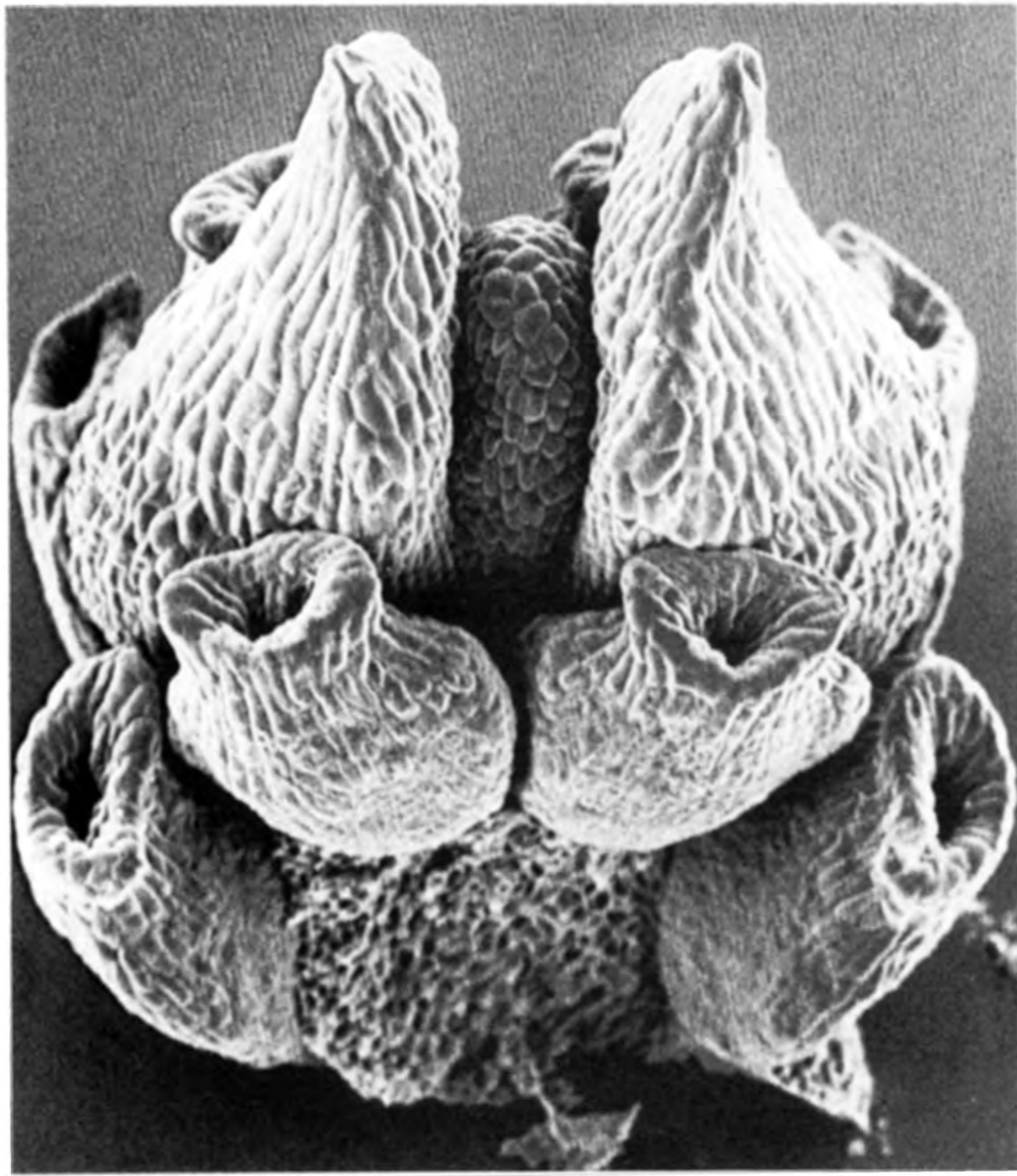




# THE HARVARD FOREST, 1988-89

Harvard University





John G. Torrey  
Director



David R. Foster  
Assistant Director



John O'Keefe  
Museum Coordinator



Emery Boose  
Computer Manager



John Edwards  
Forest Manager

# ANNUAL REPORT OF ACTIVITIES AT THE HARVARD FOREST

1988-1989

## PERSONNEL

A. E. Akachuku, Charles Bullard Fellow (from October 1988)  
Donna Barker, Research Assistant  
Jeanne Boutelle, Custodian  
John Brady, Assistant to the Manager of the Black Rock Forest  
Jonathan Cherin, Field Aide (From July 1988 through April 1989)  
Elaine Doughty, Laboratory Assistant  
John Edwards, Forest Manager, Harvard Forest  
Marion Ellsworth, Laboratory Aide (part-time)  
Barbara Flye, Secretary  
David R. Foster, Associate Professor of Biology and  
Assistant Director of the Harvard Forest  
Denise Gaudreau, Charles Bullard Fellow (from September 1988  
through May 1989)  
Anne K. Hachey, Greenhouse Assistant (part-time)  
Gray S. Henderson, Charles Bullard Fellow (until December 1988)  
Donald Hesselton, Woods Crew  
Jack J. Karnig, Forest Manager, Black Rock Forest  
Ann L. Lezberg, Research Assistant (from December 1988)  
Isabelle Louis, Post-doctoral Fellow (Mellon)  
Ralph L. Lundquist, Head of Greenhouse  
Ellen G. Moriarty, Graphic Artist (part-time)  
Frances E. O'Brien, Secretary  
John F. O'Keefe, Museum Coordinator (from July 1988)  
Frances N. Phillips, Secretary  
Suzanne Racette, Research Assistant  
Hugh M. Raup, Charles Bullard Professor of Forestry, *Emeritus*  
Robin Scribailo, Post-doctoral Fellow (from May 1989)  
Dorothy R. Smith, Secretary  
Charles C. Spooner, Woods Crew  
Keith Spooner, Woods Crew (part-time)  
Tokushiro Takaso, Post-doctoral Fellow (NSF)  
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 and  
Director of the Harvard Forest  
Gordon Whitney, Archivist  
John Wisnewski, Woods Crew  
Tad Zebryk, Research Assistant (from December 1988)

