THE HARVARD FOREST 1990 - 91

Harvard University

Front Cover: Eastern hemlock and black birch, Tom Swamp tract.

ANNUAL REPORT OF THE HARVARD FOREST 1990-1991

Table of Contents

Personnel at the Harvard Forest 1990-1991 ---- 4
Introduction to the Harvard Forest ---- 5
Research Activities ---- 6
- Hurricane Impacts to Temperate and Tropical Forests ---- 6
- Historical Ecology and Paleoecology ---- 9
- Wetland Development and Ecology ---- 11
- Developmental and Reproductive Biology ---- 12
- Ecophysiology and Micrometeorology ---- 14
- Biosphere/Atmosphere Interactions ---- 15
- Harvard Forest LTER Program ---- 16

Bullard Fellows ---- 18
Educational Activities ---- 19
Activities of the Fisher Museum ---- 22
Forest and Maintenance Activities ---- 24
Activities of the Harvard Forest Staff ---- 26
Visiting Research Scientists ---- 28
Publications 1990-1991 ---- 29
New Funding ---- 30
Acknowledgement of Support ---- 30

Compiled by Dorothy R. Smith

Photography by Marcheterre Fluet

PERSONNEL AT THE HARVARD FOREST 1990-91

Mollie H. Beattie	Charles Bullard Fellow
John E. Bertram	Charles Bullard Fellow
Emery R. Boose	Computer Scientist
Jeanne M. Boutelle	Custodian
Jeannette M. Bowlen	Accountant
Gary C. Carlton	PhD Candidate
Elaine D. Doughty	Laboratory Assistant
John A. Edwards	Forest Manager
Marcheterre Fluet	Research Assistant
Barbara J. Flye	Secretary
David R. Foster	Associate Professor of Biology and Director, Harvard Forest
Denise C. Gaudreau	Research Associate
Lisa George	PhD Candidate
Fritz Gerhardt	MFS Candidate
Donald E. Hesselton	Woods Crew
Heather A. Jacobson	Research Assistant
Michael D. Korzukhin	Charles Bullard Fellow
Ann L. Lezberg	Research Assistant
Ellen G. Moriarty	Graphic Artist (part-time)
Raouf A. Moustafa	Graduate Student
John F. O'Keefe	Museum Coordinator
Frances N. Phillips	Secretary
Hugh M. Raup	Charles Bullard Professor of Forestry, *Emeritus*
Peter K. Schoonmaker	PhD Candidate
Robin W. Scribailo	Post-doctoral Fellow
Dorothy R. Smith	Secretary
Charles C. Spooner	Woods Crew
Keith A. Spooner	Woods Crew (part-time)
Russell D. Stafford	MFS Candidate
C. Dana Tomlin	Associate of the Harvard Forest
P. Barry Tomlinson	E. C. Jeffrey Professor of Biology
John G. Torrey	Charles Bullard Professor of Forestry
Gordon G. Whitney	Archivist and Research Associate
John S. Wisnewski	Woods Crew
Steven C. Wofsy	Associate of the Harvard Forest
Tad M. Zebryk	MFS Candidate

INTRODUCTION TO THE HARVARD FOREST

Since its establishment in 1907 the Harvard Forest has served as a base for research, education and demonstration 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 economics and vegetation development. Today, this research history continues as staff scientists and visiting scientists seek to understand historical and modern changes in the forests of central New England resulting from human and natural disturbance processes. This research 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.

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 comprised of diverse 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 Torrey Labs provide office and laboratory space, computer, greenhouse, and growth-chamber 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 past 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 directly 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, which awards the Ph.D. degree, and through the Freshman Seminar Program. Close association is maintained with the Department of Earth and Planetary Sciences and the Graduate School of Design at Harvard and with the Department of Forestry and Wildlife Management at the University of Massachusetts, Ecosystem Center (MBL) at Woods Hole, and Complex Research Center at the University of New Hampshire.

The staff of approximately 30 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-man Woods Crew and directed by the Forest Manager. The Coordinator of the Fisher Museum oversees many of our educational, audio-visual 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 (Ecology, Ecosystems, Human Dimensions of Global Change), Department of Energy (NIGEC), USDA, and the Andrew W. Mellon Foundation. Our Summer Program for Student Research is supported by the Research Experience for Undergraduates program at NSF, the Northeastern Consortium for Undergraduate Science Education (Pew Charitable Trust) and the R. T. Fisher Fund at the Harvard Forest.

RESEARCH ACTIVITIES

Major research programs at the Harvard Forest focus on the ecology of organisms, communities, and ecosystems, the morphology and development of plants, atmospheric/biosphere interactions, and the history of vegetation and environmental change. Current activity in each of these areas is summarized below.

Hurricane Impacts to Temperate and Tropical Forests

A number of interrelated projects are seeking to understand the historical role of tropical windstorms in the landscape of central New England and to evaluate wind effects through experimental studies and modelling.

Modelling Hurricane Winds

A computer model is being developed by E. Boose that uses meteorological data on the size, intensity, and track of a hurricane to make estimates of the sustained winds on the ground at specified locations and times, before the winds are modified by local topography. The model may be used to study historical hurricanes, where model output complements damage assessments from field surveys or remote sensing, or to explore possible effects of future storms.

Though instantaneous wind gusts are highly variable, the sustained winds of a mature hurricane are fairly stable and symmetrical about the eye of the storm, when considered on a broad scale (measured in kilometers and tens of minutes). The model estimates these sustained winds at a particular point and time, calculating the wind vector as a function of the storm's location, size, and intensity (using standard equations), and then adding the vector describing the forward motion of the storm itself.

As input the model requires data on the location and size of the hurricane eye, and the maximum sustained surface wind speed, as a function of time. Model parameters can be fine-tuned for a particular storm if enough surface observations are available. Output can be generated for a single point or a rectangular grid. Point output includes wind speed and direction at specified times. Grid output includes wind speed and direction at specified times, and cumulative estimates over an entire time series, including maximum velocity, duration of winds above certain speeds, and total sustained wind energy.

Instantaneous wind gusts, caused by surface-level turbulence and probably responsible for much of the damage to the forest, may be 30% to 50% higher than the sustained wind speed and vary 30 degrees or more from the sustained wind direction. Output from the model thus provides an approximate range of speed and direction for these damaging gusts.

Future improvements of the model may take into account the effects of local topography on the wind, and the asymmetries that develop in a hurricane as it weakens over land or is transformed into an extratropical cyclone.

The model has been developed and tested as part of a study of Hurricane Hugo and its effect on eastern Puerto Rico in September 1989 (Fig. 1). Model estimates have been found to agree with the patterns of damage and orientation of treefall identified from aerial photographs. Ongoing applications include the 1938 hurricane in New England, to compare model output with detailed damage assessments; and known historical hurricanes in both New England and Puerto Rico, to study long-term susceptibility to hurricane disturbance as a function of location and topography.

Emery Boose

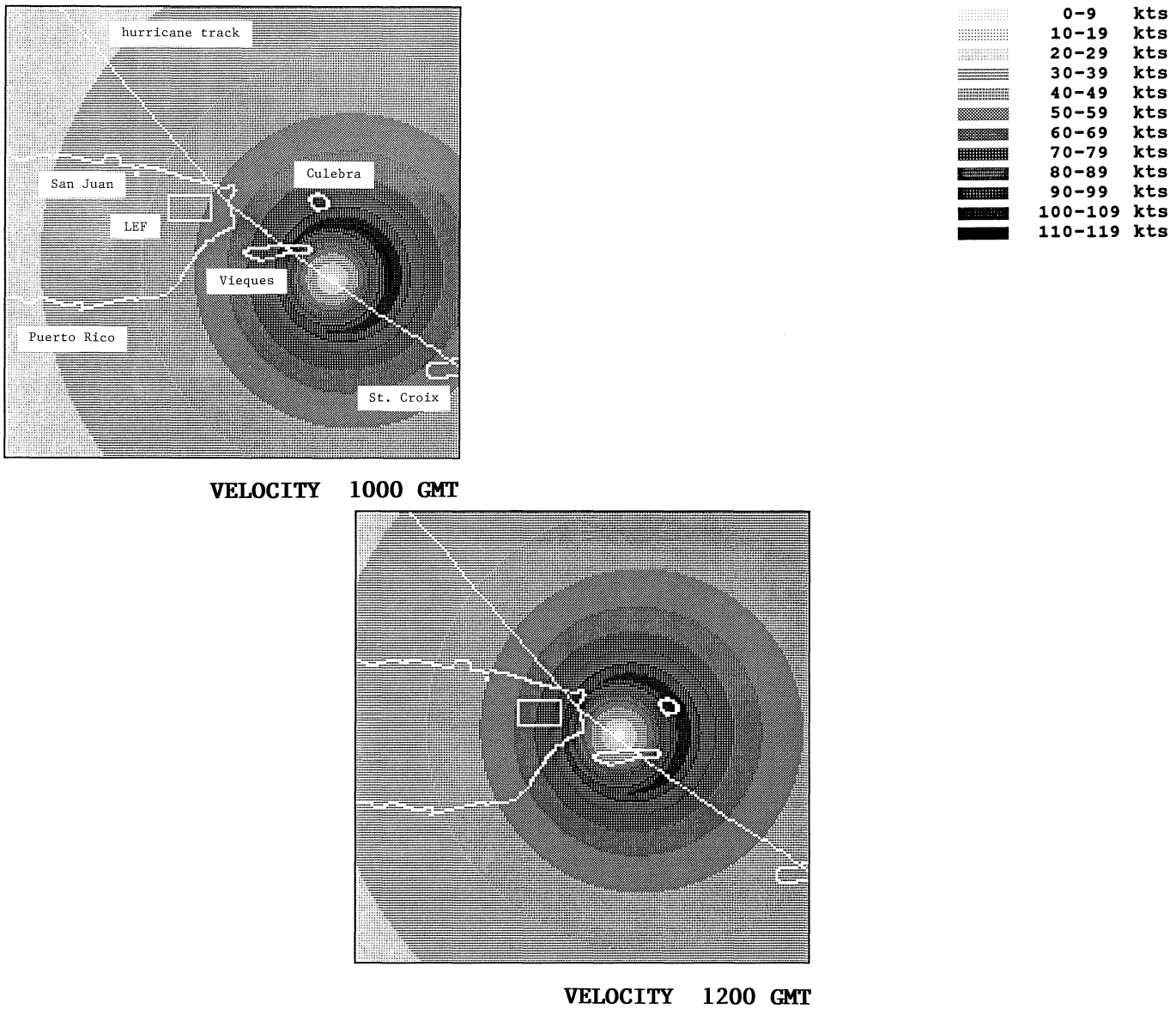


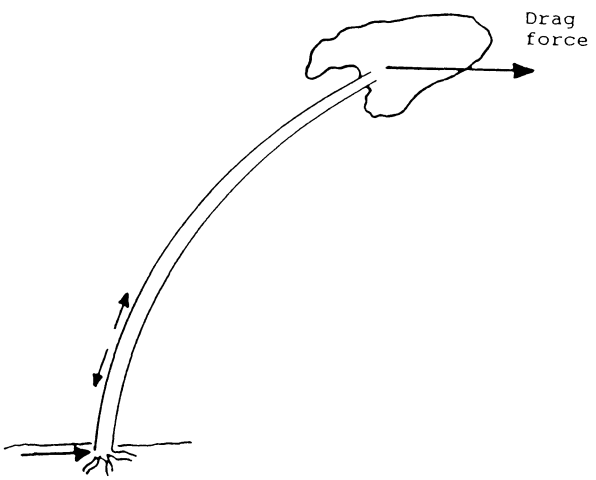
Fig. 1. Model estimates of the sustained surface wind velocity of Hurricane Hugo at two hour intervals (Greenwich Mean Time) as the storm moved northwest across the eastern tip of Puerto Rico on September 18, 1989. Input data from the National Hurricane Center and the National Weather Service include location of the eye and maximum sustained wind speed every 6 hours, radius of the eye from aerial reconnaissance roughly every 2 hours, and surface observations from San Juan Airport every hour. The strongest winds are predicted to have occurred on the right half of the hurricane, where the forward velocity of the storm is added to the rotational velocity of the wind, and in fact the highest gust in Hugo's history was recorded at Culebra. Peak sustained winds at the study site, the Luquillo Experimental Forest, are estimated at approximately 95 knots (kts) from the North with the arrival of the leading eyewall. There is good evidence that Hugo was temporarily weakened as its left half passed over the interior mountains of Puerto Rico, and lesser winds of about 50 knots from the SSW are predicted at the study site during passage of the trailing eyewall. These values agree with forest damage identified from aerial photographs.

