Ecophysiology of red spruce decline

Julian Hadley investigated the effect of elevation and latitude in southern and northern New England on microclimate and the development of cold tolerance in red spruce. This work will identify the climatic factors responsible for extensive red spruce winter injury in some years. Continuous measurements have been made since November 1994 of solar radiation, wind speed, and red spruce foliage temperatures, using dataloggers and temperature sensors installed near the top of tree canopies, 8-15 m above ground. In the spring of 1995, Julian made the third annual survey of red spruce winter damage from northern New York to Maine.

Soils and Ecosystem Studies

Biological and physical controls on soil organic matter quantity and quality

Rich Boone, Knute Nadelhoffer, and Jana Canary continued to examine the long-term influence of plant litter type on soil respiration, soil microclimate, and soil solution chemistry (DIRT study). Soil respiration continues to vary by treatment, and appears more sensitive to temperature on plots with roots than on plots without roots or minimal roots (OA-less). The results suggest that the sensitivity of soil respiration to soil temperature will be higher when roots (including the rhizosphere) contribute a larger fraction of total soil CO₂ efflux. Rich and Knute are also examining biogeochemical processes on the DIRT plots at the Harvard Forest, the Bousson Experimental Forest (Meadville, PA), and the University of Wisconsin (Madison, WI). The work will allow examination of litter influence on various dynamic soil processes and properties including available carbon and nitrogen, gross nitrogen dynamics, and the microbial community.

The ¹⁵N pulse-chase experiment on the Harvard Forest soil warming plots

Rich Boone and Pat Micks collaborated with Knute Nadelhoffer on a ¹⁵N tracer study to examine how elevated soil temperatures influence the partitioning and transformations of nitrogen on the Harvard Forest soil warming plots. The results suggest that gross N mineralization rates were higher on the heated plots and that soil warming reduced the competitive success of roots for inorganic N. We expect that soil warming increased the relative uptake of inorganic N by other sinks.



A red spruce branch tip is analyzed for winter freezing damage by Julian Hadley

Animal Ecology

Richard Lent continued his studies of animal ecology in Petersham and across New England assisted by summer student Solai Buchanan, who is conducting a study of bird usage of clearcut areas and a study of nesting Ovenbirds on the Prospect Hill tract. Two Amherst College students, Martha Schumann and James Chen, worked with Rich during the year, conducting field and greenhouse studies of the landscape ecology and population biology of New England butterflies. Each student studied phenotypic variation and habitat relationships in a different species of Satyrid butterfly in twenty grassland sites arranged in a transect running from Petersham north to the Vermont-Canadian border. The work examines environmental and genetic influences on the morphology of butterflies that exist as isolated populations in the patchy New England landscape. A third Amherst student, Rebecca Tatum, studied insect-plant relationships in a series of grassland habitats in the Pioneer Valley. All three students wrote a senior honors thesis on their research.

Population, Developmental and Reproductive Biology

Paul Wilson and Michael Donoghue continued their work on the pollination biology of hobblebush, a plant with huge sterile flowers around the margins of its inflorescences. The intensity of pollination and the species of pollinator was found to vary among sites. The flowers attract a wide range of bees, beetles, and flies. In sites where bees are abundant, fruit set is higher than in sites where only flies and beetles visit the flowers. An experiment was performed in which the showy marginal flowers were removed or not removed. So far, the reduction in showiness has not affected the number of fruits set, despite the fact that fruit set was pollinator-limited at these sites. The dramatic display of these inflorescences seems to be of small or inconsistent adaptive value.

Recent research by Barry Tomlinson addresses the morphology of the seed cone of conifers in relation to the processes of pollination and seed protection. It has been shown that there is a diversity of pollen capture mechanisms that increases the chances of successful fertilization. Quite subtle structural variants can have important benefits and the hydrodynamics of conifer pollen is a major factor. Emphasis on Podocarpaceae, a conifer family neglected because of its primarily tropical and south temperate distribution, has been a key to many of the discoveries made. Most recently it has been shown that in podocarps a basic structural pattern is capable of producing several variants on a distinctive pollination process. These are followed by progressive changes that lead to remarkable diversity of seed structures, all of which tend to converge toward an animal-dispersal syndrome.



Jason McLachlan examines a pollen sample for information on past vegetation

In Cambridge, in collaboration with sophomore Elizabeth Zacharias, SEM study of seed cone biology and morphology of the southern conifer family Araucarieae was carried out. This is regarded as an ancient group because of its long fossil history, but aspects of the reproductive biology of araucarians suggest the advanced features of flowering plant reproduction.

Post-Glacial Vegetation and Climate History

The recent discovery of a 10,000-year-old buried forest in a gravel pit along the south shore of Lake Superior has provided David Foster and Jason McLachlan with an interesting opportunity to evaluate forest fossils of a very different nature than usually available. As a result of rapid burial in an oxygen-free environment by silt from melting glacial ice, the forest was preserved intact, including the soils, litter layer and standing trees. Collaborators from Michigan Technical University, Kurt Pregitzer and Dave Reed, obtained soil organic samples and tree cross-sections that we have had dated using C-14 analyses. With funding from NSF and cooperation from the mining company that owns the site, we plan to undertake a coordinated study of the composition, structure, and age of the forest, which appears to be dominated by white spruce. The study is particularly exciting because the forest dates to a period at the end of the last ice age when the climate was changing at an extremely rapid rate.

Another effort involves Jason and David in a collaboration with Fred Paillet at the U.S. Geological Survey investigating the dynamics of red spruce across New England during the last 2000 years. During this time period the climate underwent a minor change that is reflected in changing abundance and distribution of a few species such as spruce. To evaluate the regional nature of this change we have gathered all published data and are developing additional pollen records in critical areas. Currently Jason is analyzing the pollen from Levi Pond, a small waterbody at 600-m elevation in northeastern Vermont.

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, U.S. funding agencies, and international research groups 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 historical regime of disturbance.

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, R. Boone, 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. McCaugherty), 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 1995 Symposium is shown on the following page.

Dave Fitzjarrald adjusts atmospheric device 15 m up on the Environmental Monitoring Station tower

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 (Aber, Bazzaz, Boone, Melillo, 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 Oregon State University (R. Waring and R. McCreight).