## STAFF

During the past year a major restructuring of the Harvard Forest Management was accomplished in a quiet and unobtrusive manner. David Foster was appointed Assistant Director of the Harvard Forest, to assist in the operation of the Forest and empowered to act for the Director in his absence. Three management-level appointments were made. John O'Keefe began his duties in charge of the Fisher Museum in July 1988 and has begun to implement changes leading to a greater public education role for the Fisher Museum. John Edwards was appointed Forest Manager, in recognition of his professional forestry training and the breadth of his responsibilities for the operation of the Forest and its facilities. Emery Boose became computer manager for the Harvard Forest starting July 1989. His duties involve responsibilities for computer operations in several realms - Harvard Forest administration, data collection and storage and LTER-related computer uses including Geographic Information Systems (GIS).

Gordon Whitney, former Bullard Fellow, served on the Harvard Forest staff as Archivist for the year. His activities centered on the long-term records stored in the Shaler Hall vault that serve as the foundations for the on-going and expanding historical record of land-use. He continues in the position as Research Associate, especially in relation to LTER studies on forest history and disturbance.

John Edwards completed his thesis for the Master of Science Degree in the Department of Forestry and Wildlife Management, University of Massachusetts, Amherst in September 1988. John's thesis was "An Accuracy Assessment of the Prime Land Classification System in 7 Massachusetts Counties".

The secretarial staff and the woods crew continue providing logistical support in the laboratory and in the field for faculty and students and for the on-going operation of the Forest.

The Harvard Forest was designated a Long-Term Ecological Research (LTER) site and awarded \$2.4 million for a six-year period by the National Science Foundation. Resident technical staff have been added to the LTER operations in Petersham (see pp. 10-13 of this Annual Report for a detailed account of the Harvard Forest LTER).

A long-time friend of the Harvard Forest, resident of Petersham and one-time staff member of the Harvard Forest, Shelley W. Potter, Jr. died in 1989 at the age of 73. Before retirement in 1979 Shelley was director-manager of the Pack Forest in Warrensburg, New York. Wayne Elliott, long-time custodian at the Harvard Forest died in 1988 at the age of 74.

## COURSES AND STUDENTS

Professor Tomlinson devoted a busy fall term to teaching by offering two courses, a new course, Biology 24 (*Introductory Plant Biology*) and a more specialized course, Biology 102 (*Biology of Gymnosperms*). Professor Foster taught Biology 160 (*Forest Ecology*) in the fall term and Biology 298 (*Forest Practice and Research*) in the spring.

In the spring term Professor Foster, with help from Professors Tomlinson and Torrey, ran the Harvard Forest Freshman Seminar with four weekends based in Petersham, the first three devoted to an introduction to forest biology in central New England and the fourth weekend devoted to independent projects. Professor Torrey presented a set of lectures on symbiotic microbial-root associations in Biology 120 (*Plant Physiology*).

In past years we have experimented with summer teaching at the Harvard Forest. Over the seven-year-period from 1971-1977 various kinds of courses were offered by the faculty at the Harvard Forest with formal student enrollment through the Harvard University Summer School. Over the years we have changed this approach. We increasingly make available research experience for undergraduate students by employing them full-time for the summer months to work on research projects at the Harvard Forest. This approach has been made possible by funds from the Harvard University Faculty-Aid Program, NSF-supported summer research programs, research grants to faculty at the Forest and modest matching funds from the Harvard Forest endowment.

The summer of 1989 illustrates the success of this form of teaching through research experience. Three Harvard undergraduates, Shona Armstrong, Cecily Morgan and Christine Chi are involved in field work relating to the vegetation survey of the Harvard Forest or to baseline data establishment for the LTER. Martha Varnot, a consulting forester from Barre and Ann Lezberg serve as supervisors of these students.

Martha Kennan, a junior at Salem State College, is a cartography major employed for the summer under an NSF grant to Dr. Foster. Martha is digitizing maps and aerial photographs for a study on disturbance processes and vegetation dynamics in western Pennsylvania.

In a laboratory-based setting, Dr. Tomlinson has used NSF funds to provide research experience on gymnosperm cone and ovule development for two undergraduate students. Jonathan Harrod (Harvard College) and Marcheterre Fluett (Smith College) have developed technical skills relating to plant development during these studies of conifer species. Dr. Takaso, post-doctoral fellow with Dr. Tomlinson supervised this research.

Peter Schoonmaker, graduate student and PhD candidate in the Department of Organismic and Evolutionary Biology, resides in Petersham with his family and continues his paleoecological research at the Pisgah Tract under the

supervision of Dr. Foster. Peter presented a poster at the annual meeting of the Ecological Society of America in Davis, California in August 1988. His presentation emphasized the interactions between disturbance, original vegetation and site conditions in controlling vegetation patterns.

During the past year the Harvard Forest has served as research base for two doctoral students from Suez Canal University, Ismailia, Egypt. Both have come to the Harvard Forest with financial support from the government of Egypt to work with faculty members in their areas of specialty and to conduct research for their PhD degrees from their home institution.

Samira Mansour from the Faculty of Science and Lecturer in Microbiology is pursuing her research with Dr. Torrey. She has isolated strains of *Frankia* from root nodules of *Casuarina* in Egypt, is characterizing these and other *Frankia* strains effective on *Casuarina* species and working toward improving symbiotic nitrogen fixation by these associations. Her professor from Suez Canal University, Dr. A. Dewedar, spent ten days in Petersham in early June, reviewing Samira's research progress.