Mechanical Stability in Forest Trees

The susceptibility of a forest stand to wind disturbance depends on the force applied by the wind to individual trees within the stand and on their mechanical stability. In this project, coordinated by John Bertram, we are determining the relationship between horizontal force on the crown and the resulting stem deflection, stem mechanical strain during loading and root plate failure that lead to windthrow. The experimental design involves applying a horizontal force by winching individual trees and taking continuous force records through tension transducers on the winch cable. Stem deflection is recorded via lateral filming of the tree by a video camera as it is pulled over. Deflection is quantified by digitizing the video image and undertaking single frame analysis. Force and deflection records are synchronized electronically.

Results to-date include the analyses of 65 trees pulled over during an experimental hurricane simulation. This initial study resulted in the formulation of a preliminary, though comprehensive, model of size effects and anchorage mechanics in trees relative to wind loading. This model is serving as the working hypothesis in an ongoing set of experiments, which are designed explicitly to test the model (see Fig. 2).

Bill Wilson (UMASS Forestry) and Conor O'Dwyer examining a tree in the experimental pull-down.



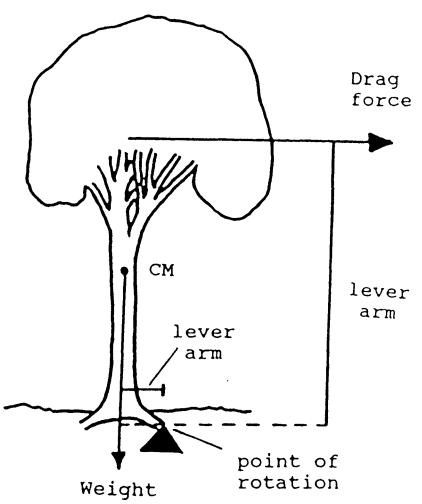


Fig. 2. Models of failure in trees of different size. Left: In slender saplings deflection of the trunk can be extensive causing high levels of tensile strain in the lower trunk. Due to the large lateral deflections of the crown it is impossible to stabilize the tree with compression-resisting members on the leeward side. Anchorage is provided by tensile elements on the windward side of the root plate and the crown is allowed to deflect (note, the low mass of trunk and crown means that overturning moments due to gravitational loads on the above portion of the tree is minimal in comparison to drag forces from wind loading) (after Ennos, 1989).

Right: In mature trees the trunk is robust and heavy. The overturning moment of the drag force acting on the crown is resisted by the weight of the tree (acting vertically through the center of mass - CM) and the lever arm provided by the compression and bending-resistant structural roots on the leeward side of the root plate. Lateral deflection of the stem is a severe disadvantage in this case because it will decrease the leeward root lever arm. Windward root anchorage and soil adhesion beneath the root plate need not be major contributing factors for stability in large trees (after Vogel, 1981).

Landscape Level Impacts on Hurricanes

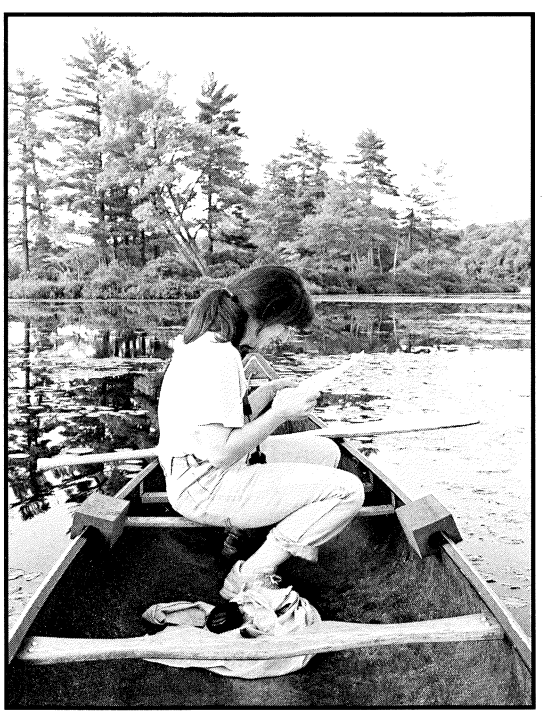
The effects that hurricane winds exert on forested landscapes are determined by complex interactions among the meteorology of the storm, the physiography of the landscape, and the structure and composition of the forests and their arrangement on the terrain. A group including D. Foster, E. Boose, A. Lezberg and M. Fluet is evaluating these interactions for the effects of Hurricane Hugo on the Luquillo Experimental Forest in Puerto Rico and the 1938 hurricane on the landscape of central New England. This research relies extensively on the interpretation of aerial photography and spatial analysis with GIS and is being coordinated with the modelling of hurricane meteorology described above.

Results from the analysis of effects of the 1938 hurricane in central Massachusetts suggest that site exposure, determined by slope orientation and angle, is the major edaphic control of damage. The actual damage pattern consisted of patches of different damage intensity that form a negative exponential distribution of size with a preponderance less than 0.25 ha and maximum greater than 35 ha. Different forest types exhibited strikingly different susceptibility to wind, with conifer stands much more prone to windfall than hardwood stands. A GIS-based model of landscape level response to wind has been developed and tested. Results indicate that a relatively small number of site factors (exposure) and vegetational factors (height and species composition) can be used to predict a large percentage of the variability in observed damage.

Historical Ecology and Paleoecology

Our historical research focuses on the post-glacial period particularly the last 1000 years, as we explore the changes in environmental factors and vegetational changes in central New England resulting from natural processes and human activities. Major researchers in this project include G. Whitney, D. Foster, D. Gaudreau, E. Boose, and R. Boone. Of particular interest are the contrasts between vegetation response to human factors, such as agricultural land-use activity, logging, and atmospheric pollution, and forest dynamics driven by such natural factors as climate change, wind damage and fire. We also seek to understand long-lasting impacts of historical changes in the landscape, their influence on modern forests, and how they affect the way we study and understand our forest ecosystems. This research continues a long tradition of investigation at the Harvard Forest and is a major emphasis of our LTER research.

This research effort has two major approaches: (i) intensive site-based and landscape studies, and (ii) extensive regional investigations. Detailed studies during the past year have focussed on forest stands that have been permanently wooded throughout the settlement period when more than 70% of the uplands were deforested for agricultural purposes (Fig. 3). Paleoecological forest reconstructions have revealed entire Holocene (last 10,000 years) vegetation and disturbance histories for a hemlock forest and an extensive red spruce swamp (Black Gum Swamp) in the center of the Prospect Hill tract.



Ann Lezberg

Fritz Gerhardt and Peter Schoonmaker

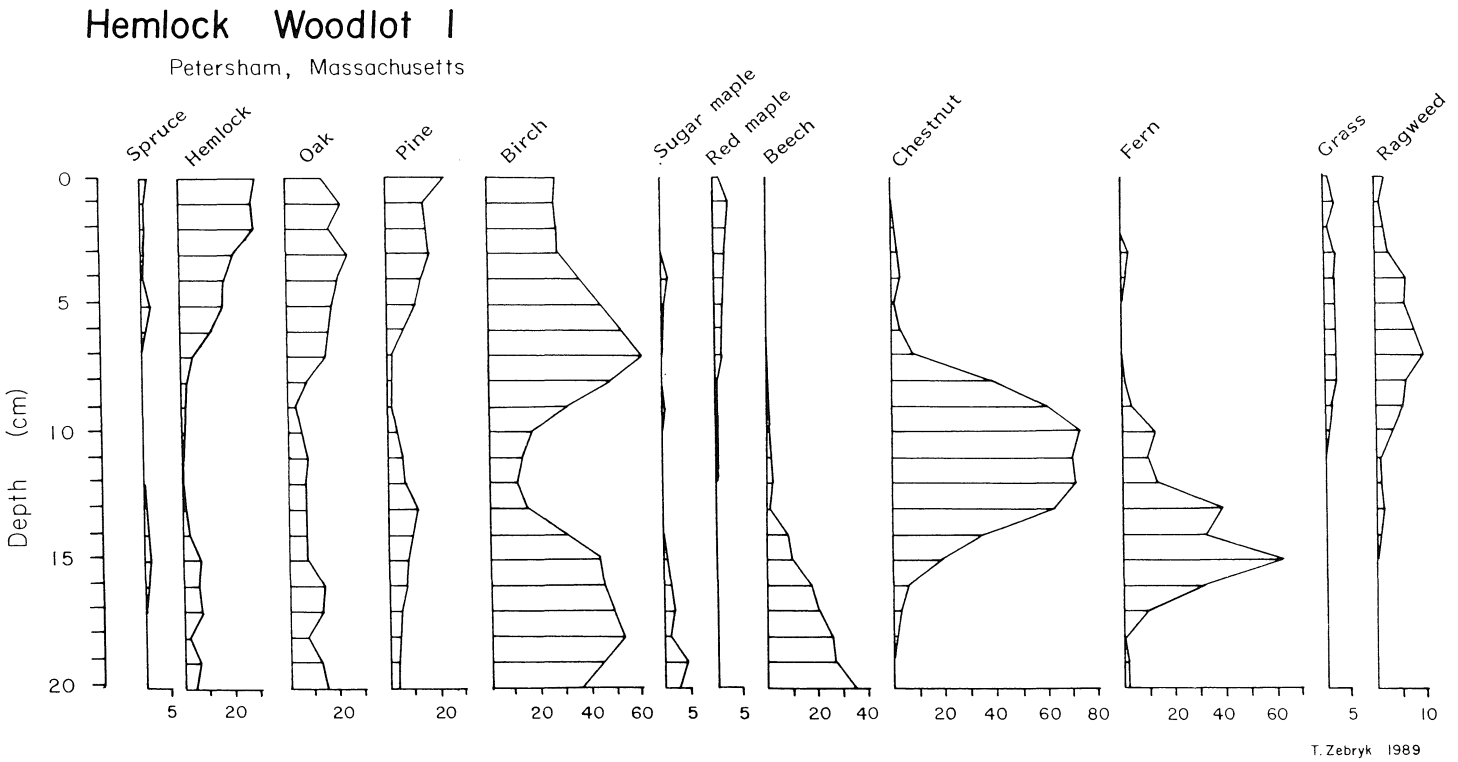


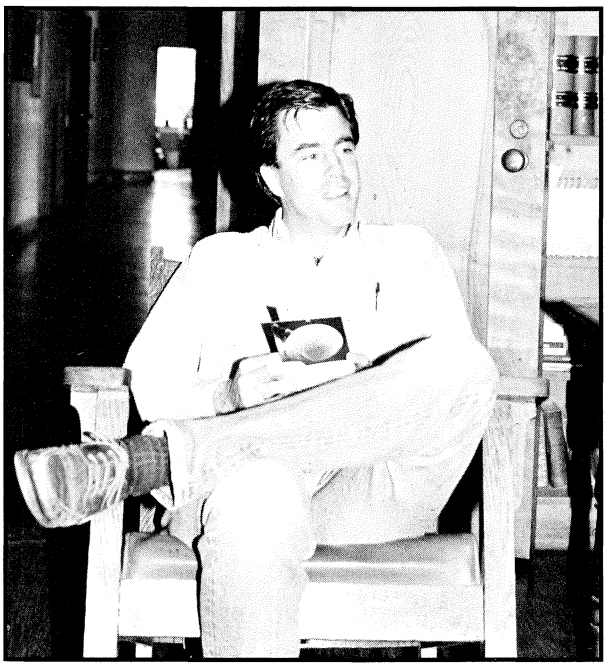
Fig. 3. Pollen diagram from the humus soil of a hemlock stand in the Prospect Hill tract depicting the relative changes in abundance of major species over the past 250 years. At the bottom of the diagram the forest at the time of settlement was comprised of beech, birch, oak and hemlock. Cutting of the stand and regional deforestation caused a reduction in these species and increase in ragweed and grass and conversion of the forest to a chestnut sprout woodland through much of the 19th century. The chestnut blight (1915), land abandonment and vegetation development resulted in the formation of the current 100-year-old stand of hemlock, oak, birch and pine.

The long-term history of these individual stands is being placed in a landscape context through the analysis of land-use history and vegetation change for the 1000-acre Prospect Hill tract and the town of Petersham. This effort seeks to determine the environmental and cultural controls of land-use activity (e.g. tillage, pasturage, woodlots) and the effects of the interaction of site conditions and land-use on vegetation pattern. Much of this work utilizes GIS and builds on the data base accumulated over the past 80 years at the Harvard Forest.