HARVARD FOREST ECOLOGY SYMPOSIUM 1995

Titles of Abstracts and Presentations

- Aber, J., M. Goulden and P. Reich. Are Harvard Forest Trees Stressed?: Applying the PnET Models
- Allen, A. Soil Survey and Land-use Map Update Activities at Harvard Forest
- Bassow, S. and F. Bazzaz. Photosynthetic Variation in the Canopy of a Mixed Deciduous Forest
- Birford, M., J. McLachlan and E. Doughty. Limnological Response to Four Centuries of Human Activities
- Boone, R., K. Nadelhoffer, P. Micks and N. Werdin. ¹⁵N Pulse-Chase on the Soil Warming Plots
- Boone, R., K. Nadelhoffer, J. Canary and J. Kaye. Soil Respiration at the Litter Manipulation (DIRT) Plots
- Boose, E. and S. Baker. Reconstructing the 1815 New England Hurricane
- Boose, E., K. Chamberlin and D. Foster. Landscape and Regional Impacts of New England Hurricanes
- Bowden, R., K. Newkirk and G. Rullo. Effects of Soil Moisture and Temperature on Fluxes of CO₂ and CO₄
- Carlson, J., W. Patterson III and D. Foster. Simulated Hurricane Effects on Fuel Loading and Fire Hazard
- Catricala, C., K. Newkirk and J. Melillo. Effect of Temperature on Respiration and N-mineralization on Arctic and Temperate Soils
- Compton, J. and R. Boone. Land-use Legacies on Soil N Dynamics in Two Central Massachusetts Forests
- Cooper-Ellis, S. Checklist of the Bryophytes of Massachusetts
- Cooper-Ellis, S. and D. Foster. Effects of Land-use History on the Persistent Seed Bank at the Harvard Forest
- Currie, W., J. Aber, W. McDowell and R. Boone. Dissolved Organic C and N Under Chronic N Amendments
- Davidson, E. Modeling Soil Respiration at the Harvard Forest Core Experiment
- Donohue, K. Population Studies on Species Restriction to Plowed Sites
- Fitzjarrald, D., K. Moore, R. Sakai and J. Freedman. Forest-atmosphere Exchange Processes
- Foster, D. and S. Cooper-Ellis. Reorganization of Understory Vegetation Following Blowdown Disturbance
- Foster, D., J. Aber, J. Melillo, R. Bowden and F. Bazzaz. Forest Response to Disturbance and Stress
- Foster, D., M. Birford, M. Mulholland, N. Drake and J. McLachlan. Forest Response to Human Disturbance
- Foster, D., J. McLachlan, S. Cooper-Ellis, G. Motzkin and J. O'Keefe. Impact of the Hemlock Woolly Adelgid Outbreak on Forest Ecosystems of Southern New England
- Foster, D., G. Motzkin, J. O'Keefe, J. Carlson and D. Strauss. The Past and Present Distribution of White Pine and Hemlock
- Golodetz, A. and D. Foster. The North Quabbin Region: History, Ecology and Conservation Value
- Hadley, J. Cold Hardiness, Canopy Microclimate, and Bud Mortality of Red Spruce at Harvard Forest
- Kittredge, D. Protection of Rare Wetland Wildlife Species During Timber Harvesting
- Kittredge, D. Fragmentation of Interior Forest in North Central Massachusetts
- Kittredge, D. and D. Foster. Timber Harvesting as a Form of Forest Disturbance
- Lent, R. and D. Cooper. Influence of Land-Use History and Current Vegetation on Breeding Bird Distribution
- Lent, R. and M. Schumann. Variation in the Invading Butterfly *Coenonympha tullia* (Satyridae)
- Magill, A. and J. Aber. Plant and Soil Response of Red Pine and Mixed Hardwood Stands to Chronic Nitrogen
- McLachlan, J. and D. Foster. Post-Settlement History of Harvard Forest Woodlots
- Melillo, J., K. Newkirk, C. Catricala, P. Steudler and J. Aber. Soil Warming, an Update
- Miller, A. and J. O'Keefe. Winter (1992-93) Storm Damage Update
- Moody, J. Harvard Forest Airmass Chemical Composition as a Function of PATH
- Motzkin, G. and D. Foster. Uncommon Plant Communities: a Landscape Approach
- Motzkin, G., D. Foster, A. Allen, J. Harrod. Land-use, Disturbance History, and Vegetation Patterns of a New England Sand Plain
- Nadelhoffer, K. and M. Downs. The Harvard Forest Chronic N Plots: Where is the Added Nitrogen?
- Newkirk, K., F. Bowles and C. Catricala. Time Domain Reflectometry in Forest Soils
- O'Keefe, J. and A. Boyd. Regeneration Following Clearcutting of Red Pine Overstory - Year 5
- O'Keefe, J. and A. Boyd. Woody Species Phenology, Prospect Hill Tract, Harvard Forest - 1994
- O'Keefe, J., A. Allen, J. Edwards and E. Doughty. Schwarz Lot Harvest/Interpretation
- Ollinger, S., J. Aber and P. Reich. Modeling the Effects of Ozone on Forest Growth
- Paillet, F., D. Foster and J. McLachlan. Neoglacial Red Spruce Migration in New England
- Shipham, M., P. Crill, K. Bartlett and D. Blaha. Elevated Ambient Methane Observed at Harvard Forest
- Steudler, P., R. Jones, M. Castro, J. Melillo and D. Lewis. Microbial Controls of Methane Oxidation in Soils
- Stiles, K., G. Stevens and R. Bowden. Influence of Nitrogen Fertilization on Trace Gas Fluxes
- Wilson, P. and M. Donoghue. The Showy Marginal Flowers of *Viburnum lantanoides*
- Wilson, P. and G. Motzkin. The Individualistic Nature of Bryophyte Habitat Associations on Prospect Hill
- Wilson, P. and M. Stine. Floral Constancy in Bumble Bees: Handling Efficiency or Perceptual Conditioning?
- Wilson, P., M. Buonopane and T. Allison. The Natural History of Reproduction in *Taxus canadensis*

BULLARD FELLOWS

The Bullard Fellowship Program in Forest Studies supported eleven visiting faculty this year: David Bowman, John Connolly, Evan DeLucia, E. David Ford, David Janos, David Kittredge, Gong Wool Khoon, Sharachchandra Lele, Timothy Sipe, Jacob Weiner, and Carlos Vazquez Yanes.

David Bowman is completing a book on spatial patterns and dynamics of the Australian rain forest and has revised six manuscripts. David presented seminars at the Harvard Forest, the Department of Forestry and Wildlife Management at UMASS, and Harvard University. He has participated in the weekly ecophysiology laboratory meetings hosted by Fakhri Bazzaz in Cambridge.

John Connolly's research was aimed at developing an appropriate quantitative framework for the investigation of plant interspecific competition. This included clarification of fundamental concepts and modeling competitive interactions. John presented seminars on the definition and measurement of interspecific competition at Harvard Forest, the Department of Organismic and Evolutionary Biology at Harvard, National Wetlands Research Center, and at the University of California, Berkeley.

Evan DeLucia's research focused on differences in carbon and nitrogen allocation of hardwood saplings. In collaboration with Tim Sipe, Evan is preparing allometric equations describing the growth of understory sugar maple, red oak, white ash, and black cherry. Despite a rich literature on the photosynthetic physiology of these species, knowledge of the

patterns of biomass deployment above and below-ground is limited. By comparing the allometric relationships and reconstructing the growth histories of species representing different degrees of shade tolerance, a further understanding will be gained of the mechanisms of shade tolerance that contribute to forest regeneration.

David Ford completed nine chapters on a book that provides a comprehensive approach to the analysis and synthesis necessary for ecological research that can be applied by beginning graduate students. Included are the characterization of experiments in ecology, definition and techniques for exploratory analysis in ecology, and techniques for analyzing and studying integrative concepts such as stability, resilience, and diversity. With Dr. Heikki Smolander of the Finnish Forest Research Station, David planned an experiment to investigate genetic and environmental variation in branching structure and foliage display in *Pinus sylvestris* to determine what difference physiological acclimation and morphological plasticity make to photosynthesis in closed conifer canopies, and to incorporate this understanding into computer models that predict production from radiation interception. David gave three seminars at Harvard and neighboring institutions. His student, Mr. Joel Reynolds, visited Harvard Forest in January and gave seminars at Harvard Forest, Woods Hole and Dartmouth.

David Janos divided his time working with students, conducting greenhouse research, and analyzing data from a 20-year study of the effects of



Bullard Fellows David Bowman and David Janos tend an experiment in the small glasshouse



Bullard Fellow David Kittredge digitizes a forest cutting area in the North Quabbin Region study

mycorrhizal fungi on tropical tree diversity in Costa Rica. He was joined by Philipp Noger, a student from Zurich, who examined the influence of arbuscular mycorrhizae on intraspecific interactions of sunflowers. David gave a five-week course on the biology of mycorrhizae to students and staff from Harvard Forest, Department of Organismic and Evolutionary Biology, and the University of Massachusetts. With the help of Mohamed Bakarr, a graduate student from Sierra Leone, David conducted studies concerning the relative benefits to the pyrethrum chrysanthemum of arbuscular mycorrhizae versus phosphorus fertilization. The flowers of this plant produce a natural insecticide and are an important crop for small farmers in Kenya. David's data on the long-term effects of a one-time removal of mycorrhizal fungi from rain forest trees in Costa Rica show that in the absence of mycorrhizae, species richness is significantly reduced due to the diminished probability of seedling establishment. The work has implications for the preservation of biodiversity in the tropics, and underscores the need to include microbial diversity in biological conservation. David presented a talk at the Fifth International Mycological Congress in Vancouver and seminars at Ohio State University, UMASS and Dartmouth College.