Raouf Moustafa arrived from Egypt in November 1988 to work with Dr. Foster. Raouf is undertaking a gradient analysis of the vegetation in the mountains of the southern Sinai and has come to the Harvard Forest to study multivariate statistics. Last year Dr. Foster travelled with Raouf throughout his study area, which is a spectacular mountainous region known for its historical significance as well as its beauty. In Egypt Raouf works with Professor Mohamed Helmy at Suez Canal University and Professor M. Ayyad of Alexandria University. Dr. Ayyad visited the Harvard Forest for two weeks in July 1989.

Steven Burleigh completed his Division III senior thesis for his BA degree at Hampshire College in January 1989 after a nine-month period of research in Dr. Torrey's laboratory studying inoculation and infection of *Casuarina* seedling roots by *Frankia* strain HFPCcI3. In April he travelled to Alison Berry's laboratory at the University of California at Davis to continue inoculation trials with *Casuarina*.



*Silver Lake in Athol was the site of a coring trip by the paleoecology group including M. Kennan, D. Gaudreau, P. Schoonmaker, and T. Zebryk. (Photo by D. Foster)*

## MEETINGS AND VISITORS

On September 24, 1988 the Massachusetts Forestry Association in cooperation with the Trustees of Reservations, met at Harvard Forest to commemorate the 50th anniversary of the 1938 hurricane. Dr. David Foster reviewed the history of hurricanes in New England and the Fisher Museum exhibits on the 1938 event were examined. Of special interest was the display of pine lumber sawn from logs dredged from the bottom of Harvard Pond by the woods crew this summer. The logs were in remarkably good condition after their 50 years of submersion with the label "U.S." stamped on the log ends preserved and legible. These special boards are being used in a number of innovative ways by the woods crew.

On the weekend of October 21-23, the Trustees of Reservations held a fall field trip organized by Richard O'Brien and centered at the Harvard Forest. Sites in central Massachusetts, illustrating locations protected by agricultural preservation restrictions, conservation restrictions or general issues related to land use were visited.

On March 27-30, 1989 about 35 scientists from the United States and abroad met for three days of discussions at the Harvard Forest on the functioning of roots and the rhizosphere in relation to plant productivity. The scientists debated how best to measure below-ground productivity and to assure the effectiveness of root systems for production of above-ground vegetation. Research on temperate, tropical and wetland ecosystems was reviewed and progress reported on confronting environmental impacts imposed by increasing human populations throughout the world. Scientists from Sweden, Venezuela, Oregon and Colorado joined in the presentation of new data and ideas for research for the future. The meeting was organized through the joint efforts of the Harvard Forest and the Yale School of Forestry, under the Program for Forest Microbiology.

On the weekend of May 12-14, 1989 the New England Fern Conference held its twentieth meeting with about 25 participants. Special emphasis in the program was placed on different approaches to pteridophyte systematic research. An evening was devoted to an informal retrospective of the twenty years of fern research.

Other meetings held at the Harvard Forest included the Northeast Solar Energy Association, Massachusetts Project Learning Tree, Massachusetts Department of Environmental Management/Cooperative Extension Service Coverts Project, New England Chapter of the Wildlife Society, Massachusetts Audubon, and DEQE/MACC Wetlands/Wildlife Workshop.

During the fall term the Harvard Forest seminar series was devoted to research presentations, largely from local scientists, including Suzanne Racette, Isabelle Louis, John O'Keefe, Denise Gaudreau, Gordon Whitney, and Tim Sipe. Dr. Siegfried Fink from West Germany gave the opening seminar in October on effects of acid deposition in the



Schwarzwald, Dr. Søren Ødum, a former Bullard Fellow, spoke to us in February, Dr. Henry Art of Williams College in March, and Andrew Williams, agricultural historian of Old Sturbridge Village in April.

In place of regular seminars in the spring term 1989 we met each Friday to review a VCR tape devoted to some aspect of forestry. The review process included discussion of the appropriateness of the tape for acquisition for the Fisher Museum Library to be used for public presentation to Museum visitors or for special events. This process allowed the faculty, staff and students to cover a wide subject area and learn not only about the subjects but how best to present them.

### FISHER MUSEUM

The Fisher Museum has seen a number of changes over the past year starting with the appointment of Dr. John O'Keefe as Coordinator on July 1, 1988. The most noticeable of these are the contribution box near the Museum entrance and the audio-visual booth at the rear of the auditorium. The contribution box was crafted beautifully by Donald Hesselton of our woods crew from wide pine boards salvaged from a barn on Prospect Hill Road which housed draft horses used on the Forest until the 1930's.

A generous grant from the George I. Alden Trust, together with gifts given in memory of Ernie Gould, enabled construction of the production/projection booth, part of the Gould Audio-Visual Education Center. The first multi-media presentation, "An Introduction to the Harvard Forest" is in production for a September premiere. The video-cassette/television monitor began visitor-initiated operation in June with the excellent show, "From Stump to Ship: A 1930 Logging Film". The VCR show will change each month.

Less visible, but perhaps of greatest importance, has been the initiation of weekend hours for the Museum. Starting in May the Museum has been open Saturdays 10 AM - 4 PM. These hours are possible thanks to the effort of a dedicated group of volunteers from the ranks of both the Friends of Harvard Forest and others interested in the Museum and forestry. In 1989 the Museum will be open on Saturdays through October and, if visitor interest and volunteers permit, weekend opening may be expanded in the future.

A new exhibit of an early 1900's woodsmen's camp kit has been installed upstairs in the Museum. This kit, which contains all the cooking and eating utensils needed for a crew of six was generously donated by Bob Brooks of New Salem through Pete Spooner of our woods crew. The Black Gum Trail guide has been up-dated to reflect vegetation changes that have occurred since it was originally written.

In addition to regular visits by school groups ranging from elementary to college and graduate level, the Museum hosted several special events during the year (see Meetings and Visitors).