Gordon Whitney is analyzing the historical factors influencing the flora of central New England's woodlands. This study represents an elaboration on early vegetation - site analyses by John Goodlett, a former staff member. The fern and woody plant flora of over 400 plots, distributed across a range of sites in north central Massachusetts, has been related to site factors including soil type and slope position. The effect of site history on species composition is currently being examined. Sites are classified as primary woodlands (i.e. never cleared) versus young (< 50 year) or old (> 50 year) secondary woodlands. This study complements the earlier work by G. Whitney and D. Foster (1988) in which the herbaceous flora of different aged woodlands was described. It should allow us to determine the degree to which the flora reflects the past history versus the physical characteristics of the site.

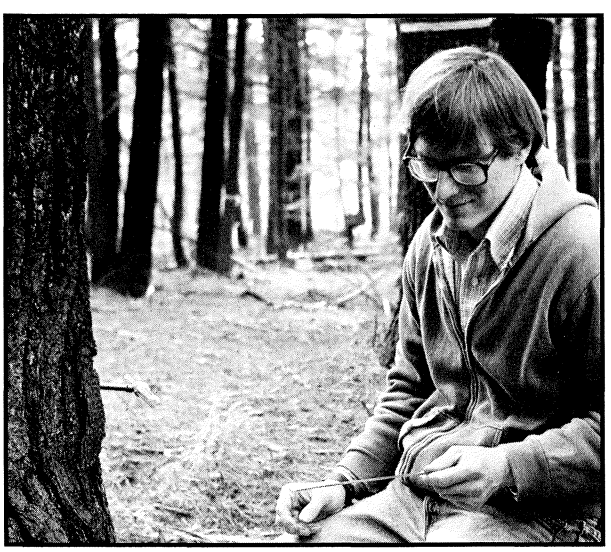
At the regional scale we are examining forest history across 200 townships comprising the Central Highlands (Worcester County) and the adjoining Connecticut Valley Lowland (Hampden, Hampshire and Franklin Counties) in Massachusetts. This study area incorporates strong regional gradients in environmental factors (climate and soils) and in cultural factors (settlement history, agricultural practices, population density, transportation development). Our interest is in examining the interaction between these gradients in terms of changes in the extent, structure and composition of the forest vegetation. The study involves collaboration with researchers from Old Sturbridge Village and has generated new interactions with social scientists from the George Perkins Marsh Institute at Clark University.

For Gordon much of the year was spent collating township-level vegetation and land use information from the manuscript files of the Massachusetts State Archives, the State Library and the State Forester's Office in Boston and the Special Collection Section at the University of Massachusetts in Amherst. A considerable amount of time was devoted to finding and implementing appropriate techniques for statistically analyzing the spatial data. Gordon is currently building a data base and utilizing spatial regression analysis to determine the impact of various cultural and physical features of the environment on the nature and extent of Massachusetts' historical woodlands.



David Foster

Gordon Whitney



Tad Zebryk

Wetland Development and Ecology

Temperate wetlands in central New England and central Sweden are being investigated using stratigraphic analyses to determine the role of climate change on the rate and direction of their development over the post-glacial period. Modern hydrological, environmental and floristic information is also being collected in order to correlate current and historical conditions and processes. Tad Zebryk has just completed his MFS thesis on the history of the Black Gum Swamp in the Prospect Hill Tract. Tad documented modern hydrology, water chemistry and floristics over two growing seasons and produced a comprehensive bathymetric map of the basin. Detailed pollen diagrams and macrofossil diagrams, aged using radiocarbon dating, were used to reconstruct the site history. Major findings included the progressive lateral expansion of the wetland through time as the wetland encroached into the adjoining upland forest area. The development and expansion of the wetland appeared to be controlled by climate change, topography and hydrology, and most recently by human activity.

In central Sweden David Foster is studying the development of raised bog ecosystems in collaboration with Heather Jacobson (University of Maine), Jim Almendinger (U.S. Geological Survey) and H. E. Wright (University of Minnesota). Prior stratigraphic studies have revealed that some bogs there have expanded in depth and lateral extent continually over the past 6000 years. Current studies examine the relationship between bog development and climate change as revealed through studies of vegetation and water level changes in adjacent lakes. The paleoclimatic and paleolimnological research forms the basis for Heather's doctoral studies at the University of Lund in Sweden. Last summer the group installed a series of piezometers in transects across Hammarmossen Bog in order to monitor the groundwater table and to develop a hydrological model for the peatland. Monitoring of the piezometers throughout the year by a collaborator in Sweden has allowed the assessment of groundwater fluctuations as influenced by weather and flow patterns of the bog. Initial measurements indicate that the bog is hydrologically perched above the regional groundwater table due to the presence of a relatively impermeable layer of fine organic material and charcoal at the base of the peat. Current efforts are seeking to tie the hydrology of the bog to that of the adjacent lakes and river in order to understand historical changes in the hydrology of this system.

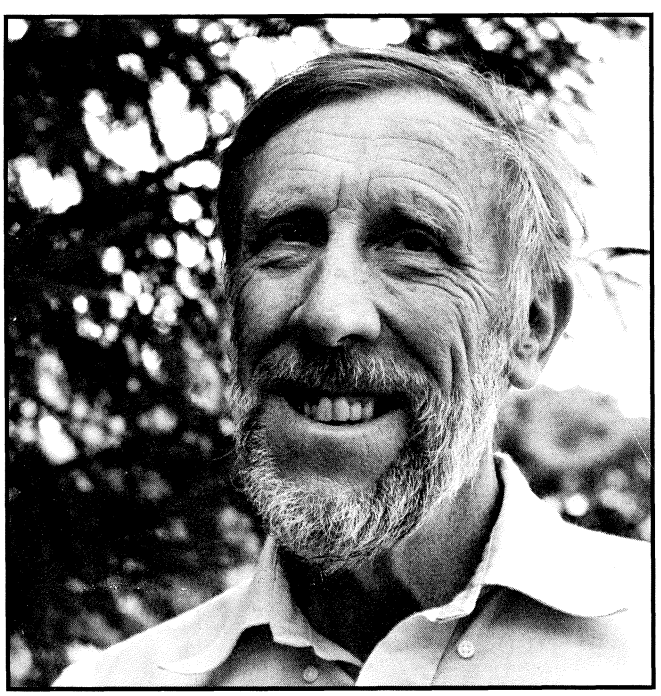
Developmental and Reproductive Biology

The research program in developmental and reproductive biology is headed by P. B. Tomlinson with collaboration during this past year from post-doctoral fellows Robin Scribailo, Tokushiro Takaso (University of British Columbia), and colleagues especially in the South Pacific. Effort has concentrated on writing projects, including a study of the reproductive biology of the southern coniferous family Podocarpaceae and continued work on the developmental morphology of the coniferous seed cone centered on the families Taxodiaceae and Cupressaceae. In Taxodiaceae the ovule-supporting structure associated with each bract of the cone is expressed in different ways and may even be absent, while in Cupressaceae no ovuliferous scale is ever developed as a discrete axillary structure. A special study of the New Zealand genus *Libocedrus* showed that a ligular structure that has usually been interpreted as an ovuliferous scale is an outgrowth that develops late and protects the developing seed.

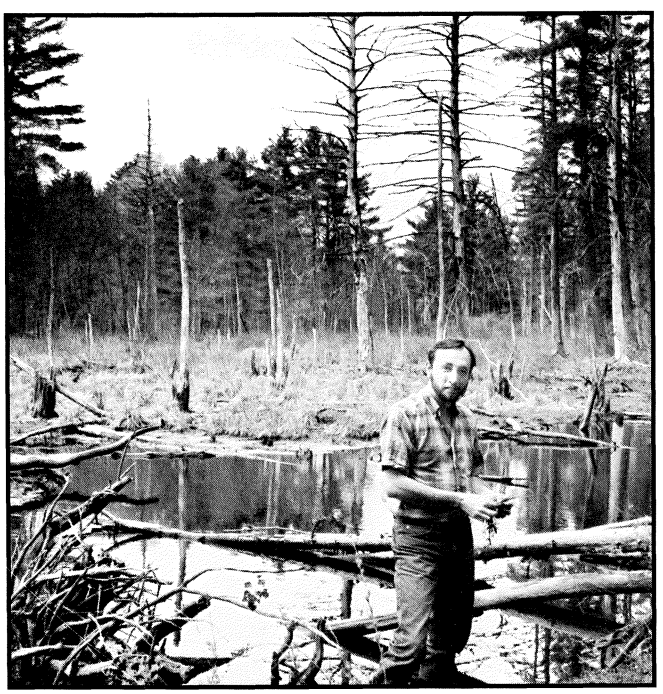
Collaboration with Usher Posluszny from the University of Guelph, Ontario, has revealed the intricate and compact organization of the shoot in the seagrass *Halophila* (Fig. 4).

Dr. Scribailo completed in April his two-year period of study supported by a post-doctoral fellowship from the Canadian National Sciences Engineering and Research Council. In addition to finishing a number of papers arising from his thesis research he has worked on floral development in the tropical family Araceae, concentrating on genera with perfect (hermaphroditic) flowers. In a detailed study of *Calla* no evidence for trimery in floral organization was found, despite the usual interpretation of flowers in the family as being ancestrally three-parted. Rather than adopting a rigid typological approach, emphasis was placed on the trend in the spadix towards maleness distally and femaleness proximally as morphogenetic variability that may presage the unisexuality of flowers otherwise dominant in the family. Robin moved to a position at the University of Guelph, Ontario, Canada; in August he will be taking a faculty position in the Biology Department at the North Central Campus of Purdue University, Westville, Indiana.

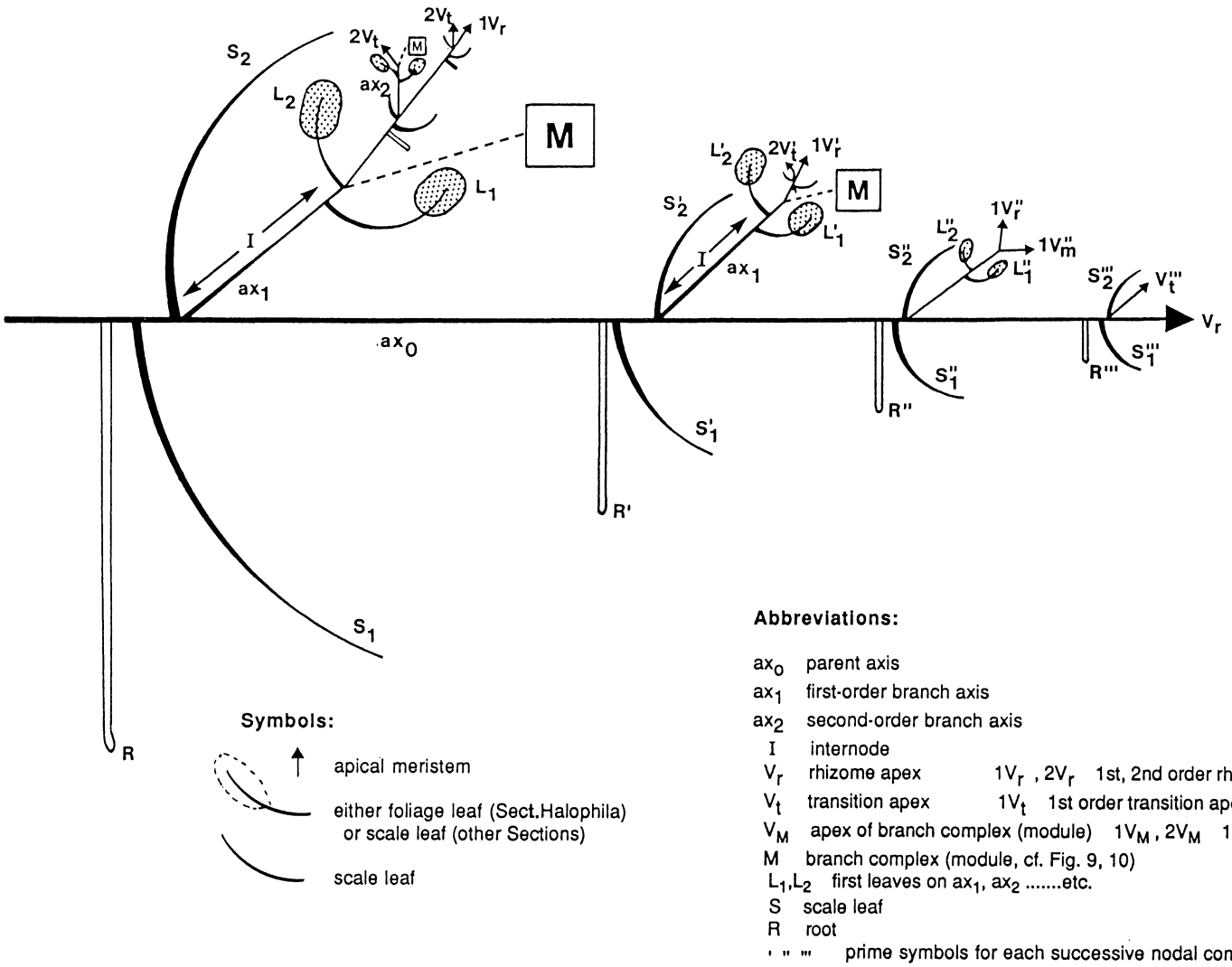
Peter Del Tredici completed part of his research for a PhD at Boston University in Dr. Tomlinson's laboratory at Harvard Forest. Peter discovered that *Ginkgo biloba* (maidenhair tree), native to China and commonly cultivated, produces renewal shoots from meristems in the axils of cotyledons. These meristems are responsible for the ability of *Ginkgo* to sprout extensively in plantation culture, facilitating harvesting of leaves in commercial quantities. *Ginkgo* leaves are the source of unique compounds (ginkgolides) that are of major pharmaceutical importance since they increase blood flow in patients suffering from circulatory disorders. Dr. Del Tredici is on the staff of the Arnold Arboretum.