David Kittredge used GIS to explore the recent changes in interior forest in the North Quabbin Region caused by increasing residential land use. He presented a seminar on endangered species protection during timber harvesting to the Department of Environment Management foresters and worked with Cinnie Chou, summer student from Yale, and David

Foster to explore the extent to which timber harvesting is occurring in central Massachusetts. He completed manuscripts on the future of timber harvesting in a landscape that is becoming increasingly fragmented and effects of timber harvesting on endangered wetland species habit. He collaborated on an article as well as a manual describing an ecosystem-based approach to management. David also completed a Forestry Best Management Practices Manual outlining Massachusetts timber harvesting regulations and environmental protection, served on a national committee organizing the Seventh American Forest Congress to be held in 1996, attended planning meetings in Nebraska and Minnesota, and attended a meeting of the National Policy Committee of the Society of American Foresters in Washington, DC.

Gong Wool Khoon continued her research in the laboratory of Fakhri Bazzaz on the effects of elevated CO_2 on growth and biomass allocation as well as net photosynthesis, respiration and fluorescence on tropical forest seedlings and the mangrove species, *Rhizophora mangle*. With Peter Ashton she studied growth and mortality of emergent forest trees from 4 different families on 50-ha plots in Malaysia.

Sharachchandra Lélé collaborated with Kamal Bawa (UMASS, Boston) and Dr. Ricardo Godoy (Harvard Institute for International Development) on research strategies and work plans for a project studying human impact on biodiversity in a sanctuary in Mysore district, southern India. Sharad gave a seminar at the Harvard University Tropical Ecology Seminar and attended research seminars at HIID.

In addition to his collaboration with Evan DeLucia, Tim Sipe remeasured survival growth of trees in a natural regeneration experiment that was started in 1985. With the assistance of Hafiz Maheralli, Evan's doctoral student, a study was conducted of hydraulic conductivity and gas-exchange by maple saplings in canopy gaps on Prospect Hill. Tim gave a seminar in the Department of Forestry and Wildlife Management at the University of Massachusetts and began a collaboration with Rich Bowden and Charles McClaugherty which led to a successful proposal to the NSF Collaborative Research at Undergraduate Institutions program, which will focus on impacts of land-use legacies on soil-plant-atmosphere interactions at the Harvard Forest.

Jacob Weiner completed a paper on the scientific problems in predicting the ecological effects of elevated CO_2 for a volume from the Global Change in Terrestrial Ecosystems program and submitted articles on environmental maternal effects in plants, competition among stand plants, size-dependency of clonal growth and sexual reproduction in two perennial species, below-ground competition in *Kochia scoparia*, and forest vegetation management. With F. Bazzaz, Jacob worked on a spatially-explicit individually-based model of plant stand development, analyzed the effects of elevated CO_2 on reproductive allometry in two species, and conducted a greenhouse experiment on the relationship between size and competitive effect in *Kochia scoparia*.

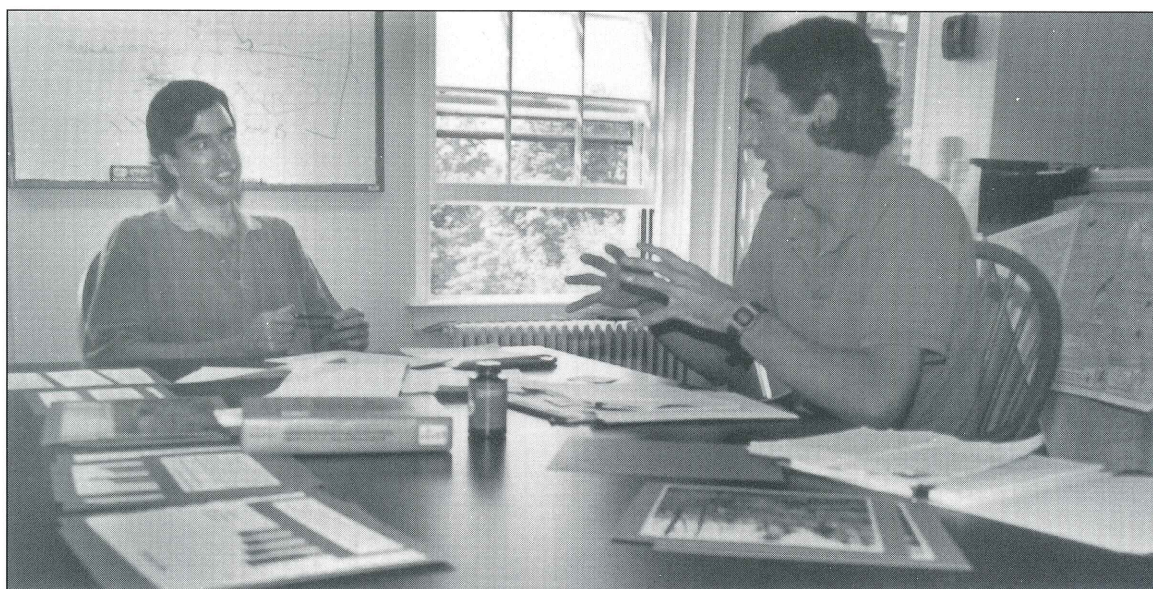
Carlos Vázquez Yanes worked on the effect of atmospheric CO_2 levels on the photoblastic response of light sensitive seeds. Seminars were given at the Bazzaz laboratory and the University of Connecticut.

He attended the conference "First Global Change Impact on Terrestrial Ecosystems Science", the 45th American Institute of Biological Sciences Annual Meeting, presented a paper at the International Conference on Landscape Degradation in Mediterranean Type Ecosystems, Renaca, Chile and presented a poster on seed longevity in the soil of the tropical rain forest at the Latin American Botanical Congress.

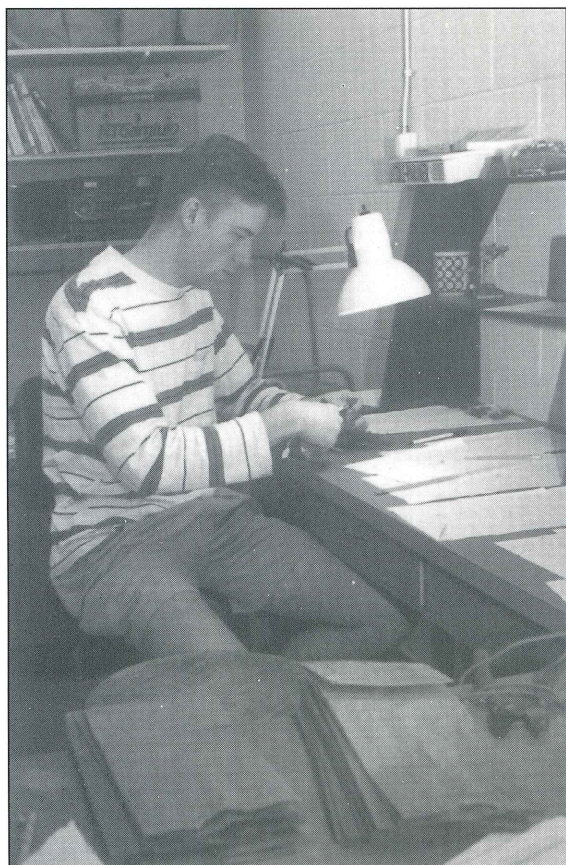
EDUCATIONAL ACTIVITIES

In the fall David Foster taught Biology 160 - *Forest Ecology* to a class of 22 students and participated as a panelist in the Kennedy School of Government Course ENR 522 (*Topics in Environmental Policy: Ecosystem Management*). In the spring term David joined Barry Tomlinson in leading the Harvard Forest Freshman Seminar, which is in its 23rd year. In this course a maximum of 11 students spend four weekends at the Harvard Forest becoming exposed to the biology of forests and ultimately conducting an independent project on the final weekend. David participated as a project reviewer for the mid-year and final reviews of the Graduate School of Design Studio 1212 - *Planning and Design of Landscapes*.

Dr. Tomlinson taught 3 courses and the Freshman Seminar. Biology S-105 (Plants of the Tropics), under the auspices of the Harvard Summer School, was held at Fairchild Tropical Garden, Florida in June and July. Biology 24 (Introductory Plant Biology) was taught in the fall semester, and Biology 178 (a new course) was taught with Dr. E. A. Kellogg in the spring semester.