## BULLARD FELLOWS

Dr. Denise Gaudreau, Assistant Professor of Geology and Biology at Southampton College in New York State arrived as a Bullard Fellow in September 1988. Her research interests center on the relative importance of climatic and biotic factors in controlling plant biogeographic change on a broad scale across eastern North America. She uses pollen distributions in lake sediments sampled from the Quaternary geological period to elucidate long-term forest dynamics.

While at Petersham, Dr. Gaudreau has been involved in writing and in planning future research and presented a seminar at the Forest and at the University of Massachusetts on the subject: Forest change in Northeastern North America over the last 14,000 years. She also assisted faculty in the Graduate School of Design at Harvard in field trips and work shops on landscape architecture. Dr. Gaudreau will stay on at the Harvard Forest as a Research Associate under the HF LTER.

Dr. A. E. Akachuku arrived with his family in October 1988 from the Department of Forest Resources Management, University of Ibadan, Nigeria, where he is Senior Lecturer in Wood Science. Dr. Akachuku had visited the Forest briefly in 1982 when he worked with Professor Zimmermann on wood structure in *Quercus rubra*.

His current studies at the Harvard Forest are concerned with effects on wood structure from tree displacement associated with hurricanes. Wood growth in *Pinus resinosa* was determined before and up to 50 years after they were displaced by a hurricane. Objective methods of characterizing leaning trees in the process of reorientation to the vertical were developed and the extent to which the trees had regained vertical growth was assessed. The effect of bole angle of deviation on tree growth parameters and indices of bole shape were determined.



Dr. Akachuku has applied video-analysis to his studies of tracheid length and growth rings. (Photo by J. O'Keefe)

## THE HARVARD FOREST - LTER

The Harvard Forest was designated a Long-Term Ecological Research (LTER) site by the NSF and was awarded a six-year grant for \$2.4 million beginning October 15, 1988. The Harvard Forest-LTER is one of a national network of 17 research sites.

The following excerpts from the NSF brochure produced by the LTER Network Office characterize the site and the research directions to be pursued at the Harvard Forest.

\* \* \* \* \*

**Location:** 110 km W of Boston; latitude: 42°32' N; longitude: 72°10' W;  
elevation: 120-410 m; area: 1,200 ha

**Climate Synopsis:** Climate is cool temperate (summer mean 20°C, winter -4°C) and humid, with annual mean precipitation of 110 cm distributed fairly evenly through the year.

**Principal Biome:** Temperate deciduous-coniferous forest

**Main Communities:** Hardwood-white pine-hemlock forest  
Spruce swamp forest; Conifer plantations

**Existing Data Bases:** GIS-based map series from 1907; aerial photography from 1937; climate record from 1913; record of land-use history extending from 1740 and stand-level documentation of vegetation and disturbance since mid-1800's; long-term silvicultural experiments and permanent plots; small watershed hydrology; physiology, hydraulic architecture and development of prominent tree species; nitrogen budget, nutrient cycling and organic dynamics for major forest types; survey of mycorrhizal associations.

**LTER Research Topics:** Forest-atmosphere trace gas fluxes  
Long-term history of climate, disturbance, & vegetation  
Comparative ecosystem study of anthropogenic & natural disturbance  
Community, population & plant architectural response to disturbance  
Ecophysiology and micrometeorology  
Organic matter accumulation, decomposition, and mineralization  
Element cycling, fine root dynamics and forest microbiology

**Investigators:** John Aber, University of New Hampshire - Forest ecology, remote sensing

Robert Antibus, Clarkson Univ. (Biology) - Soil microbiology

Fakhri Bazzaz, Harvard Univ. (\*QEB) - Ecophysiology

Richard Forman, Harvard Univ. (\*GSD) - Landscape ecology

David Foster, Harvard Forest - Forest ecology, paleoecology

Arthur E. Linkins, Clarkson Univ. (Biology) - Soil chemistry & biology

Charles McClaugherty, Mt. Albion College (Biology) - Soil biology

Michael McElroy, Harvard Univ. (\*EPS) - Atmosphere/biosphere interactions

Jerry Melillo, Ecosystems Center, \*MBL - Element cycling

Knute Nadelhoffer, Ecosystems Center, MBL - Soil organic matter  
William Patterson, Univ. of Massachusetts (Forestry) - Paleoecology  
Paul Steudler, Ecosystems Center, MBL - Trace gas fluxes  
C. Dana Tomlin, Harvard Forest - Geographic Information Systems  
P. Barry Tomlinson, Harvard Forest - Plant architecture and development  
John G. Torrey, Harvard Forest - Soil Microbiology  
Steven Wofsy, Harvard Univ. (EPS) - Atmosphere/biosphere interactions

\*EPS = Earth and Planetary Sciences; GSD = Graduate School of Design;  
MBL = Marine Biological Laboratory; OEB = Organismic & Evolutionary Biology

**Research Plan:** The Harvard Forest has been operated as an ecological research facility by Harvard University since 1907. Research on long-term biological processes has always been a major objective of the staff. Beginning in 1907 studies focussed on forest management and production. By the 1930's research had expanded to include studies of forest nitrogen economy, forest dynamics, soil morphology, mycorrhizal fungi and microclimate. The effects of land-use history and the 1938 hurricane on forests in central New England prompted the initiation of research in long-term vegetation change, historical ecology and remote sensing. Over the past 20 years studies have focussed on organism-, community-, and ecosystem-level research and have involved collaboration with investigators from many institutions.

The central theme of the Harvard Forest LTER is a comparison of historically-important physical disturbances and recent and projected chemical disturbances 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 lasting alteration of ecosystem function than does the historical regime of disturbance.

Four core experiments involve: 1) re-creation of physical types of disturbance, including catastrophic hurricane blowdown, smaller windthrows, and selective mortality of overstory species; 2) simulation of chronic nitrogen and sulfur inputs through atmospheric deposition; 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 being aided through the application of remote sensing, geographic information systems, and modelling.