Barry Tomlinson



Robin Scribailo



Symbols:

apical meristem

either foliage leaf (Sect.Halophila) or scale leaf (other Sections)

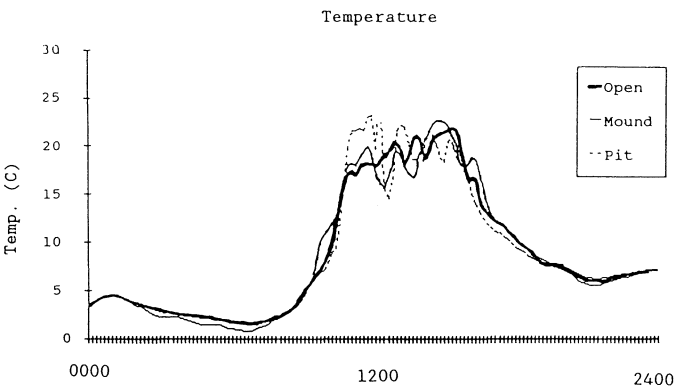
scale leaf

Abbreviations:

ax_0	parent axis	
ax_1	first-order branch axis	
ax_2	second-order branch axis	
I	internode	
V_r	rhizome apex	$1V_r$, $2V_r$ 1st, 2nd order rhizome
V_t	transition apex	$1V_t$ 1st order transition apex
V_M	apex of branch complex (module)	$1V_M$, $2V_M$ 1st, 2nd order
M	branch complex (module, cf. Fig. 9, 10)	
L_1,L_2	first leaves on ax_1, ax_2 .....etc.	
S	scale leaf	
R	root	
' " "'	prime symbols for each successive nodal complex	

Fig. 4. Shoot organization in the marine flowering plant (seagrass) *Halophila* (Hydrocharitaceae), from Posluszny and Tomlinson, 1991. This genus of diminutive seagrasses is pantropical but has been little studied developmentally. The diagram shows the large number of components packed into a single apical bud, enclosed in the outermost pair of scale leaves, S_1 and S_2. Since the bud is only 2-3 mm long, the system is very tightly packed. As many as eight nodes may be preformed with over 120 visible appendages. This high degree of proliferation can account for the ability of the plant to persist in unstable marine environments.

Fig. 5. Diagram of five forest floor microsites created by hurricane blowdown: 1) pit, 2) tip-up mound, 3) mound top, 4) level shaded site, 5) level open site.



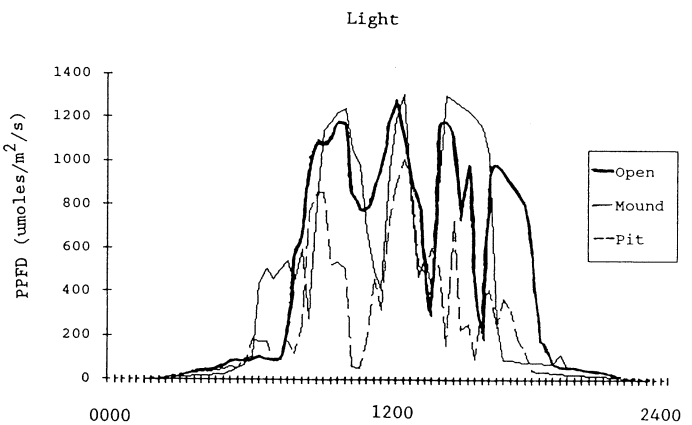
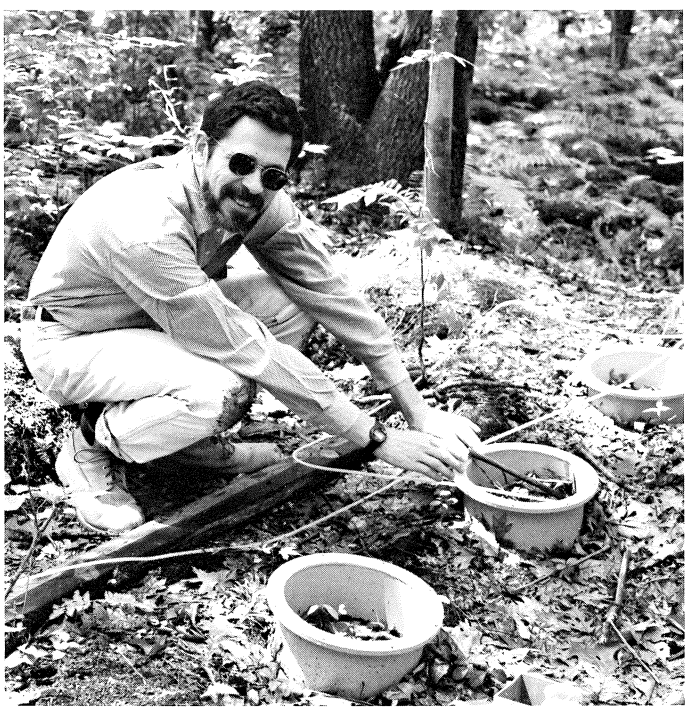


Fig. 6. Diurnal patterns of air temperature and radiation (photosynthetic photon flux density) on three microsites at the Prospect Hill blowdown on 4 October 1989.

Ecophysiology and Micrometeorology

The ways in which hurricane blowdowns alter the environmental conditions in forest stands and change the establishment and growth of tree species are being examined by Gary Carlton, graduate student of Fakhri Bazzaz. Gary's work is based on the hypothesis that alteration in the fluxes of a few key resources (light, water, nitrogen and CO_2) following the disturbance of a forest stand is the main factor controlling the subsequent dynamics of the vegetation. On experimental blowdowns in the Tom Swamp and Prospect Hill tracts he is examining the fluxes of these resources on five microsites created by the disturbance: root tip-up mounds, adjacent pits, mound tops, level sites in open areas, and level sites below herbaceous vegetation (Fig. 5). The diurnal and seasonal patterns of light, air and soil temperature, relative humidity, and wind speeds are being monitored on the different microsites (Fig. 6). Physiological and growth responses to resource fluxes are being investigated in red oak, red maple, yellow birch, black birch and white birch. Quantitative surveys of seedling demography and community composition are also being monitored in collaboration with Ann Lezberg.

Jason McLachlan and Gary Carlton

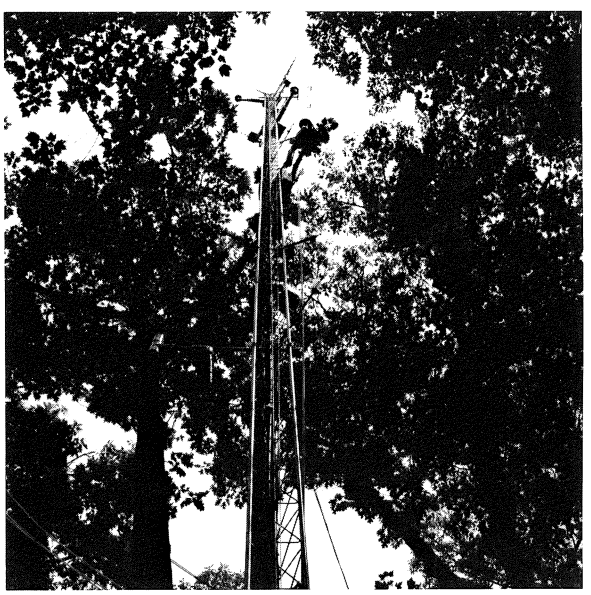


Steve Wofsy

Biosphere/Atmosphere Interactions

Despite 30 years of intensive study, the global cycle of carbon dioxide remains poorly understood. Approximately 1 billion tons per year of CO_2 is removed from the atmosphere by an unknown process, representing 20% of the annual release from burning of fossil fuels. It has been proposed that forests at temperate latitudes, like Harvard Forest, might be the "missing sink" for carbon dioxide, but until recently there has been no test of this idea by direct observation.

Since October, 1989 Steve Wofsy, Associate of the Harvard Forest and Senior Research Fellow at the Department of Earth and Planetary Sciences at Harvard, has been measuring the net transfer of carbon dioxide between the forest and the atmosphere on the 30-m tower at the Environmental Monitoring Station at Prospect Hill. Direct measurements of exchange of carbon dioxide have been made over a period far longer than successfully attempted anywhere else. In summer the expected diurnal pattern was with net uptake by the forest observed during the day (due to photosynthesis) and release at night (respiration). In winter slow release as expected during cold periods was observed, but during thaw intervals net uptake was measured, reflecting photosynthesis by conifers. Each hectare of this tract in Harvard Forest removed about 3 metric tons of carbon from the atmosphere during 1990, approximately equivalent to the carbon dioxide added by one automobile. This observation provides the first concrete evidence supporting the view that forests of the temperate zone may be important in removing carbon dioxide added by burning of fossil fuel.



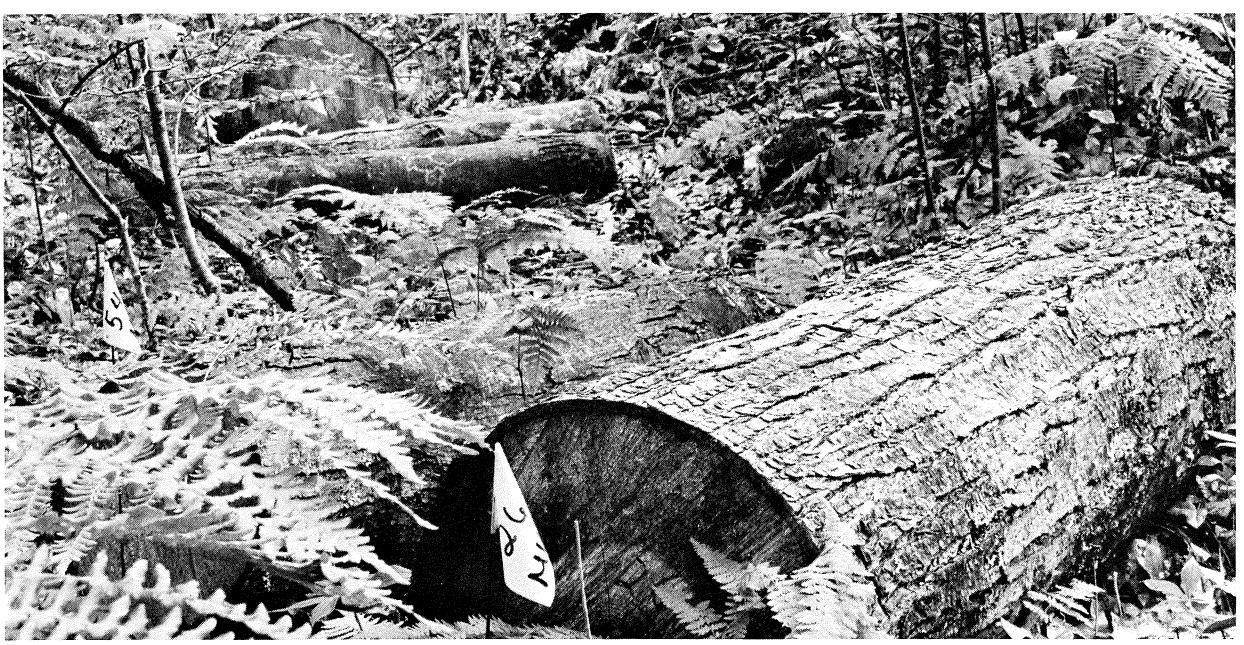
Harvard Forest LTER Program

The Harvard Forest is one of eighteen sites forming the Long Term Ecological Research program sponsored by the National Science Foundation. Each site is addressing ecological questions and concerns of a long-term nature and collectively the sites provide the basis for comparative studies across ecosystems. Representatives from the LTER sites, U.S. funding agencies and other national and international research groups meet at least twice annually to develop collaborative studies and to exchange information.