David Foster discusses a thesis project on Hawaiian vegetation dynamics with new MFS student Guy Hughes



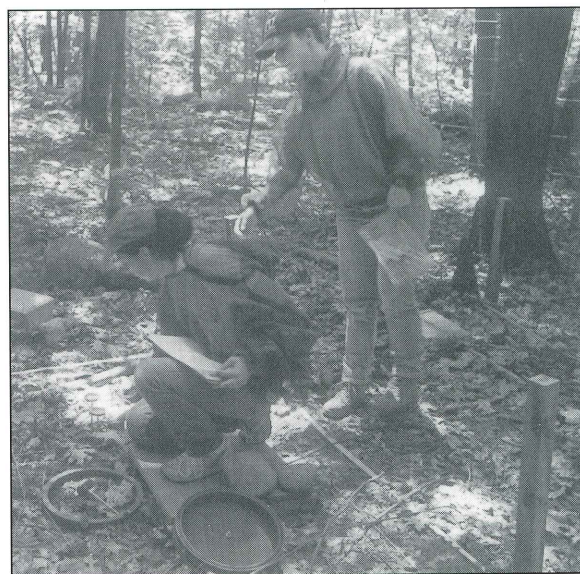
Summer student Jeff Herrick prepares some red spruce foliage for analysis of winter damage

Summer Students, 1995:

Jacqueline Bartee	Stillman College
Annabel Bradford	Harvard University
Solai Buchanan	Swarthmore College
Cinnie Chou	Yale University
Jamie DeNormandie	Harvard University
Adrien Elseroad	Cornell University
Melissa Feldberg	Wesleyan University
Amanda Gardner	Antioch New England
Laura Geer	Hampshire College
Jeffrey Herrick	SUNY, Syracuse
Karin Kryger	Northland College
Anne Lawrence	Allegheny College
Todd Lieske	Northland College
Satya Maliakal	Brown University
Fabian Menalled	University of Massachusetts
Jeffrey Milder	Harvard University
Sarah Neelon	Smith College
Susan Rainey	Boston University
Jesse Reynolds	Hampshire College
Raul Romero	SUNY, Stony Brook
Michelle Soucy	Hampshire College
Lonnie Williams III	Wiley College
Elizabeth Zacharias	Harvard University

Summer Research Program

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 Richard Bowden of Allegheny College and Harvard Forest staff, was supported by the NSF Research Experience for Undergraduates program, National Institute for Global Environmental Change, Mellon Foundation, and the Harvard Forest. Students worked closely with faculty and scientists, and many conducted their own independent research studies. The program included 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 and vegetation of the forest. In June, the group travelled to the Institute of Ecosystem Studies (Millbrook, NY) to participate in a Forum on Jobs in Ecology, which included discussions of environmental occupations with students and professionals employed in the field. The summer program culminated in the Third Annual Summer Student Research Symposium, in which students presented the major findings of their summer work.



Chris Catricala and summer student Anne Lawrence in the soil warming experiment

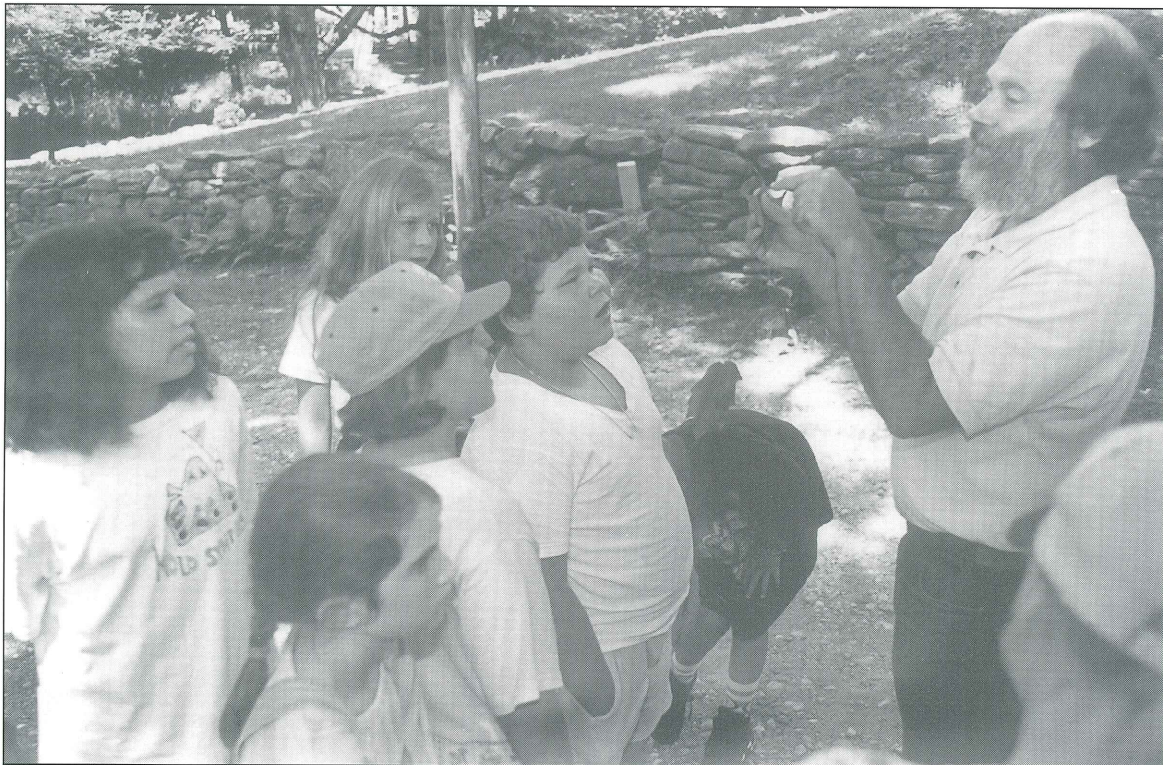
ACTIVITIES OF THE FISHER MUSEUM

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.

The dedication and enthusiasm of our Museum volunteers ensured the most successful weekend schedule yet during the summer and fall of 1994, welcoming over eleven hundred visitors. The Fourth Annual Volunteer Recognition Dinner on November 10th provided an opportunity to review the season's accomplishments while sharing good food and good fellowship. Bob Lane received special recognition for the second year in a row as the most active volunteer as did Helen Gronich for her continuing work as volunteer coordinator.

The new entrance way to the Museum from Shaler Hall is nearing completion. The handicapped access entrance and the display area for Forest reprints, clothing, slides, etc., are finished and have received many compliments. The exhibit describing the history and current research activity of the Harvard Forest, which will fill the central wall, is progressing rapidly. The development of this exhibit continues our collaboration with the exhibit design staff of the Harvard Peabody Museum of Anthropology.

As part of the Museum's continuing collaboration with the Petersham Craft Center, John O'Keefe led a children's nature walk in July and a tree identification workshop in May and the Forest hosted a Boston Mycological Society field trip in October. Harvard Forest again hosted 35 inner-city, middle and high school students, their teachers and UMASS staff for two weekends in the fall as a cooperator in the Rainforest Collaboration. This joint UMASS-Boston Public Schools program to excite students about careers in the biological sciences is now entering its fifth year.