\* \* \* \* \*

#### CURRENT HF-LTER RESEARCH STAFF

With the initiation of the LTER grant, new staff members have been added. Following the completion of her Bullard Fellowship in June 1989, Dr. Denise Gaudreau was appointed a Research Associate. Denise represented the HF-LTER at the Wide Area Networking (WAN) Conference at the National Center for Supercomputing Applications at the University of Illinois in April. She is currently extending her research on post-glacial vegetation and climate dynamics in central New England.

Ann Lezberg was appointed Research Assistant, having previously worked with the Massachusetts Audubon Society. Ann serves as LTER project coordinator, supervising the summer research crew, assisting in project administration as well as undertaking her own research in cooperation with David Foster. For example, Ann has developed a GIS data base for the Prospect Hill Tract and has installed a grid of permanent sampling points to facilitate long-term study at the Pisgah Tract in southwestern New Hampshire. She is also coordinating the establishment of experimental manipulations on the Tom Swamp Tract.

Tad Zebryk was appointed a Research Assistant working with David Foster on the post-glacial history of vegetation in central New England. His qualifications in paleoecology include training at the University of Massachusetts in geology and botany and employment with the U.S. Geological Survey. Currently Tad is finishing a detailed analysis of the Black Gum Swamp area of the Prospect Hill tract.

#### CURRENT HF-LTER RESEARCH ACTIVITIES

During the first year research activity has been coordinated by a monthly meeting of a science team comprised of the Principal Investigators. Emphasis during this period has been on the development of a data management system, site selection and the collection of baseline information for long-term experiments, establishment of an environmental monitoring station, development of meteorological and trace-gas flux equipment and coordination of ongoing studies.

**Long-Term Monitoring.** Three sites, which have been the focus of research for the past 20-60 years at Harvard Forest, were selected for long-term analysis as part of the LTER. The sites represent an old-growth forest uprooted in the 1938 hurricane (Pisgah Tract), an even-aged oak and maple forest on an upper slope (Tom Swamp Tract) and a mixed oak stand on undulating terrain (Prospect Hill Tract). Each area will be the focus of population, community and ecosystem studies. The Prospect Hill site has been extensively studied for plant-soil interactions. This site will continue to be analyzed for production/decomposition, above-and-below-ground biomass, and forest response to chronic N additions and liming. The Tom Swamp site has been studied in the past for gypsy moth effects, gap dynamics, silvicultural research and stand development. This relatively homogeneous forest will serve as a central study site for the physical and chemical manipulations proposed in the LTER. At the Pisgah Tract studies will continue to concentrate on community description and forest dynamics following disturbance.

**Data base Management.** Efforts have been directed towards developing spatial data bases for the Harvard Forest, publication of a site bibliography, computerization of research records from 1908 to present, and installation of a new computer facility for Geographic Information Systems research and data base management. A research computer facility has been developed with two of four computers installed to date. A separate computer room for visiting scientists and general use is under development. A complete upgrading and standardization of all secretarial computers this summer will complete the computer enhancements.

**Micrometeorology.** Ten micrometeorological stations and 2 data logging systems were assembled and tested in the field. These portable stations permit continuous measurement of photosynthetic photon flux density (PPFD), windspeed, air temperature, relative humidity, and soil temperature, and are designed to allow finely resolved sampling of environmental conditions in numerous study sites and spatial configurations. Data are stored on magnetic tape in the field and downloaded to IBM computers. Baseline sampling of micrometeorological conditions in the experimental sites will occur throughout the 1990 field season prior to the initiation of treatments.

**Chemical Climate and Gas Flux Analysis.** Another focus of activity during the first year has been acquisition and testing of equipment and modification of our data handling software and hardware to permit gas flux analysis. An important aspect of this measurement program is the determination of fluxes of reactive nitrogen compounds ( $\text{NO}_y$ ) to the forest. The flux of  $\text{NO}_y$  will be determined by the eddy correlation method. A second measurement system that has been developed is a device to measure directly the photolysis rate for  $\text{NO}_2$ .



*The newly erected tower at the Environmental Monitoring Station provides an unusual view down onto the forest canopy of oak and maple. (Photo by P. K. Schoonmaker)*

## RESEARCH

**Comparative morphology and anatomy of plants.** As a reflection of past research activities, in March 1989 Dr. Barry Tomlinson was able to deliver (in person) a book manuscript to Oxford University Press in England entitled "Structural Biology of Palms".

Over the past several years Dr. Tomlinson has directed his interests to the gymnosperms. Research on cone and ovule development in conifers is being pursued under a grant from NSF and in collaboration with Dr. Tokushiro Takaso, post-doctoral fellow, who also received an award as Putnam Fellow of the Arnold Arboretum. This grant was supplemented for the summer of 1989 with an award from the Research Experience for Undergraduate Program of the NSF (see Courses and Students). In research to date, all 8 genera in the Taxodiaceae have been examined and 8 out of the 16 genera in the Cupressaceae. Apart from the systematic and developmental information obtained, knowledge of the early stages of cone initiation in conifers is important in understanding reproductive processes in the group. Dr. Takaso attended the A.I.B.S. meeting in Davis, California in August 1988, presenting preliminary results of his research. In November, Dr. Takaso and Dr. Tomlinson attended a plant development workshop at the University of Toronto and visited the University of Guelph.

Dr. Robin Scribailo, recently graduated from Toronto University, came with his family to the Harvard Forest in April 1989. Robin will be studying inflorescence and flower development in the family Araceae (aroids) with the support of a post-doctoral fellowship from the National Research and Engineering Council of Canada. The aroids, such as the familiar Jack-in-the-pulpit in the eastern United States, form a primarily tropical group. The research concerns the developmental modifications of uniform floral parts in relation to their aggregation as floral units of diverse function.