The central theme of the Harvard Forest LTER is a comparison of historically-important physical disturbances and recent and projected chemical disturbances (i.e. resulting from atmospheric pollution) in terms of their effect 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 to which components of the system may be adapted.

The research project involves soil scientists, atmospheric chemists, and researchers studying physiological, population, community, ecosystem and historical ecology. Principal investigators in the research represent the departments of Biology (F. Bazzaz), Earth and Planetary Sciences (S. Wofsy), and Harvard Forest (D. Foster, E. Boose) at Harvard University as well as the Ecosystems Center at Woods Hole (J. Melillo, K. Nadelhoffer, and P. Steudler) and the Complex Systems Research Center at the University of New Hampshire (J. Aber). The research is organized to maximize the interactions and exchanges among scientists from different disciplines and to assess processes comprehensively. Four core experiments include: (1) re-creation of physical types of disturbance, including catastrophic hurricane blowdown, smaller windthrows and selective mortality of overstory species, 2) simulation of chronic chemical disturbance by altering inputs of important nutrients or pollutants, 3) interactions between physical and chemical disturbances, and 4) repetition of treatments to assess the range of variation in organism and ecosystem response. Synthesis of the research is achieved through the application of remote sensing, GIS, and modelling. Much of the research described in this annual report comprises part of the LTER activity.

The LTER science group meets approximately monthly. An annual Harvard Forest Ecology Symposium is held during mid-winter in order to present the results of current research by scientists, research assistants and students. Abstracts from this meeting are published annually. The program for the 1991 Symposium is shown on the following page.



Red maple logs on the forest floor in Prospect Hill. Part of a long-term study designed by Chuck McClaugherty, a member of the LTER project, these logs will be recovered at 5-year intervals to investigate structural and chemical changes in wood resulting from decomposition processes.

HARVARD FOREST ECOLOGY SYMPOSIUM 1991

Titles of Abstracts and Presentations

J. Aber, J. Melillo, P. Steudler, A. MaGill and R. Boone. Effects of three years of chronic N additions to red pine and mixed hardwoods at the Harvard Forest.

P. Bakwin, J. W. Munger, B. Daube, S. Fan and S. Wofsy. Nitrogen oxide concentrations and dry and wet deposition rates in rural central New England.

J. Bertram. Mechanical stability in hardwoods: formulating the question.

R. Boone and J. Aber. Effect of chronic nitrogen (N) additions on N immobilization by forest floor material at the Harvard Forest.

E. Boose. Hurricane wind model.

G. Carlton and F. Bazzaz. Physiological and demographic mechanisms of tree regeneration following hurricane blowdown in a temperate deciduous forest.

R. Crabtree and F. Bazzaz. Birch regeneration in a changing nitrogen environment.

A. Ellison. Understory perennials: reproduction, recruitment, and effects on forest structure.

D. Foster. Land-use and vegetation dynamics in central Massachusetts: an historical perspective.

D. Foster and E. Boose. Patterns of forest damage resulting from catastrophic wind in central New England, U.S.A.

D. Foster and T. Zebryk. Long-term vegetation dynamics and disturbance history of a *Tsuga*-dominated forest in central New England.

D. Gaudreau. A network of pollen sites for central Massachusetts: toward an understanding of postglacial vegetation dynamics at the Mesoscale.

L. George. Response to disturbance in *Lycopodium* species with contrasting branching patterns.

M. Korzukhin. A simulation model of tree and grass communities.

A. Lezberg and D. Foster. Disturbance effects and vegetation dynamics in an old-growth forest landscape.

A. Lezberg and D. Foster. Post hurricane response in old-field white pine forests.

A. Lezberg and D. Foster. Effects of hurricane simulation on red oak-red maple forest: an integrated experiment of the Harvard Forest LTER.

M. Martin and J. Aber. Remote sensing of canopy chemistry at Harvard Forest.

C. McClaugherty. Decomposition of coarse woody debris.

J. W. Munger, P. Bakwin, S. Fan, B. Daube and S. Wofsy. Dry deposition of NO_3 and O_3 to snow in a New England Forest: comparison of eddy correlation flux and snowpack accumulation.

K. Nadelhoffer. Long-term impact of organic matter inputs on soil and ecosystem development.

W. Peterjohn, J. Melillo, F. Bowles and P. Steudler. Soil warming and trace gas fluxes: experimental design and preliminary gas flux results.

R. Primack and S. Miao. Dispersal as a factor limiting the distribution of plant species.

P. Schoonmaker. Long-term vegetation dynamics in southwestern New Hampshire.

P. Schoonmaker and D. Foster. Some implications of paleoecology for contemporary ecology.

R. Stafford. Recent disturbance history and forest dynamics on permanent plots at the Pisgah Tract.

C. D. Tomlin and D. Foster. A Mapbox/System 9 interface for GIS Analysis.

P. B. Tomlinson. Differential regenerative ability in forest trees.

P. Wayne, S. Miao and F. Bazzaz. Radiation, ectomycorrhizae, and the responses of four sympatric birches (*Betula*) to the gap-understory continuum.

G. Whitney. Relation of plant species to substrate, landscape position and aspect in north-central Massachusetts.

G. Whitney. A spatial analysis of central New England's changing vegetation and its relation to land-use practices.

G. Whitney. Historical determinants of the flora of central New England's woods.

S. Wofsy, J. W. Munger, B. Daube, P. Bakwin and S. Fan. Exchanges of CO_2 and NO_y at Harvard Forest: the first year.

T. Zebryk. Ecology and Holocene paleoecology of the Black Gum Swamp - a forested peatland in the Harvard Forest.

T. Zebryk. Vegetation and site characteristics of a *Nyssa*-dominated wetland in central Massachusetts.

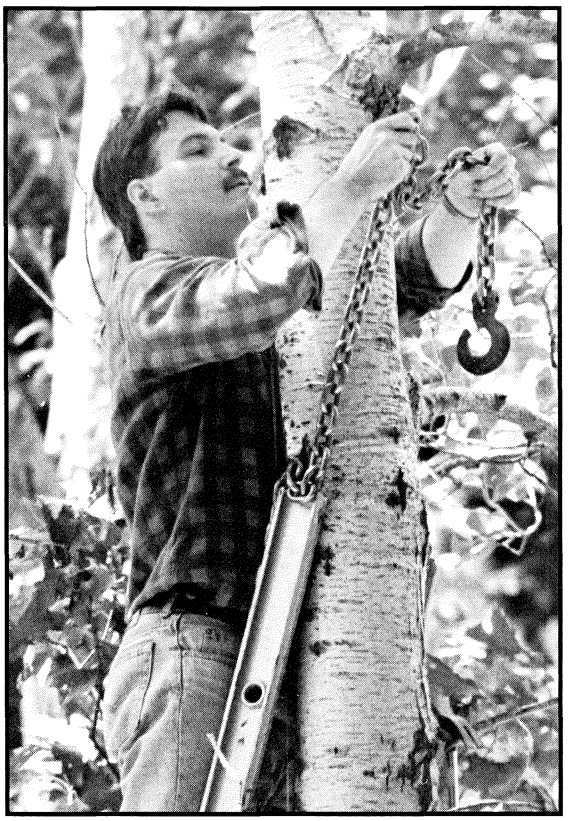
BULLARD FELLOWS

The Bullard Fellowship Program in Forestry at Harvard University supported three visiting faculty this year: Ms. Mollie Beattie, former Commissioner of Forests for the state of Vermont, Dr. Michael Korzukhin from the Moscow Academy of Sciences, and Dr. John Bertram from Dalhousie University. Dr. Bertram resided in Petersham with his family and became actively involved in the research program investigating biomechanical response of forest trees to wind loading. He interacted actively with faculty at the Division of Applied Sciences, Museum of Comparative Zoology, and Concord Field Station, at Harvard University and in the Forestry and Wildlife and Engineering Departments at the University of Massachusetts on projects ranging from biomechanics of horse and emu locomotion to swimming activity in hammerhead sharks. John will join the faculty at the Veterinary School of Cornell University in January.

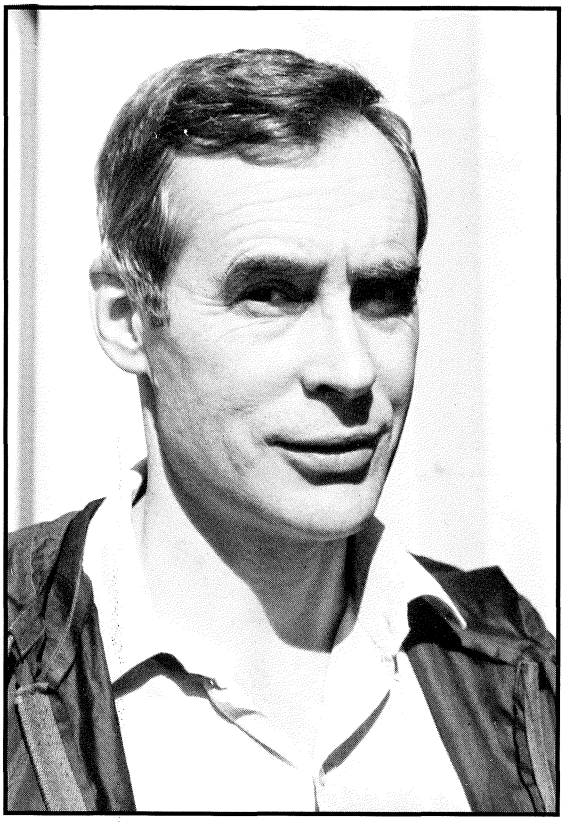
As a candidate for a Masters degree in Public Administration at the Kennedy School of Government Mollie Beattie took a full course program at the Kennedy School and the Harvard Law School focussing on knowledge and skills relative to the public administration of forest and other natural resources. Her course work included micro-economics, environmental law, law and public policy and leadership and authority among others. Having achieved her Master's degree in June 1991, Ms. Beattie is currently employed in land management for the Vermont Land Trust. Future plans include a continued career in state or federal government concerned with natural resources.

Dr. Korzukhin and his wife resided at the Harvard Forest with their daughter and worked through the year adapting a computer model of forest stand dynamics to the microcomputer and developing it for general use. Michael outlined the model at two seminars at the Harvard Forest and developed a manual for its distribution.

Bullard Fellows for 1991-92 include Dr. Jan Cermak, Brno University of Agriculture, Czechoslovakia, Dr. Ned Fetcher, University of Puerto Rico, Dr. Steve Hamburg, University of Kansas, and Dr. Miguel Marinez-Ramos, Ciudad Universitaria, Mexico.



John Bertram



Michael Korzukhin

EDUCATIONAL ACTIVITIES

Staff at the Harvard Forest seek to relate their interests and the results of their research to students through the Summer Research Program, the Masters Program in Forestry, and courses offered in the Department of Organismic and Evolutionary Biology and the Freshman Seminar Program at Harvard University.

Two students, Tad Zebryk and Russell Stafford were enrolled in the Master of Forest Science program working with Dr. Foster this year. Tad successfully defended his thesis on the modern ecology and development of the Black Gum Swamp. Russell is completing his thesis, which is an analysis of spatial heterogeneity in forest vegetation and development at the Pisgah Forest in southwestern New Hampshire. New graduate students include Fritz Gerhardt who has been working with the U.S. Forest Service in Alaska and will conduct studies for his MFS degree with David Foster, and Lisa George, second year student in the PhD program in biology who will be working with Barry Tomlinson on the developmental biology of *Lycopodium.*

Peter Schoonmaker is completing his thesis on the vegetation history of the Pisgah tract and had the first chapter of his dissertation, a review of the contributions of paleoecology to contemporary ecology, accepted for publication. In the fall Peter will be teaching courses in forest ecology and a seminar on the values and characteristics of old-growth forests at the University of Massachusetts.