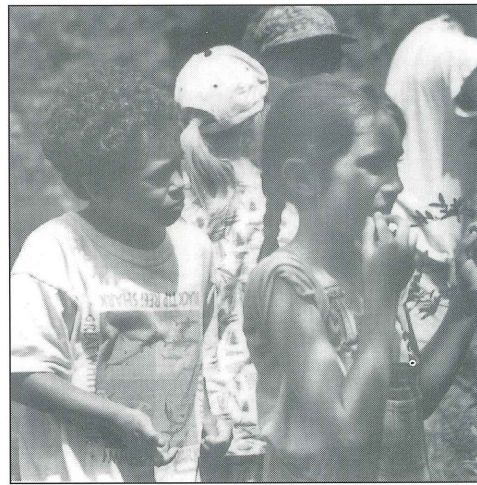
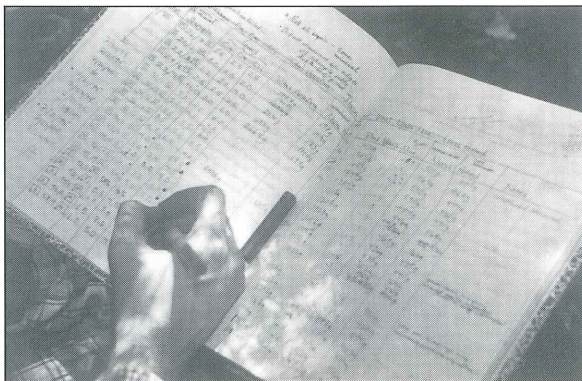
A group of local students meet nature up-close with John O'Keefe

Meetings, Seminars, Conferences

At the end of October the Fisher Museum hosted a series of working-group sessions for a three day conference on the Status and Management of Old-Growth Forests in the Northeast. The second and third days of the conference were held in Williamstown, Massachusetts. This conference organized in part by John O'Keefe brought together over forty scientists from throughout the eastern United States and Canada to debate the current issues regarding definition and management of old-growth and present the results of their most recent research. Other meetings at Harvard Forest included the Millers River Watershed Council, Massachusetts Wood Producers Association, Northeast Forest Economists, New England Chapter of the Wildlife Society, Massachusetts Project Learning Tree, University of Massachusetts Forestry Faculty retreat, Science Center of New Hampshire staff retreat, and the New England Forestry Foundation.

Starting in the fall the Fisher Museum hosted the monthly meetings of the Athol Bird and Nature Club. Presentations at these meetings have ranged from research on black bears and butterflies in Massachusetts to the natural history of Argentina. In August, for the third year, we hosted a group of Spanish environmental scientists attending Real Collegio Complutense, a collaborative program between Spanish universities and Harvard. John Silander from the University of Connecticut brought a group of seven researchers and graduate students to the Harvard Forest in October to discuss collaborative interests on forest dynamics with Tim Sipe and the lab group of David Foster.

During the spring two major journalism fellowship programs made field trips to the Harvard Forest. A group of 25 Nieman Fellows and families from Harvard University joined J. O'Keefe, J. Edwards, D. Foster and P. B. Tomlinson for a discussion of tree structure, forest history and silviculture at the Schwartz lot. Victor McElheny and 15 Knight Fellows from M.I.T. spent one day with D. Foster and J. O'Keefe reviewing research projects and environmental issues in Northeastern U.S.



Ripe blueberries command attention on the nature trail

Speakers in the Harvard Forest seminar series included:

David Ackerly	Harvard University
Sandra Anagnostakis	Conn. Agric. Exp. Sta.
David Baum	Harvard University
Robert Bertin	Holy Cross College
David Bowman	Bullard Fellow
Nick Brokaw	Manomet Observatory
John Connolly	Bullard Fellow
Evan DeLucia	Bullard Fellow
Kathleen Donohue	Brown University
David Ford	Bullard Fellow
Andy Friedland	Dartmouth College
Janice Fuller	Cambridge University
Allen Goldstein	Harvard University
Martha Groom	University of Washington
Jerry Jenkins	White Creek Field School
Humaira Khan	Johns Hopkins University
David Kittredge	Bullard Fellow
Mark McClure	Conn. Agric. Exp. Sta.
Mitch Mulholland	UMASS
Philip Noger	Swiss Fed. Inst. of Tech.
Tom O'Dell	U.S. Forest Service
Gunilla Olsson	University of Trondheim
David Orwig	Pennsylvania State Univ.
Matt Peterson	Michigan Tech
Joel Reynolds	University of Washington
Emily Russell	Rutgers University
Nancy Slack	Russell Sage College
Paul Teese	SUNY, Stony Brook
Pierre Vollenweider	University of Lausanne
Jacob Weiner	Bullard Fellow
Paul Wilson	Harvard University
Rick Wyman	Huyck Preserve
Eric York	UMASS

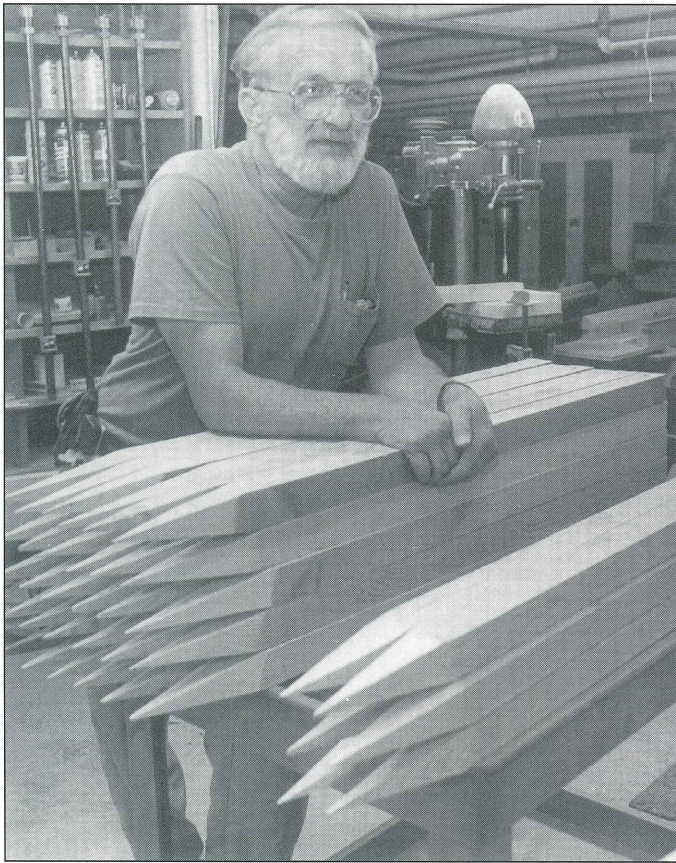
FOREST AND MAINTENANCE ACTIVITIES

Forest management was centered at the Schwarz Lot, located off West Road on the western edge of Petersham. The objective was to conduct selective harvesting and then to develop a series of interpretive walks through the managed woodlot as a demonstration area of practical and aesthetic management for owners of small parcels of forest land. These objectives follow the original wishes of the benefactor of the 45-acre property and a small endowment. In 1929 when the land was conveyed to the Harvard Forest G. Frederick Schwarz indicated his desire to "show the effect which practical forest operations may have on the scenic value of the forest and how such operations sometimes may be modified to advantage without undue sacrifice to financial return, it being my purpose to bring about a broader conception and better understanding of the nature and value of landscape forestry and its relation to the more comprehensive subject of general economic forestry." In order to document and study this forest operation Art Allen and Elaine Doughty surveyed and mapped permanent vegetation plots prior to harvest, which was conducted by John Wisniewski of the Woods Crew. A total of 230 cords of wood were removed from the 45 acres that were thinned to approximately 60% of original basal area.

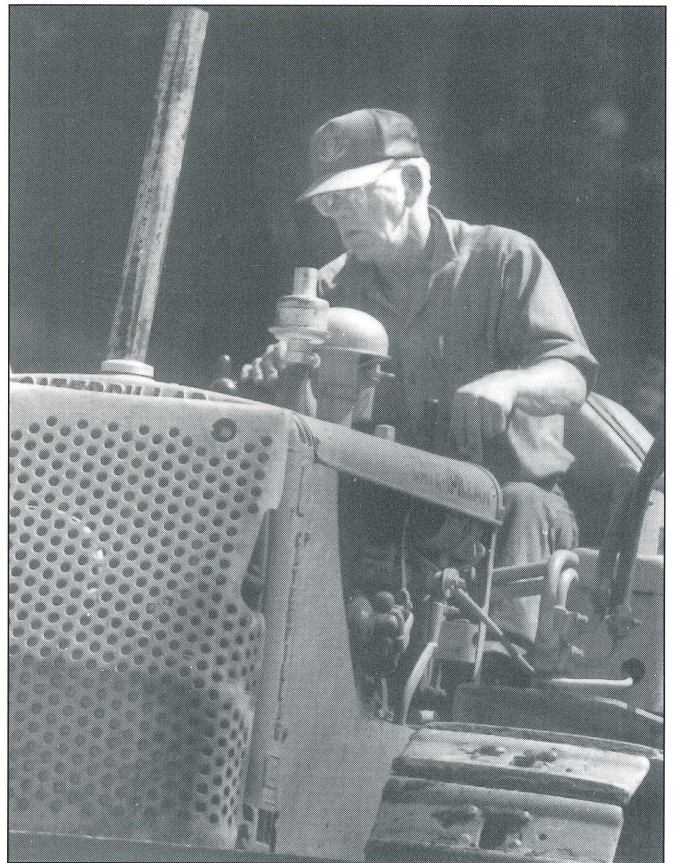
Recent improvements in Shaler Hall include an extensive renovation of the main kitchen, expansion of the Archive facilities, development of a Pollen Laboratory, Pb-210 dating facility, and installation of dendrochronological analytical equipment in the Zimmermann Lab, and air conditioning in first floor offices.