In April 1989 Dr. Tomlinson spent a week in Monterey, California, observing pollination of the seagrass *Phyllospadix* (Zosteraceae) as part of a collaborative program on seagrass biology organized by Dr. Paul Cox, Brigham Young University.

**Forest dynamics and natural disturbances.** David Foster is currently involved in four projects that are separately funded by NSF. These studies broadly cover the areas of forest and wetland dynamics in response to natural disturbance, environmental change and human activities.

In central New England David and others are examining the pre- and post-settlement changes in forest vegetation using pollen analysis, historical sources, and field studies. The project is largely funded under the LTER and involves Denise Gaudreau, Gordon Whitney, Peter Schoonmaker, Tad Zebryk and Ann Lezberg. The research is focused on two spatial scales: viz., one, a regional study of Worcester County, Massachusetts, employing pollen studies of lake sediments and histor-

ical study of township, county, and state archives, and the other, a local study of the Harvard Forest and the town of Petersham that utilizes pollen analysis of soils and small hollows and emphasizes field studies and historical records.

Considerable information has been assembled. Tad Zebryk has completed a 13,000-year pollen record from the Black Gum Swamp which is being compared with soil pollen profiles from nearby old-growth hemlock stands prepared by Peter Schoonmaker and Tad. The results indicate considerable change in the overall representation of major taxa (notably a decline in beech and significant rise in chestnut and birch) through the settlement period. These findings are being contrasted with Peter's study at the Pisgah Forest site in SW New Hampshire, which has never been altered by human activity. Ann Lezberg, Emery Boose and David Foster are utilizing GIS to interpret spatial patterns in the vegetational data at both sites.

In a related study David is collaborating with Steward Pickett (Institute of Ecosystem Studies) on an investigation of damage patterns and revegetation following tornado blow-down of the old-growth forest in the Tionesta Natural Area, Allegheny National Forest. This project, which is funded by the Ecology program of NSF, will use remote sensing, GIS and field studies to interpret patterns of tree blow-down and population and community dynamics.

As part of a separate LTER program in Puerto Rico, David is using a GIS data-base for the Luquillo National Forest to interpret natural patterns of disturbance. Disturbance processes involve land-slides, which are being documented by Fred Swanson of the U.S. Forest Service, treefall gaps, which are studied by Nick Brokaw at the Manomet Bird Observatory and hurricane damage, studied by D. Foster.

For the past five years David has been involved in comparative studies of peatland development in Scandinavia and E. North America. Recent publications in collaboration with H. E. Wright and S. Fritz (U. of Minnesota), M. Thelaus (U. of Lund, Sweden) and G. King (EPA, Corvallis) indicate striking similarities in the development of fens and bogs in the different regions. In order to separate climatological and internal hydrological processes that control mire development David has expanded the Swedish project in collaboration with Heather Jacobson (U. of Maine/U. of Lund) and Jim Almendinger (U. of Minnesota) with funding provided by the Ecology program at NSF. Heather is investigating the regional climatological and hydrological setting, whereas Jim is studying hydrology of mires and their underlying sand plain. David is coordinating the study and continuing analyses of peat stratigraphy.

**Archival research.** Gordon Whitney assumed the position of archivist of the Harvard Forest in June of 1988. As one of the earliest demonstration forests in the eastern U.S., the Harvard Forest has amassed one of the best documentary records of temperate forest change in North America. Much of the past year was spent sorting through, repairing and cataloguing the maps, manuscripts, and published and unpublished reports of the Forest. Walter Lyford and Ernie Gould's research



materials were incorporated into the archives along with research of the 1980's. The work culminated in the production of "A Guide to the Harvard Forest Map Collection", "A Guide to the Harvard Forest Archives" and the 500+ entry "Harvard Forest Bibliography". All of the materials are accessible in the Harvard Forest archives, library and computer system, catalogued by author and subject.

**Ecophysiology.** Professor F. Bazzaz has continued part of his research program in collaboration with PhD graduate students working at the Harvard Forest. Tim Sipe completed the second year of a three-year project on the performance of three maple (*Acer*) species in response to understory and canopy gap environments in the Prospect Hill and Tom Swamp tracts. Micrometeorological conditions were measured at the seedling level throughout the summer using portable stations and electronic data loggers. Hemispherical canopy photographs were taken above each seedling plot at several times during the summer to provide complementary data on light environments. Photosynthetic gas-exchange was measured under various sampling schemes. The result will be a more precise understanding of the mechanisms underlying differential regeneration by co-occurring tree species in the context of forest gap dynamics.

Rose Crabtree, a doctoral student working with Dr. Bazzaz, began an investigation of the effects of light, inorganic nitrogen, and changing form of nitrogen (nitrate versus ammonium) on the performance of seedlings of four co-occurring species of birch (*Betula*). Two experiments have been initiated. In the first, potted seedlings are being grown in forest soil in shadehouses that parallel light levels measured in experimental gap and understory sites. Subsets of the seedlings receive different amounts and forms of nitrogen. The second experiment is in the forest, where plots have been established in a clearcut area and an undisturbed understory site on the same soil type. A control and two nitrogen treatments are underway. In both experiments, seedling survival, growth (dimensions and biomass), biomass allocation, and nitrogen content will be measured. The results will determine how the two physical and chemical disturbances, and their interaction, affect tree species differentially during the regeneration phase.