Two visiting graduate students worked with David Foster this year. Raouf Moustafa completed his PhD research on vegetation gradients in the Sinai Mountains and returned to his home institution, Suez Canal University in Ismailia, Egypt. Jakob Riis from the Veterinary and Agricultural University in Copenhagen, Denmark, spent four months at the Harvard Forest writing a Masters thesis on decision making in forest management. In addition, faculty and staff at the Harvard Forest served on thesis committees for students at Harvard University, Hampshire College, University of Lund, Sweden, McGill University, and the Department of Forestry and Wildlife Management at the University of Massachusetts.

Dr. Tomlinson taught Biology 24 "Introductory Plant Biology" and Biology 102 "Biology of Gymnosperms" in Cambridge during the spring term. Dr. Foster taught Biology 299 "Seminar in Forest Research." Together they led the Harvard Forest Freshman Seminar program which meets at the Harvard Forest over four weekends during the spring term. The seminar provides an introduction to a range of topics in forest biology in an informal setting for a class of eleven students. Professor Torrey conducted a graduate tutorial in biology during the fall term and gave three lectures on root and rhizosphere biology in Biology 120 "Plant Physiology" during the spring term.

Summer Research Program

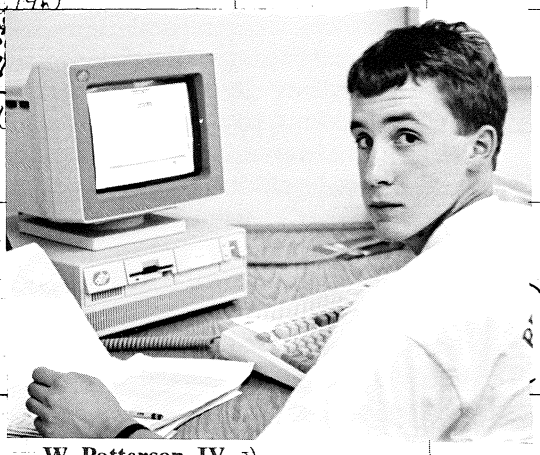
The lack of hands-on field and laboratory research experience is one of the greatest deficiencies in the educational background of most science students. The Summer Research Program at the Harvard Forest seeks to address this need while furthering the research objectives of the Forest by involving students as research assistants on a wide range of ecological studies. This program, which provides students with experience working alongside graduate students, post-doctoral associates, faculty and staff is one of the most effective educational uses of the resources and facilities at the Harvard Forest. During the current summer a total of 21 students worked on various projects.

Karen Bush	University of Massachusetts
Michael Buckley	Allegheny College
Sumati Buradagunta	Mount Holyoke College
Holly Christoferson	Williams College
Anne Dix	Mount Holyoke College
Jason Garrison	Allegheny College
Theodora Jaster	University of New Hampshire
Kathleen Keith	University of Massachusetts
Martha Kennan	Salem State College
Tobe Korsgren	Yale University
Catherine Mabry	Harvard University
Jason McLachlan	Columbia University
Patricia Micks	Texas A & M University
Cathy Milliken	Allegheny College
Conor O'Dwyer	Harvard University
William Patterson, IV	Cornell University
Mark Potosnak	Harvard University
Nishanta Rajakaruna	College of the Atlantic
Scott Ringgold	Williams College
Martha Varnot	Quabbin Regional High School
Susanna Walter	University of New Hampshire

Overleaf: Summer research students

C. Mabry, T. Korsgren

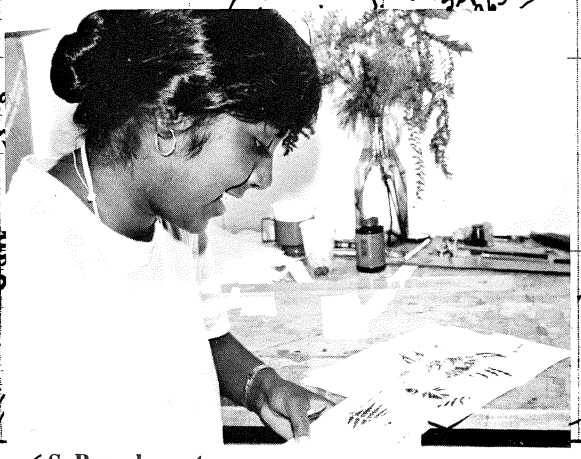
N. Rajakaruna



W. Patterson, IV

K. Keith

C. Milliken, M. Buckley



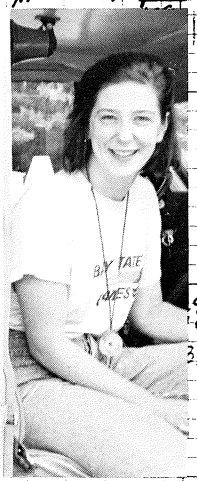
S.S. Buradagunta

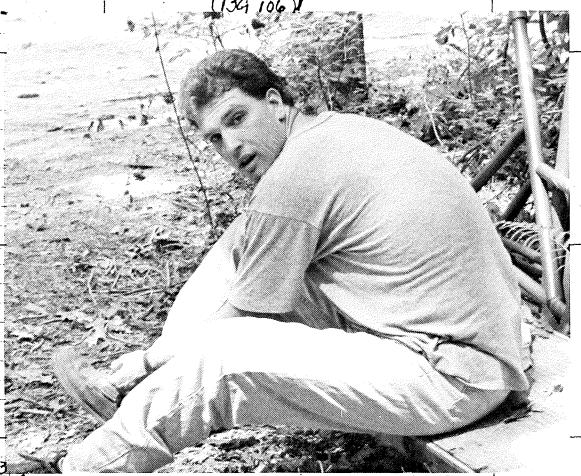
K+E STANDARD ® CROSS SECTION
10×10 TO THE INCH

So.1 boundary is between soils that

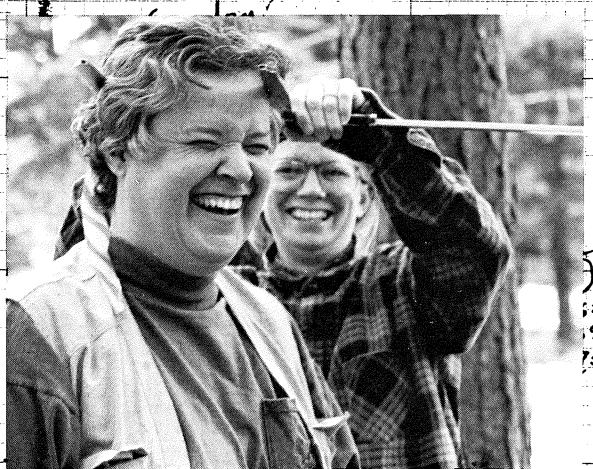
Aluminum bands on a few Trees in 1962 to obtain yearly diameter increment.

P. Micks, M. Kennan

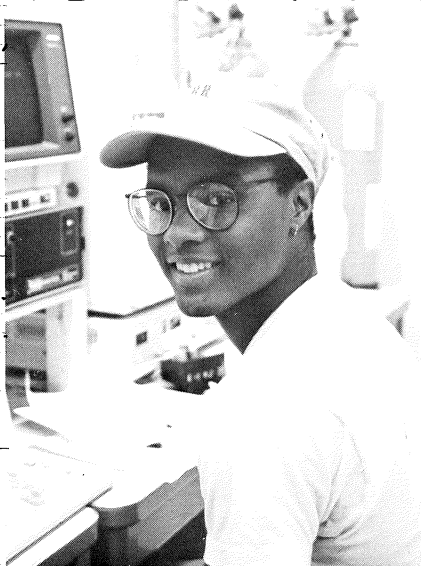




M. Potosnak



M. Varnot, K. Bush



J. Garrison

T. Jaster

S. Ringgold, H. Christoferson

KEUFFEL & ESSER CO.
MADE IN U.S.A.

gray just below A1 and those that are brown

MOUNDS & PITS shown ON THIS SQUARE

Only Conspicuous & DISTINCT MOUNDS ARE SHOW

MOUNDS THAT SHOW UP ONLY WHEN T

"*Cornus canadensis* as element in ground cover on site of reproduction study, Tom Swamp III."
10 June 1914. Photograph by R. T. Fisher

ACTIVITIES OF THE FISHER MUSEUM

The Fisher Museum plays a very important role in the operation of the Harvard Forest by providing a public outlet for information concerning research activities and the fields of forest biology and management. In addition the Museum serves as the site for many conferences sponsored by the Forest and outside groups. As Museum Coordinator, Dr. John O'Keefe has primary responsibility for the development of activities and coordination of use of the Museum.

In February the multi-image slide show "LTER - Long-Term Ecological Research at Harvard Forest," produced by John O'Keefe, premiered at the 2nd Annual Harvard Forest Ecology Symposium. This 15-minute program, describing the background for and current research being conducted as part of our LTER program and how Harvard Forest fits into the National Science Foundation's nationwide LTER Network, has proved extremely useful for introducing students, researchers and interested groups to this increasingly important aspect of our activity. In conjunction with our first slide show, "The Harvard Forest," and a steadily growing collection of videotape programs, the new show highlights the importance of the Gould Audio-Visual Education Center as a focus for our activities in the Fisher Museum. These developments would be impossible without the generous support of the Friends of the Harvard Forest.

The second major development at the Museum was the expansion of our weekend schedule to include both Saturdays and Sundays during the 1991 season (May-October). The hours each weekend day are noon-4 pm and the self-guided nature trails are readily available to early arrivals thanks to the map shelter on the lawn. The enthusiasm and dedication of our growing group of volunteers enabled this expansion to take place without difficulty.

Kasey Keith, a recent graduate of the University of Massachusetts in plant and soil science, was employed as Museum Intern to assist with continued updating of the two nature trails, establishing additional trails, and developing new exhibits. One exhibit in preparation presents photographs and information about different plants visitors can observe as they walk the trails.

The Museum received a generous grant from the Massachusetts Wood Producers' Association to construct three pairs of double display panels for temporary exhibits in the Museum. These panels were beautifully constructed by Donald Hesselton of our Woods Crew and will enable us to display our own exhibits as well as make use of some of the many travelling exhibits available from other sources.

Meetings, Seminars and Conferences

In October the Fisher Museum hosted the Harvard Museums' Council on a beautiful fall day. Other meetings at Harvard Forest included the New England Forest Economists, Massachusetts Cooperative Extension Service Coverts Project, Massachusetts Association of Conservation Commissions Wetlands/Wildlife Workshop, Massachusetts Project Learning Tree, Massachusetts Department of Environmental Management Forestry Aesthetics Workshop, New England Chapter of the Wildlife Society and the New England Fern Conference.

The Harvard Forest seminar series continued with a mixture of previews and evaluations of videotapes for possible inclusion in the expanding library of the Gould Audio-Visual Education Center and research presentations by local and visiting scientists. Seminar speakers included: Dr. John Bertram and Dr. Michael Korzukhin, both Charles Bullard Fellows at Harvard Forest; Dr. Peter Del Tredici, Editor, *Arnoldia*, Arnold Arboretum; Dr. Copeland MacClintock, Peabody Museum of Natural History, Yale University; Dr. Richard Bowden, Allegheny College; Dr. William Peterjohn and Mark Castro, Ecosystems Center at MBL; as well as Mr. Raouf Moustafa, Ms. Ann Lezberg, Dr. David Foster, Dr. Emery Boose and Mr. Tad Zebryk all of Harvard Forest reviewing their current work.

The Harvard Forest was the site for a number of regional, national and international conferences this year. Of particular interest was the conferences on Biodiversity, sponsored by NSF, ICSU, IGBP and UNESCO held in June and the conference on Global Change and Modelling of Savanna Ecosystems, sponsored by the International Union of Biological Science, UNESCO and the International Geosphere-Biosphere Program of ICSU held in October. Both conferences were organized by Dr. Otto Solbrig from the Department of Organismic and Evolutionary Biology at Harvard.