Computers

The past year has seen dramatic improvements in computer and telecommunication facilities at the Forest. Twenty new computers were installed with funds from the Harvard Forest and National Science Foundation, so that all staff members now have their own computers. In the fall, wiring for telephone and data was installed to all rooms in Shaler Hall, the Torrey Lab, and the Garage Laboratory, with the vault in Shaler serving as the new electronic "nerve center." A new telephone system now provides separate office phones and voice mail for all staff and visiting scientists and installation of a computer network connection to the Harvard University campus was begun this spring. When completed, the network will provide access to the Internet for electronic mail, file transfer, and information retrieval (using such programs as "Gopher" and "Mozaic"), from each desktop computer.



Don Hesselton - stake maker



Pete Spooner



John Wisnewski and skidder thinning the Schwartz Lot

ACTIVITIES OF THE HARVARD FOREST STAFF

Art Allen presented a paper on the relationship of soil properties to land-use history at the annual meeting of the Soil Science Society of America in Seattle, participated in the Franklin County Soil Survey Update with the presentation of workshops on wetland delineation, and attended the Northeast Forest Soils Conference at Stockton State College in the New Jersey Pine Barrens. Art completed a course in Statistics at the Harvard University Extension School.

Rich Boone gave lectures at the International Congress of Ecology in Manchester, England, at the first Global Change and Terrestrial Ecosystems Conference at Woods Hole, and at the Ecosystems Center, Woods Hole. Rich served as member of the NSF CRUI and Dissertation Improvement, and USDA Ecosystems panels.

Emery Boose continued to serve on the LTER Climate Committee and presented a seminar in a series on how plants cope with environmental stress, at the University of Massachusetts.

Jana Compton gave a lecture at the Soil Science Society of America annual meetings in Seattle and led a field trip in the western Cascades. She gave talks at Woods Hole Ecosystem Center and University of Rhode Island and attended the Northeast American Forest Soils Conference. Sarah Cooper-Ellis presented a talk "Bryophytes in Old-Growth Forests of Western Massachusetts" at the Northeastern Old-Growth Forests conference. With Jason McLachlan she attended a meeting on the Hemlock Woolly Adelgid at the Delaware Water Gap.

During the spring, Kathleen Donohue taught a course in Population Genetics at the University of New Hampshire. She also collaborated with Johanna Schmitt at Brown University on studies of plasticity in

seed dispersal of *Impatiens capensis*, or jewel weed. Since her arrival she has prepared a manuscript on the spatial demography of mistletoe parasitism on *Yemeni acacia*.

David Foster was an invited speaker at the American Quaternary Association meeting, the Symposium on Community Ecology and Conservation Biology in Bern, Switzerland, the Eastern Old-Growth Conference, and the Graduate Program in Ecology and Evolutionary Biology at Brown University in April. David participated with Dan Botkin, Tom Lovejoy, Fred Swanson, and others in a Video Conference panel on *Evolving Concepts in Forest Ecosystem Management* sponsored by the Society of American Foresters in February and coordinated the sixth annual Long Term Ecological Research and National Institutes of Global Environmental Change conference at the Harvard Forest in April. He joined John O'Keefe of the Harvard Forest staff in a videotaping of a U.S. Forest Service documentary on forest dynamics resulting from the hemlock wooly adelgid.

David was appointed to the Executive Committee of the Long Term Ecological Research Program administered by the National Science Foundation. He continues to serve on the Editorial Boards of *Ecology* and *Ecological Monographs*, and on the boards of the National Institutes of Environmental Change Northeastern Center, Mount Grace Land Conservation Trust, Conservation Research Foundation and Highstead Arboretum, and UNESCO Man and the Biosphere Program Temperate Ecosystem Directorate.

Julian Hadley presented a poster at the ESA meeting in Knoxville, Tennessee, attended the annual meeting of the Vermont Monitoring Cooperative, and designed a Harvard University tutorial on biological adaptations of plants and animals for winter survival for 1995-96.

Schwarz Lot Thinning - A Demonstration of Woodlot Management

Across New England increasing numbers of individuals own small acreages of forest in their backyard, at their summer home, or as an investment property and are interested in learning methods of managing these areas for aesthetics, firewood, and profit. To provide a living example of one approach to managing a typical New England woodlot we conducted a selective harvest or thinning on our 45-acre Schwarz Lot. In the process we measured the forest volume and composition before and after cutting in permanently marked plots, we set aside uncut "control" areas as examples of unmanaged woodland, and we are creating interpretative trails and handouts so that interested visitors can understand and assess our efforts. The results of removing approximately 40% of the timber from this second-growth stand include: 230 cords of firewood, a few sawlogs, a more open and attractive forest of faster growing trees, a new layer of regeneration from seedlings and sprouts, and a new long-term experiment and demonstration at the Harvard Forest.

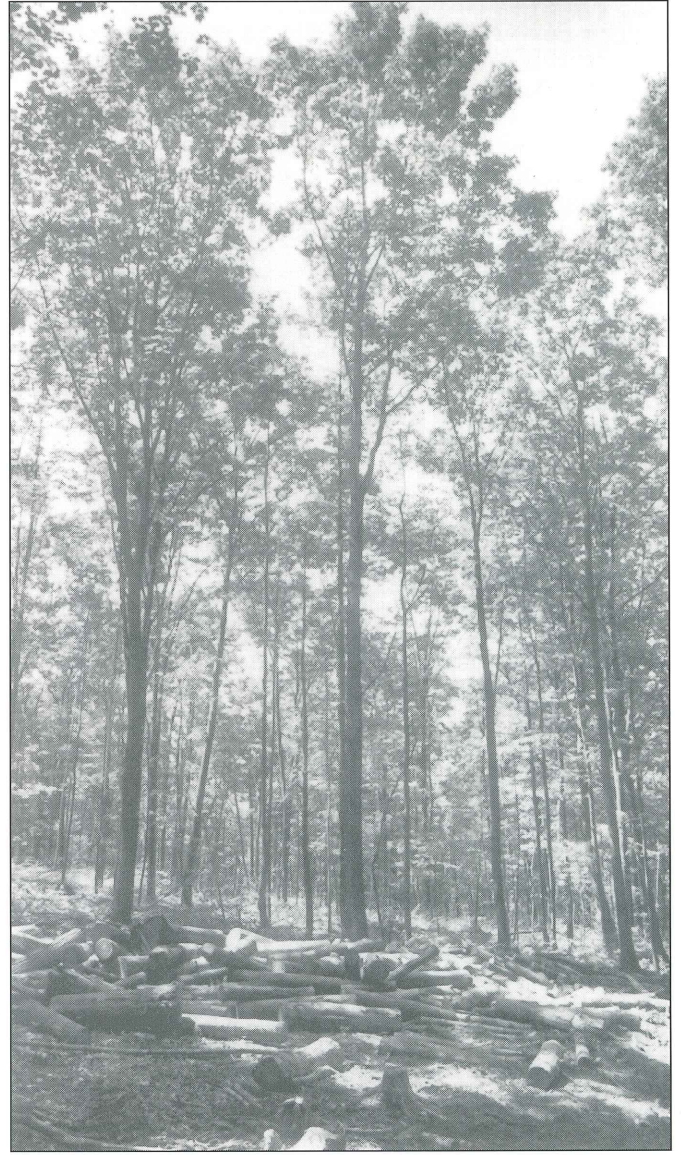


A main product of a good thinning operation - neatly stacked cordwood

Schwarz Lot Thinning



"Before"



"After"

**The agricultural past revealed
in a forest's stone walls**



Richard Lent attended the LTER Data Manager's Meeting in Seattle and served on the Massachusetts Division of Fisheries and Wildlife Partners in Flight Working Group. Richard lectured to the Harvard Freshman Seminar, and ecology class at Amherst College and developed a series of computer workshops for Harvard Forest staff. He edited the Proceedings of the 6th Annual Harvard Forest Ecology Symposium with Dottie Smith.