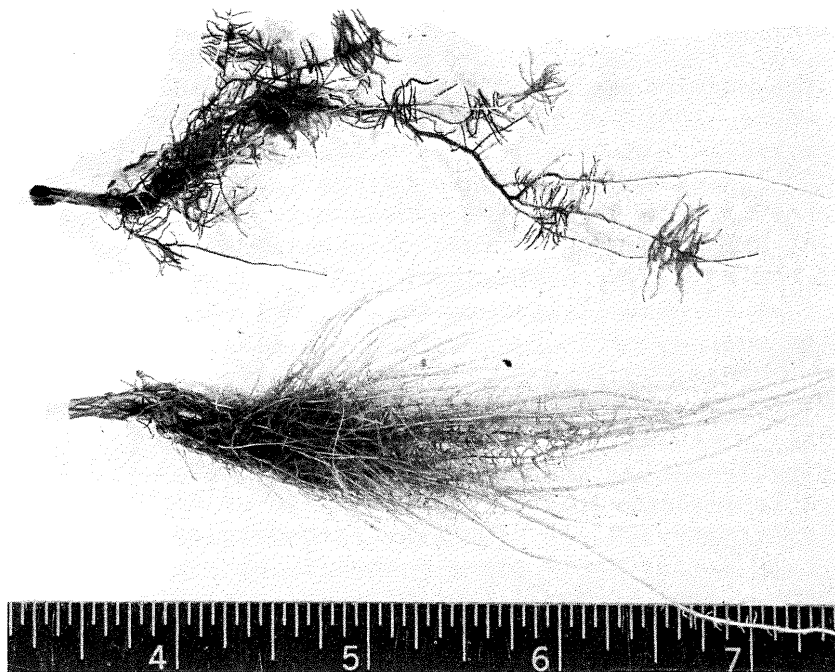
**Roots and Rhizosphere.** The major research activity of Dr. Torrey's laboratory during the past year has continued to focus on actinorhizal plants and the actinomycetous bacterium *Frankia* that nodulates the root systems resulting in symbiotic nitrogen fixation. The experimental studies on host specificity of pure cultured *Frankia* strains conducted over the past several years, primarily by Suzanne Racette, were brought together in an attempt to understand the nature of the control of infection exerted by the two partners in the symbiosis. A paper summarizing the studies within the Casuarinaceae was presented at the international meeting on *Frankia* at Storrs, Connecticut in August 1988. A broad review of the subject was written summarizing the literature as well as current work in Petersham. The review will be published by Academic Press in a book on "The Biology of *Frankia* and Actinorhizal Plants" edited by C. Schwintzer and J. Tjepkema.

Of special interest has been nodulation in *Gymnostoma* of the Casuarinaceae studied by S. Racette. As host plant, *G. papuanum* is infected by a wide range of *Frankia* strains isolated from host plants in several genera and families. This plant is said to be promiscuous. The *Frankia* isolated from root nodules of *Gymnostoma papuanum* referred to as HFPGp11 nodulates only its host of origin within the family but does effectively nodulate selected host plants in other families. *Gymnostoma papuanum* is also unique in that it is thus far the only host plant in the Casuarinaceae whose root nodules show *Frankia* vesicles. Their role in N<sub>2</sub>-fixation is not clear.

Research continues on spore germination by strains of *Frankia* from host plants in the Casuarinaceae. The work to be published from studies by Dr. S. S. Tzean is being followed up by S. Mansour in an effort to understand the chemical factors that stimulate spore development. Studies by S. Burleigh have demonstrated clearly that in air-dried inoculum for *Casuarina* host plants prepared from pure cultures of HFPGc13, only spores are infective agents with hyphal fragments of *Frankia* losing their infectivity upon dessication. Since in most soils *Frankia* released to the soil from decaying root nodules would undergo dessication, renewed interest has developed in germinating spores as the most probable infective agent in the soil.

A related study pursued by D. Barker follows earlier research by Dr. H. Lamont in our laboratory on cultural factors controlling sporulation by *Frankia* strains grown in culture. The evidence is quite strong supporting the view that sporulation by *Frankia* growing in culture is in response to stress conditions, especially stresses imposed by lack of nutrient availability.

In a new direction of research originating from our interests in tripartite associations in actinorhizal plants, Dr. I. Louis and S. Racette have collaborated in a study of mineral nutrient factors influencing the formation of cluster roots in seedlings of actinorhizal plants grown in water culture. The evidence is clear that cluster root formation is elicited in a number of actinorhizal plants including species of *Myrica*, *Comptonia* and some members of the Casuarinaceae by a lack of available phosphorus in the root environment. Cluster roots are multiple lateral roots condensed in clusters along primary and secondary roots of seedlings. Although their role is not understood, they may be involved in increasing phosphorus availability to the plant. In several of the species studied, the root systems forming cluster roots fail to show mycorrhizal associations, a known mechanism for facilitating phosphate uptake from the soil. The phosphate dependence of cluster root formation in some actinorhizal plants was presented as a poster at the Beltsville Symposium in May 1989.



Seedling roots of *Myrica gale* grown in water culture in a complete mineral nutrient solution (bottom) and the same solution lacking phosphate, which elicits cluster root formation (top). (Photo by S. Racette)

#### FOREST OPERATIONS - PETERSHAM

Environmental Monitoring Station (EMS). The Harvard Forest has established a permanent meteorological and atmospheric monitoring facility far removed from local polluting effects of vehicular traffic. The station is located 1.3 miles from Shaler Hall in the Prospect Hill Tract. An underground electrical cable and telephone lines were run this distance from the Controlled Environmental Facility. The station includes a 100-foot radio tower, an equipment building with security fencing and alarm systems, and computer facilities for automated recording of data.

The EMS construction and installation were achieved largely through the efforts of Jack Edwards and the Harvard Forest woods crew. The design and research plans for the EMS originated with Harvard faculty, primarily S. Wofsy and F. Bazzaz and with considerable input from post-doctoral fellows W. Munger and P. Bakwin. The availability of primary power and improved access in this area create the potential for more sophisticated field experimentation in the future.