In February we hosted the Second Annual Harvard Forest Ecology Symposium at which over 50 scientists listened to reports of current and future research activities in the Harvard Forest Long Term Ecological Research Program. Abstracts from the talks were published in a booklet edited by David Foster and Dottie Smith. Research progress in the National Institute for Global Environmental Change was reviewed in a meeting held at the Forest in November. Speakers at this meeting included Steve Wofsy, David Foster, John Aber, Fakhri Bazzaz and Jerry Melillo.

Volunteer Coordinator, Helen Gronich, embodies the enthusiasm that our entire volunteer group brings to the Fisher Museum. On the left is the shelter containing trail maps and brochures for visitors who arrive when the Museum is closed.

FOREST AND MAINTENANCE ACTIVITIES

Over the winter from January through early April, the Woods Crew harvested two conifer plantations comprising 11 acres. The plantations were established in the late 1920's and were dominated by red pine with mixtures of white and Norway spruce. As a result of a thinning operation and silvicultural project conducted by David Hibbs in 1981, both of the plantations had a considerable abundance of white pine seedlings in the understory. The intent of our work was to remove the current overstory and to release this advance growth. A total of 295,000 board feet of timber and 80 tons of pulp were removed from the two sites.

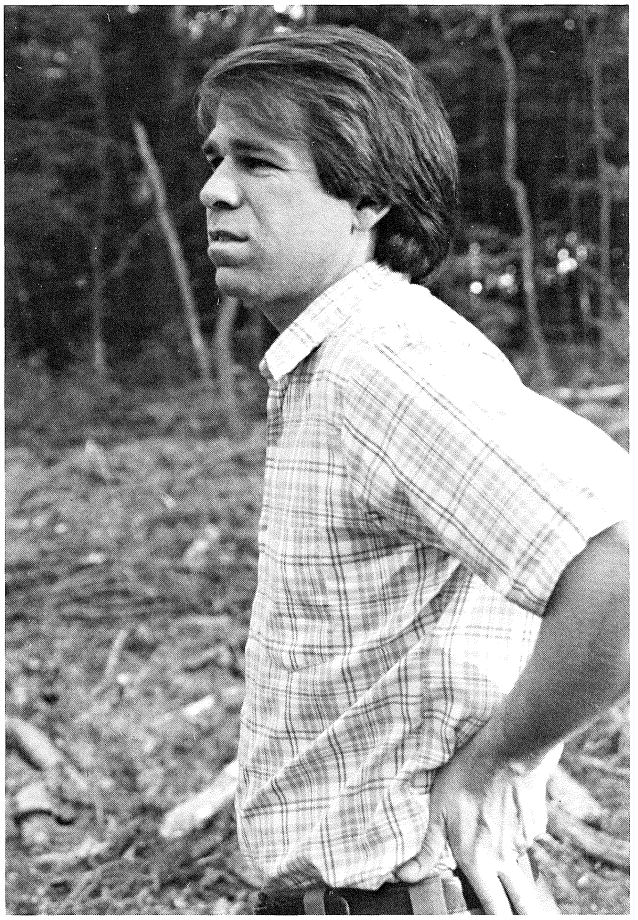
Other cuttings conducted this year were primarily cosmetic in nature. Many shade trees were removed or pruned on the grounds at the Forest Cottage and the Director's House to decrease the density of growth around the houses and to open up small fields.

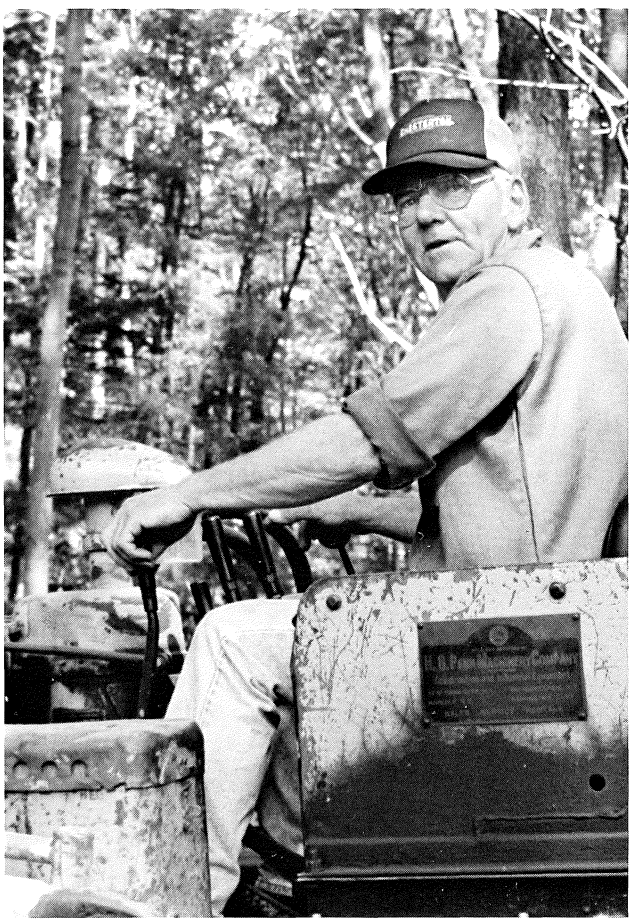
The vegetation survey crew of M. Varnot and K. Bush continued to map and inventory the vegetation at Harvard Forest. This project is nearly completed and the data base and base maps will provide valuable information for research and long-term planning at the Forest.

In our continuing effort to protect and preserve the natural setting of the Forest for research and recreation we installed 12 gates on access roads and trails into our woods. The gates have been designed to allow the passage of people for hiking, skiing and horseback riding. In addition to protecting the roads from erosion, the gating has resulted in a great reduction of littering and hopefully will prevent the dumping of rubbish.

Visitors to Shaler Hall will notice many improvements this year. We have repaired the front steps with new sandstone and rebuilt the handrail. Shade trees surrounding Shaler Hall have been pruned and thinned to provide a greater view from the building and many interior areas in Shaler have been painted. New lighting has been installed in the library and most common areas as part of an Energy Initiatives Program promoted by the Massachusetts Electric Company and new electrical distribution systems have been installed in the Higginson House and Forest Cottage to improve and modernize those facilities.

Recent equipment purchases include a 75-horsepower Massey Ferguson 4-wheel drive tractor and a 6-wheeled dump truck. These additions to our equipment have been an invaluable asset in our efforts to conduct LTER research projects and will fill an ever growing need in future projects.





Clockwise from
bottom left:

Pete Spooner
Jack Edwards
Lisa George and Don Hesselton
Keith Spooner and John Wisnewski
1942 GMC

ACTIVITIES OF THE HARVARD FOREST STAFF

In addition to their research and educational activities staff members participated in many conferences, advisory boards and committees at the local, regional, national and international level.

David Foster attended the following conferences during the past year: LTER Coordinating Committee meeting in Seattle, Washington, LTER All Scientist's meeting in Estes Park, Colorado, Ecological Society of America meeting in Snowbird, Utah, Social Science Research Council and National Science Foundation Workshop on Regional Research Centers in Rye Brook, New York, and the Fourth Cary Conference on Human Environmental Change in Millbrook, New York. David was appointed to the editorial board of the Journal of Ecology, was elected Secretary of the Vegetation Science Section of the Ecological Society of America, served as chairman of the GIS working group of the LTER Network, served on advisory boards to the Massachusetts Audubon Society and the Concord Field Station of the Museum of Comparative Zoology at Harvard, and was elected to the Planning Board for the town of Petersham. David Foster and Emery Boose authored a report on the status of scientific technology within the LTER Network as part of their activity in the LTER GIS working group.

Professor Torrey served as a member of the Harvard University NIGEC Program Management Committee and the Alan T. Waterman Award Committee of the National Science Foundation, representing the field of biological sciences. He also served as Chairman of the Charles Bullard Fellowship Committee and the Harvard University Faculty Committee on appointments in plant development.

Barry Tomlinson continued to serve in his role as Harvard University's representative to the Organization of Tropical Studies. He is a science advisory to Cambridge University Press for its publication series on tropical forests.

Emery Boose attended the LTER Data Managers meeting in Snowbird, Utah, the LTER All Scientist's meeting in Estes Park, Colorado, and served as a Harvard Forest representative of the LTER Coordinating Committee meeting in Seattle, Washington. He served as a member of the following LTER committees: GIS Working Group, Data Managers and Climate Committee.

John O'Keefe presented a seminar on methods used to reconstruct vegetation history at the American Antiquarian Society in Worcester in September. He conducted a seminar on living collections and the use of collections as educational tools to the Introduction of Museology course offered through the Museum Studies program of the Commission on Extension Studies of Harvard University. John was appointed secretary/ treasurer of the Yankee Division of the Society of American Foresters in January.

Dana Tomlin presented lectures at IBM Academic Information Systems, University of Pennsylvania, American Society of Photogrammetry, Harvard International Training Program, Environmental Systems Research Institute, and Society of American Foresters. The OSU-MAP Geographic Information System, an enhanced version of Dana's original Map Analysis Package, was recognized by the Association of American Geographers as the outstanding academic software product of 1990. In June, Dana left the Department of Natural Resources at Ohio State University for a new position as Associate Professor of Landscape Architecture at the University of Pennsylvania.

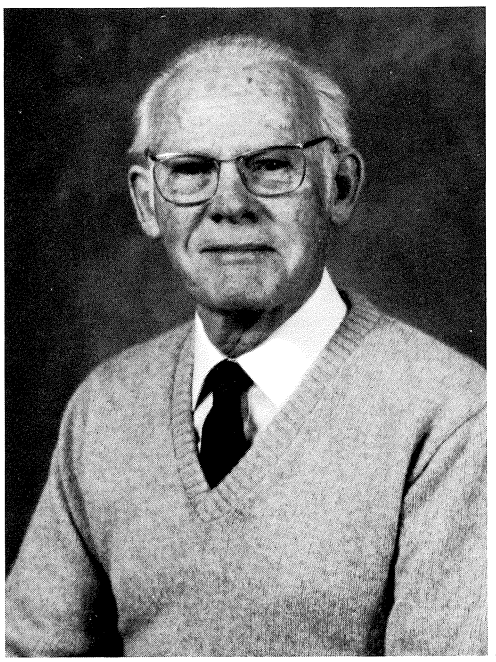
Gordon Whitney gave talks on the forest history of Massachusetts to the Biology Department at Boston University, Wellesley College and the Natural Resources Seminar Series sponsored by the Concord Field Station. Gordon served on the thesis committee of Tad Zebryk and assisted Nicholas Jones in the design of his senior thesis at Hampshire College. Gordon spent his evenings finishing his book on the historical ecology of northeastern United States, "From Coastal Wilderness to Fruited Plain - a History of Northeastern U.S. from 1500-present" to be published by Cambridge University Press.

As part of his responsibilities as Manager of the Forest and physical plant John Edwards participated in the following activities: Department of Environmental Protection Seminar on Drinking Water Regulations in Massachusetts, Harvard University Chemical Hygiene Officer Training Session for the OSHA Laboratory Standard/Chemical Hygiene Plan, University of Massachusetts Cooperative Extension Service Workshop on Forest Aesthetics, and Mahar Regional School 33rd Annual Science Fair where he served as a judge of Environmental Science entires.

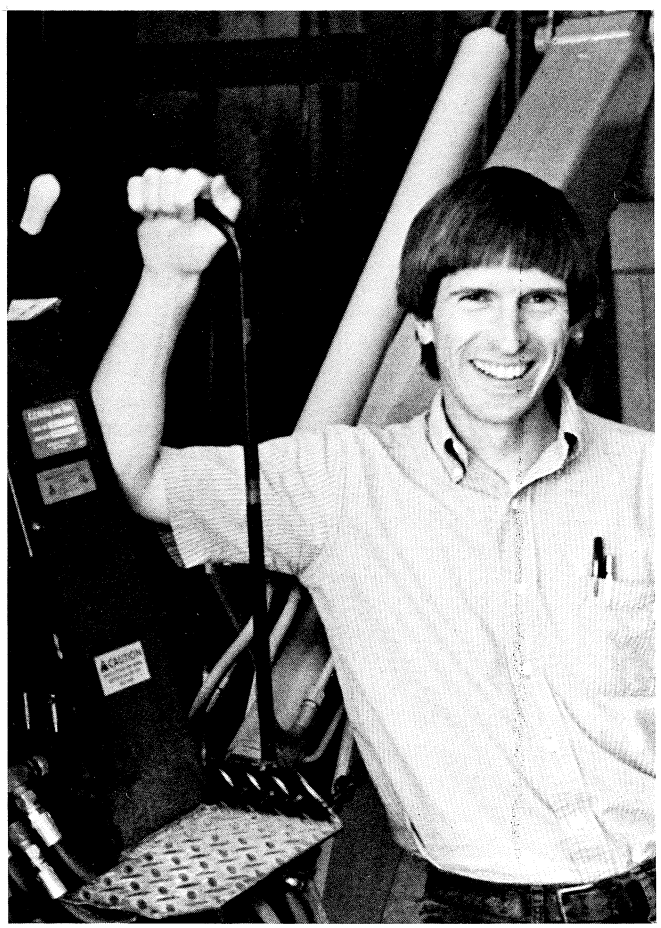
Marcheterre Fluet presented a one-person exhibit "No Place Like Home; the Florida Photographs" at the Book Mill Gallery, Montague, Massachusetts, completed a book of photographs *Artifacts, Worcester*, and served on the Arts Council for the town of Petersham.