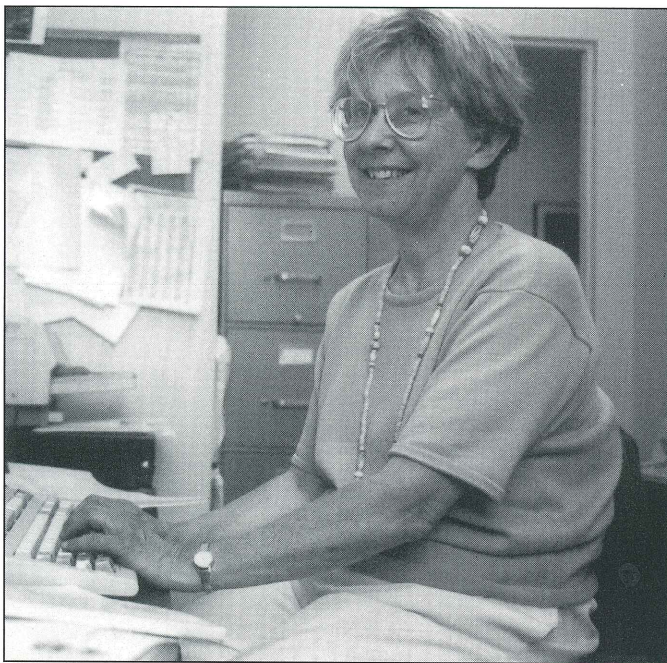
Glenn Motzkin attended the conference on Old-growth Forests in the Northeast and participated in the Northeast Forest Soils Conference in the New Jersey Pinelands.

John O'Keefe helped organize the conference on Old-Growth Forests in the Northeast and presented seminars on forest history at the Massachusetts Environmental Education Society Annual Workshop, the Science Center of New Hampshire, and the Templeton Men's Club. He attended the annual conference of the New England Society of American Foresters in Burlington, Vermont. John oversaw an independent study examining the history of forest harvesting and sawmill production in Massachusetts conducted by Chris Donnelly, a PhD candidate in forestry at UMASS/Amherst and assisted with the Harvard Forest Freshman Seminar. He accompanied the Rainforest Collaboration group on a trip to Puerto Rico in April and while there took advantage of the opportunity to explore the Puerto Rican National Forest and meet with our collaborators at the Luquillo LTER site. John joined the Board of Directors of the Massachusetts

Forestry Association and the Millers River Watershed Council and again served as a judge at the Mahar Regional High School Science Fair.

Barry Tomlinson presented two papers at the AIBS annual meeting in Knoxville, Tennessee. He was a guest of the Swedish National Academy of Science and Swedish Museum of Natural History in Stockholm at a meeting to celebrate the centenary of the birth of the Swedish Paleobotanist Rudolf Florin. Two presentations were made to show how recent research has built on the foundation of Professor Florin's classical work on the morphology of the coniferous cone by putting the subject in a functional context. Barry was a keynote speaker at a Plant Development Workshop at the University of Waterloo, Kitchener, and a guest at the University of Guelph, Ontario, Canada. He was an invited speaker at the symposium "Evolution of Plant Architecture," held at the Linnaean Society of London, England, where emphasis was laid on the reproductive morphology of conifers.

Paul Wilson attended the Eichwort Symposium at Cornell University, the Ecology and Evolution Symposium at Stony Brook, and the Molecular Evolution Symposium at Harvard University. He presented seminars at Harvard University, California State University at Northridge and Humboldt State University in California. Paul hosted discussion groups on Numerical Techniques (Harvard Forest), Plant Ecology and Evolution (Organismic and Evolutionary Biology, Harvard University) and Phylogenetics at the Herbarium (Harvard University).



Barbara Flye



Paul Wilson

GIFTS AND NEW FUNDING

David Foster and J. Hadley received a \$20,000 grant from the Mellon Foundation to support student activities on Julian's research pertaining to red spruce decline in high elevation forests. The Harvard Forest Long Term Ecological Research (LTER) project, with David Foster, Principal Investigator, received a continuation grant for \$3,780,000 for the period 1994-2000. Successful renewal of the LTER program at the University of Puerto Rico resulted in a \$110,000 subcontract to the Harvard Forest group led by David. In collaboration with Kurt Pregitzer and other researchers at Michigan Technical University David received a grant for \$36,609 for pollen analysis associated with a 10,000 year-old buried forest in northern Michigan.

Interest in the Harvard Forest Library has continued with gifts of journals and publications. Dr. James W. Hardin, Botany Department, North Carolina State University donated another year of *The Bulletin of the Torrey Botanical Club*. A collection of reports by the U.S. Fire Administration-Federal Emergency Management Agency on Urban Wildfire and California fires, and the "America Burning" report by the National Commission on Fire Prevention and Control were donated by Michael Pimental. Professor Soren Odum, Denmark, former Bullard Fellow donated a copy of the *Guide to the Arboretum, Horsholm, Denmark*.

An anonymous, long-term friend of the Harvard Forest purchased and donated 6.5 acres of land to the Harvard Forest, contiguous with the Tom Swamp tract. This property provides protection to our existing lands and experiments and expands our holdings of lowland hemlock forest.

An endowment yielding an annual gift of approximately \$1,200 has been established by the John B. and Edith M. Downs Memorial Trust, in support of Harvard Forest's educational mission.

In addition to these specific gifts the Friends of the Harvard Forest have continued to provide generous contributions to the development of our endowment funds that support our educational program for undergraduates, graduate students and the general public.



Complete restoration of the foundation and sills were in order this year for the Higginson House, an early gift to the Harvard Forest

VISITING RESEARCH SCIENTISTS AT THE HARVARD FOREST 1994-95

In addition to Harvard Forest researchers a large number of 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	Shoichi Kawano	Kyoto University
David Ackerly	Harvard University	C. Kerfoot	Ecosystems Center - MBL
Jeff Amthor	Lawrence Livermore Lab	Dave Kicklighter	Ecosystems Center - MBL
Peter Bakwin	Harvard University	Otto Klemm	University of New Hampshire
Susan Bassow	Harvard University	Barry Lefer	University of New Hampshire
Fakhri Bazzaz	Harvard University	Alison Magill	University of New Hampshire
Glenn Berntson	Harvard University	Mary Martin	University of New Hampshire
Mike Binford	Harvard University	Charles McClaugherty	Mount Union College
K. Boering	Harvard University	Ernesto Medina	Centro de Ecología y Ciencias Venezuela
Rich Bowden	Allegheny College		
Frank Bowles	Ecosystems Center - MBL	Jerry Melillo	Ecosystems Center - MBL
Mark Castro	Ecosystems Center - MBL	Shi-Li Miao	Ecosystems Center - MBL
Chris Catricala	Ecosystems Center - MBL	Kathleen Moore	State University of New York
Chaur-Fong Chen	Oregon State University	Mitch Mulholland	University of Massachusetts
Alan Coleman	Harvard University	J. William Munger	Harvard University
Patrick Crill	University of New Hampshire	Knute Nadelhoffer	Ecosystems Center - MBL
William Currie	University of New Hampshire	Kathy Newkirk	Ecosystems Center - MBL
Eric Davidson	Woods Hole Research Center	Fred Paillet	U.S. Geological Survey
Bruce Daube	Harvard University	William Patterson	University of Massachusetts
Peter Del Tredici	Arnold Arboretum	Bob Percy	University of California, Davis
Mike Donoghue	Harvard University	Donald Pigott	Cambridge Botanical Garden
Marty Downs	Ecosystems Center - MBL	Richard Primack	Boston University
Brian Drayton	Boston University	Andrea Ricca	Ecosystems Center - MBL
Todd Drummey	Ecosystems Center - MBL	Michael Rogers	GA Institute of Technology
Joseph Elkinton	University of Massachusetts	Emily Russell	Rutgers University
Aaron Ellison	Mount Holyoke College	Paul Rygielwicz	Environmental Protection Agency
Elizabeth Farnsworth	Harvard University		
David Fitzjarrald	State University of New York	Brian Shelley	College of the Holy Cross
Son-Miao Fan	Harvard University	Paul Steudler	Ecosystem Center - MBL
Alan Goldstein	Harvard University	Britt Stephens	U.S. Geological Survey
Alisa Golodetz	Hampshire College	Robert Talbot	University of New Hampshire
Michael Goulden	Harvard University	Sean Thomas	Harvard University
Robert Harriss	University of New Hampshire	Brayton Wilson	University of Massachusetts
Joseph Hendricks	University of New Hampshire	Greg Winston	U.S. Geological Survey
Doug Karpa	Harvard University		