Monitoring of meteorological parameters and trace gas-fluxes will begin in the summer of 1989 for base-line data and will continue thereafter in connection with experimental studies related to the LTER. Measurements will include ozone ( $O_3$ ), carbon dioxide ( $CO_2$ ), and carbon monoxide (CO), using fast and slow monitors and NO/ $NO_2$  gas fluxes using the eddy correlation method. Other measurements will include temperature, rainfall and windspeed.

**Buildings and grounds.** In order to facilitate the installation of 1.3 miles of primary electrical cable along Locust Opening Road at Prospect Hill, 11,000 board feet of sawlogs and 15 cords of wood were removed. Superior lumber was retained for siding on the pole barn and the remainder was sold as pallet stock. As always, the cordwood will help heat Shaler Hall during the winter.

With the exception of some minor trim, the pole barn east of Shaler Hall is complete. This new structure will provide 2,340 square feet of space for maintenance and storage of equipment. The last stage of the remodelling project in the basement of Shaler Hall is now complete. The efforts of Donald Hesselton of the woods crew and funds from a Facilities Grant from NSF created two new offices, much improved darkroom and drafting room space as well as a modern computer facility.

**Public access to Harvard Forest.** In mid-January 1989 a pickup truck fell through thin ice at the northern end of Harvard Pond while the owner was ice fishing. After three days of effort at a cost of nearly \$15,000, the truck was removed. We were fortunate that the removal process was handled professionally with no spillage of hazardous materials. Damage to vegetation around the Pond was considerable. As a result of this incident, we intend to be more vigilant about restricted vehicle access to the Pond area.

Residents of the Commonwealth no doubt are aware that many cities and towns have been forced to close their local sanitary landfills. This fact has led to an increase in illegal dumping on private property. Harvard Forest is one of the victims. In the last three years we have found everything from discarded couches and gas tanks to cars on our land. This disturbing fact has led us to rethink how forest roads and access areas are managed. Currently we are exploring the need for installation of gates in locations that are most vulnerable. Plans are now underway to reclaim and close the sandpit adjacent to Harvard Pond. This area is a chronic spot for illegal dumping and unauthorized use. We plan to close the access road to the area which intersects Route 122 just east of the Harvard Pond. A parking place will be established at the intersection where there is a pleasant grassy area and a scenic view of the Pond. These modifications will encourage greater enjoyment of this lovely area.

## HARVARD BLACK ROCK FOREST

Cornwall-on-the-Hudson, New York

**Forest operations.** The main gate relocation has been completed along with elimination of the rifle range near the Upper Reservoir. The new parking lot and freshly painted signs provide visitors with a much improved entrance to the Forest.

Early summer 1988 produced a prolonged period of hot, dry weather which culminated in a rash of forest fires in southeastern New York. Over the July Fourth weekend a wildfire advanced from the U. S. Military Academy at West Point on to Black Rock Forest and charred fifty acres of our property before manpower, helicopters and bulldozers finally subdued it. About one-third of the overstory trees within the burn died.

We continue to observe a higher than normal rate of mortality of mature oaks in areas where gypsy moth defoliation was quite severe in 1986 and 1987. Salvage operations of dead roadside trees by John Brady have yielded over 4000 board feet of oak logs and 33 cords of firewood. The logs were hauled to a local mill and sawn into lumber for new construction and repair purposes. Examples of construction projects using home-grown lumber include the new barn floors and renovated corral fence installed during this past year by John Brady and our summer employee, Chris Servedio.

**Research.** Dr. Clive Jones of the Institute of Ecological Studies of the Cary Arboretum completed his fifth year of field work at the Forest investigating the population dynamics of gypsy moths.

John Brady and Jack Karnig fenced off a half-acre area in Compartment XXV to keep out deer and allow seedlings and transplants to grow unhindered. A total of 148 seedlings of *Juglans nigra*, *J. cinerea*, *Quercus rubra*, *Q. alba*, *Q. montana*, *Picea glauca* and *Pinus sylvestris* were planted.

**Public relations.** A revised edition of The Black Rock Forest map was produced in November 1988 that incorporates all of the changes in our trail network, gates, parking lot and the addition of the fifty-acre Peck and DeWitt parcel acquired some years ago.

A modest increase of visitors to the Black Rock Forest continues to involve us in describing the history of the Highlands. Noteworthy is the increase in teachers who return with their students for field trips.

John Brady compiled a 33-page report summarizing the data collected at the Black Rock Forest on deer since 1970. Organizations that have cooperated in the management of our deer herd include: the N.Y. Department of Environmental Conservation, U. S. Military Academy at West Point and the Black Rock Fish and Game Club.

## ACKNOWLEDGEMENTS

Contributions during the year toward the activities described in this Annual Report include gifts from the following donors to whom we are indebted:

Friends of the Harvard Forest  
George I. Alden Trust  
Arnold Arboretum  
Andrew W. Mellon Foundation  
National Science Foundation  
Swedish National Research Council  
Swedish Royal Society  
United States Department of Agriculture, Competitive Research  
Grants, Forestry  
United States Department of Energy  
United States Department of Agriculture, Forest Service

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The foregoing is a list of publications which have appeared in print between July 1, 1988 and June 30, 1989. Publication lags one or more years behind the description of research in this report. Many of these publications are available as reprints. If you are interested in receiving any of these, please write to the Harvard Forest, Petersham, Massachusetts 01366, or where the address is given, directly to the authors.

Petersham, Massachusetts  
August 1989

John G. Torrey  
Director



North end of Harvard Pond showing water lilies and the bog mat of leatherleaf. (Photo by J. Silvester)

Front Cover: *Chamaecyparis thyoides* (White Cedar), scanning electron micrograph of young cone (x240), collected April 20, 1989 at Cedar Swamp, Gardner, Massachusetts. The flask-shaped structures are ovules (young seeds) shortly before the time of pollination. This cone is comparable to many other Cupressaceae in lacking an ovule-supporting scale, a structure otherwise considered to be characteristic of conifers. (Dissection and photography by Marcheterre Fluet)