In February the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Department of Commerce presented an award to the Harvard Forest in recognition of 75 years of collection of daily weather records for the town of Petersham. David Foster and Peter Schoonmaker, staff meteorologist, received the award in a ceremony in Shaler Hall.

On June 28 members of the Harvard Forest community attended a reception and dinner in recognition of the retirement of John G. Torrey as Bullard Professor of Forestry at Harvard University. Professor Torrey resided as a faculty member at the Harvard Forest from 1970 onwards and served as Director from 1984 to 1990. He oversaw the building of the Controlled Environment Facility (CEF) and renovation of the Fisher Museum, the development of an internationally recognized program in rhizosphere biology, the establishment of the LTER program and the installation of the Environmental Monitoring Station. In recognition of the physical and intellectual contributions of Professor Torrey, the CEF has been renamed in his honor as the John G. Torrey Labs.



John G. Torrey



Rich Boone

During the spring we undertook an international search for a forest soil ecologist to continue our strong tradition in soil biology. Dr. Richard Boone, Research Scientist at the University of New Hampshire (UNH), accepted our offer to join the science staff beginning in September, 1991. Rich brings strengths in ecosystem studies, nutrient cycling and organic matter dynamics as well as experience working at the Harvard Forest.

Rich's early research, including field studies at the Harvard Forest ten years ago, involved nitrogen cycling studies and modelling of the global carbon cycle as a research assistant at the Ecosystem Center - MBL. For his Masters degree at Oregon State University Rich examined stand and soil changes resulting from mountain hemlock mortality in the Oregon Cascade Mountains. His PhD research at the University of Massachusetts investigated soil organic matter and nitrogen in agricultural and forested sites. During the past two years Rich has been working with John Aber at UNH examining the effect of nitrogen deposition on ecosystem health. With Knute Nadelhoffer from MBL he has established a field study at the Harvard Forest to investigate long-term soil development under regimes of contrasting litter inputs.

Visiting Research Scientists at the Harvard Forest 1990-91

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

John Aber	University of New Hampshire
Peter Bakwin	Harvard University
Susan Bassow	Harvard University
Fakhri Bazzaz	Harvard University
Caroline Bledsoe	University of California, Davis
Rich Boone	University of New Hampshire
Rich Bowden	Allegheny College
Frank Bowles	Ecosystem Center - MBL
Wally Broecker	Lamont Doherty Observatory
Mark Castro	Ecosystem Center - MBL
Rose Crabtree	Harvard University
Bruce Daube	Harvard University
Peter Del Tredici	Boston University and Arnold Arboretum
Marty Downs	Ecosystem Center - MBL
Todd Drummey	Ecosystem Center - MBL
Aaron Ellison	Mount Holyoke College
James Ehleringer	University of Utah
Chris Field	Carnegie Institute
David Fitzjarrald	State University of New York
Song-Miao Fan	Harvard University
Richard Forman	Harvard University
Alan Goldstein	Harvard University
Kevin Harrison	Columbia University
Robert C. Harriss	University of New Hampshire
Joe Hendrix	University of New Hampshire
Dave Kicklighter	Ecosystem Center - MBL
Otto Klemm	University of New Hampshire
Alison MaGill	University of New Hampshire
Mary Martin	University of New Hampshire
Charles McClaugherty	Mount Union College
Kelly McConnaughay	Harvard University
Michael McElroy	Harvard University
Jerry Melillo	Ecosystem Center - MBL
Shi-Li Miao	Harvard University
J. William Munger	Harvard University
Knute Nadelhoffer	Ecosystem Center - MBL
Kathy Newkirk	Ecosystem Center - MBL
Fred Paillet	U. S. Geological Survey
William Patterson, III	University of Massachusetts
William Peterjohn	Ecosystem Center - MBL
Richard Primack	Boston University
Andrea Ricca	Ecosystem Center - MBL
Michael Rogers	Georgia Institute of Technology
Paul Rygiewicz	Environmental Protection Agency
Paul Steudler	Ecosystem Center - MBL
Robert Talbot	University of New Hampshire
Karl Turekian	Yale University
Peter Wayne	Harvard University

PUBLICATIONS

Baker, D. D. and J. G. Torrey. 1990. Symbiotic aspects of the actinorhizal Casuarinaceae. *In* Advances in *Casuarina* Research and Utilization. M. H. El-Lakany, J. W. Turnbull and J. L. Brewbaker (Eds.), Second International Casuarina Workshop, Cairo, Egypt, pp. 122-132.

Bowden, R. D., P. A. Steudler, J. M. Melillo and J. D. Aber. 1990. Annual nitrous oxide fluxes from temperate forest soils in northeastern United States. J. Geophys. Res. 95: 13997-14005.

Bowden, R. D., J. M. Melillo, P. A. Steudler and J. D. Aber. 1991. Effects of nitrogen additions on annual nitrous oxide fluxes from temperate forest soils in northeastern United States. J. Geophys. Res. 96: 9321-9328.

Burleigh, S. and J. G. Torrey. 1990. Effectiveness of different *Frankia* cell types as inocula for the actinorhizal plant *Casuarina*. Appl. and Environ. Microbiol. 56: 2565-2567.

Cox, P. A., T. Elmqvist and P. B. Tomlinson. 1990. Submarine pollination and reproductive morphology in *Syringodium filiforme* (Cymodoceaceae). Biotropica 22: 259-265.

Foster, D. R. and E. R. Boose. 1991. Technology development in the LTER - Current status of GIS, remote sensing, Internet connectivity, archival storage, and global positioning systems. Publication of the Long Term Ecological Research Network Office. Seattle, Washington.

Foster, D. R., F. Phillips, D. R. Smith and D. Tatlock. 1991. Family correspondence of Richard Thornton Fisher, 1895-1911. Harvard Forest, Harvard University, Petersham, Massachusetts.

Louis, I., S. Racette and J. G. Torrey. 1990. Occurrence of cluster roots on *Myrica cerifera* (Myricaceae) in water culture in relation to phosphorus nutrition. New Phytol. 115: 311-317.

Mansour, S. R., A. Dewedar and J. G. Torrey. 1990. Isolation, culture and behavior of *Frankia* strain HFPCgI4 from root nodules of *Casuarina glauca*. Bot. Gaz. 151: 490-496.

Moustafa, R. A. 1990. Environmental gradients and species distribution on the Sinai Mountains, Egypt. PhD Thesis, Suez Canal University.

Newcomb, W., S. Jackson, S. Racette and J. G. Torrey. 1990. Ultrastructure of infected cells in the actinorhizal root nodules of *Gymnostoma papuanum* (Casuarinaceae) prepared by high pressure freezing and chemical fixation. Protoplasma 157: 172-181.

Patterson, W. A. and D. R. Foster. 1990. "Tabernacle Pines" - the rest of the story. Journal of Forestry 89: 23-25.

Racette, S., I. Louis and J. G. Torrey. 1990. Cluster root formation by *Gymnostoma papuanum* (Casuarinaceae) in relation to aeration and mineral nutrient availability in water culture. Can. J. Bot. 68: 2564-2570.

Raich, J. W., R. D. Bowden and P. A. Steudler. 1991. Comparison of two static chamber techniques for determination of CO_2 efflux from forest soils. Soil Sci. Soc. Am. J. 54: 1754-1757.

Riis, J. 1991. Multiple criteria decision making with reference to forestry planning. MFS Thesis. Agricultural University of Denmark, Copenhagen.

Smith, D.R. and D.R. Foster (Eds.). 1991. Abstracts from the Second Annual Harvard Forest Ecology Symposium. Harvard Forest, Harvard University, Petersham, Massachusetts.

Takaso, T. and P. B. Tomlinson. 1990. Cone and ovule ontogeny in *Taxodium* and *Glyptostrobus* (Taxodiaceae). Amer. J. Bot. 77: 1209-1221.

Takaso, T. and P. B. Tomlinson. 1991. Cone and ovule ontogeny in *Sciadopitys* (Taxodiaceae-Coniferales). Amer. J. Bot. 78: 417-428.

Tomlin, C.D. 1991. Cartographic modeling. Ch. 23 *Of* Geographic Information Systems: Principles and Applications. M. Goodchild, D. Maguire, D. Rhind (Eds.). Longman Group, Ltd., Harlow, Essex, United Kingdom.

Tomlin, C.D. 1991. Relationships between the GRASS and Microstation geographic information systems. Report to the U.S. Army Corps of Engineers Construction Engineering Research Laboratories. The Ohio State University Center for Mapping.

Tomlin, C.D. and K. M. Johnston. 1990. The ORPHEUS land use allocation model. *IN* Geo-Information-systems: Journal for Cross-disciplinary Exchange of Knowledge in the Geo-Sciences. 3(3). pp. 10-13. Wichmann-Verlag, Bonn, West Germany.

Tomlin, C. D. and K. M. Johnston. 1991. An experiment in land use allocation with a geographic information system. Ch. 11 *IN* Introductory Readings in Geographic Information Systems. D. Peuquet and D. Marble (Eds.). Taylor and Francis, London.

Tomlinson, P. B. 1991. Pollen scavenging as a novel reproductive mechanism in Podocarpaceae (Coniferales). National Geographic Research and Exploration 7: 188-195.

Whitney, G. G. 1990. The history and status of the hemlock-hardwood forests of the Allegheny Plateau. Journal of Ecology 78: 443-458.

Zebryk, T. 1991. Holocene development of a forested wetland in central Massachusetts. MFS Thesis, Harvard University.

NEW FUNDING

A number of new grants were initiated for science and educational activities. The Andrew W. Mellon Foundation awarded $100,000 over a three-year period to David Foster to document land-use history and vegetation change at the Harvard Forest and to investigate how this history and its resulting ecosystem-level consequences affect the nature of research at ecological research sites like the Harvard Forest. Emery Boose, Gordon Whitney and Rich Boone will be active participants on this project. In a related effort David, Gordon, Emery and Denise Gaudreau were awarded a $90,000 grant from the National Science Foundation programs in Human Dimensions of Global Change and Ecology. This grant will support investigations on the historical effect of cultural and environmental gradients in central Massachusetts on landscape history and changes in forest composition and structure. David Foster and Emery Boose were awarded $47,000 as a supplement to the LTER grant to support GIS, remote sensing and computing facilities. Dana Tomlin received $180,000 from NASA and the NASA/Ohio State University Center for the Commercial Development of Space to develop GIS and cartographic modelling programs for use in landscape ecology. David Foster is a co-investigator on this project and is utilizing GIS to explore land-use history in central Massachusetts.

David Foster and Barry Tomlinson received funding from the New England Consortium for Undergraduate Science Education and from the National Science Foundation to support undergraduate student research.

ACKNOWLEDGEMENT OF SUPPORT

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

Friends of the Harvard Forest
American Association of Museums
Anonymous Donors
George I. Alden Trust
Davis Charitable Trust
Connecticut Nature Conservancy
A. W. Mellon Foundation
Massachusetts Wood Producers' Association
National Geographic Society
National Science and Engineering Research Council (NSERC) of Canada
National Science Foundation, Programs in
Ecology
Ecosystems
Human Dimensions of Global Change
Long Term Ecological Research
New England Consortium for Science Education
Swedish National Research Council
U.S. Department of Agriculture, Competitive Research Grants, Forestry
U.S. Department of Energy
Wharton Conservation Trust

David R. Foster
Director

Petersham, Massachusetts
June, 1991

Back Cover: Stem fracture of red oak resulting from a pull-down. Splintering occurred on the tension side of the tree when high levels of strain energy were released in the creation of fracture surfaces within the wood.