PUBLICATIONS

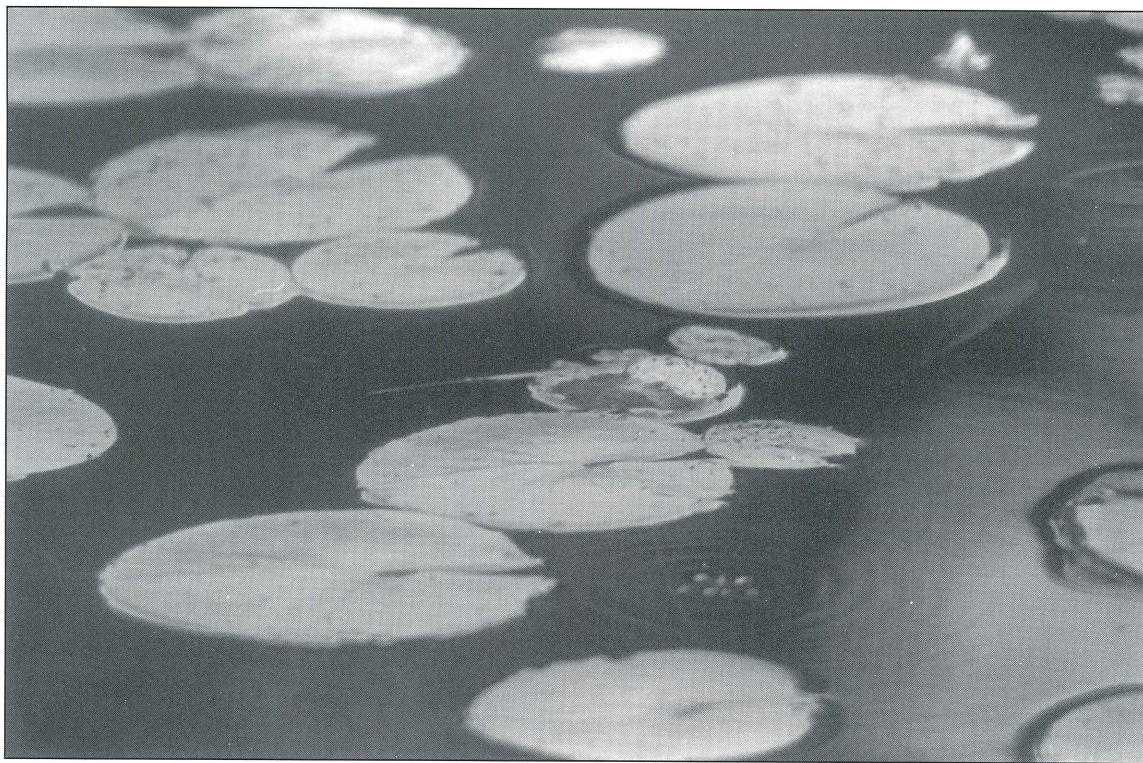
- Bassow, S. L.** 1995. Canopy photosynthesis and carbon cycling in a deciduous forest: implications of species composition and rising concentrations of CO₂. PhD Thesis, Harvard University.
- Boone, R. D.** 1994. Light fraction soil organic matter: origin and contribution to net nitrogen mineralization. *Soil Biology and Biochemistry* 26: 1459-1468.
- Boose, E. R., D. R. Foster and M. Fluet.** 1994. Hurricane impacts to tropical and temperate forest landscapes. *Ecological Monographs* 64: 369-400.
- Cole, D. W., J. E. Compton, P. S. Homann, R. L. Edmonds and H. Van Miegroet.** 1995. Comparison of carbon accumulation in Douglas fir and red alder forests. In: J. M. Kelly and W. W. McFee (Eds.), *Carbon forms and functions in forest soils*. Soil Science Society of America, Madison, WI.
- Cooper-Ellis, S.** 1994. The interpretations of ecological data. A Primer on Classification and Ordination. Review of E. C. Pielou. *The Bryologist* 97:468.
- Foster, D. R. and E. R. Boose.** Hurricane disturbance regimes in temperate and tropical forest ecosystems. Pp. 318-339, In: M. Coutts (Ed.), *Wind Effects on Trees, Forests and Landscapes*. Cambridge University Press, Cambridge.
- Foster, C.H.W. and D.R. Foster.** 1994. Managing the Greenwealth: the Forests of Quabbin. Environmental and Natural Resources Program. John F. Kennedy School of Government. Harvard University. 49 pp.
- Foster, D.R.** 1994. From Coastal Wilderness to Fruited Plain - a History of Northeastern North America since 1500 A.D. Review of G.G. Whitney. *Trends in Ecology and Evolution* 17:325-326.
- Foster, D.R.** 1994. Ecological effects of afforestation. *Studies in the History and Ecology of Afforestation in Western Europe*. Forest Ecology and Management. 123:123-124.
- Foster, D.R.** 1995. Land-use history and four hundred years of vegetation change in New England. Pp. 253-321, In: B.L. Turner, A. G. Sal, F. G. Bernaldez, and F. DiCasteri (Eds.), *Global Land Use Change: A Perspective from the Columbian Encounter*. SCOPE Publication. Consejo Superior de Investigaciones Cientificas, Madrid.
- Hadley, J. L. and W. K. Smith.** 1994. Effect of elevation and foliar age on maximum leaf resistance to water vapor diffusion in conifers of the central Rocky Mountains, U.S.A. Vol. G 36, Pp 261-268, In: K. E. Percy *et al.* (Eds.), *Air Pollutants and the Leaf Cuticle*. NATO ASI Series. Springer-Verlag, Berlin, Heidelberg.
- Lélé, Sharachandra.** 1994. Sustainable use of biomass resources: a note on definitions, criteria and practical applications. *Energy for Sustainable Development* 1 (4):42-46.
- Lent, R. A., and D. R. Smith (editors).** 1995. Abstracts from the 6th Annual Harvard Forest Ecology Symposium. Harvard Forest, Petersham, MA.
- Motzkin, G.** 1994. Calcareous fens of western New England and adjacent New York State. *Rhodora* 96:44-68.
- Noger, P.** 1995. Effects of vesicular arbuscular mycorrhizae on plant growth. "Diplomarbeit", Swiss Eidgenössische Technische Hochschule of Zürich.
- Sipe, T. W. and F. A. Bazzaz.** 1994. Gap partitioning among maples (*Acer*) in central New England: shoot architecture and photosynthesis. *Ecology* 75:2318-2332.
- Tomlinson, P. B.** 1994. Functional morphology of saccate pollen in conifers with special reference to Podocarpaceae. *Int. J. Pl. Sci.* 155: 699-715.
- Tomlinson, P. B.** 1995. Non-homology of vascular organization in monocotyledons and dicotyledons. Pp. 589-622, In: P. J. Rudall, P. J. Cribb, D. F. Cutler and C. J. Humphries (Eds.), *Monocotyledons: Systematics and Evolution*. Royal Botanic Gardens, Kew.



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National Science Foundation
New England Consortium for Science
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 Research Grants, Forestry
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 for Global Environmental Change



David R. Foster
Director

Petersham, Massachusetts
July 1995

