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Forest Service

**Northeastern
Research Station**

General Technical
Report NE-249



History of the Northeastern Research Station: 1973 to 1998

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HEADQUARTERS:

- 1 Philadelphia, Pa. (1945-1948)
- 2 Upper Darby, Pa. (1948-Present)



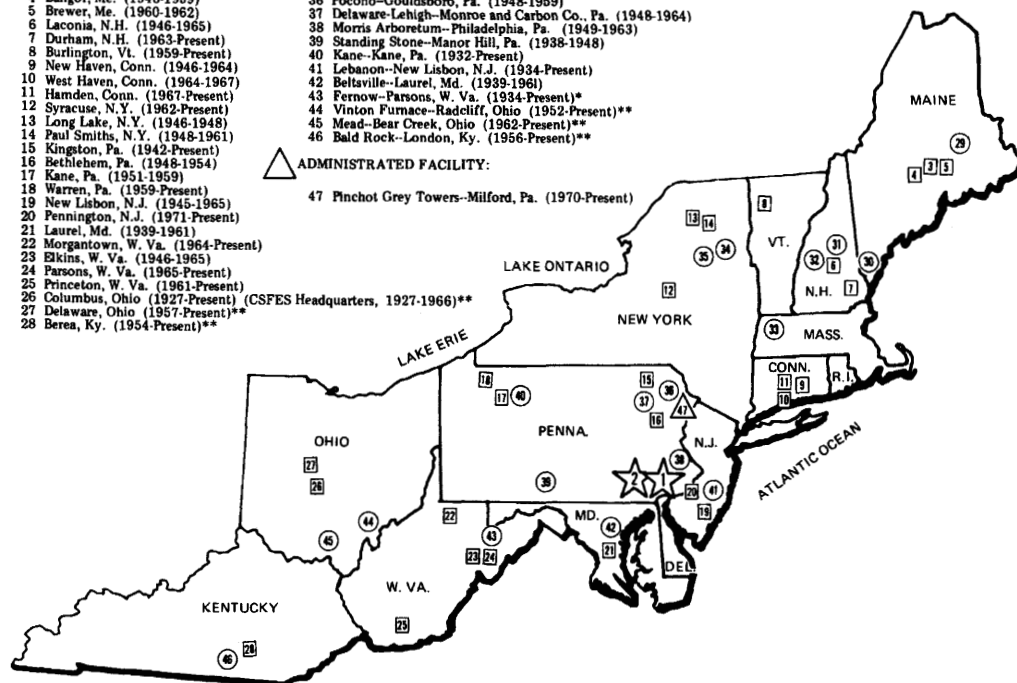
FIELD RESEARCH HEADQUARTERS:

- 3 Orono, Me. (1945; 1963-Present)
- 4 Bangor, Me. (1946-1959)
- 5 Brewer, Me. (1960-1962)
- 6 Laconia, N.H. (1946-1965)
- 7 Durham, N.H. (1963-Present)
- 8 Burlington, Vt. (1959-Present)
- 9 West Haven, Conn. (1946-1964)
- 10 West Haven, Conn. (1964-1967)
- 11 Hamden, Conn. (1967-Present)
- 12 Syracuse, N.Y. (1962-Present)
- 13 Long Lake, N.Y. (1946-1948)
- 14 Paul Smiths, N.Y. (1948-1961)
- 15 Kingston, Pa. (1942-Present)
- 16 Bethlehem, Pa. (1948-1954)
- 17 Kane, Pa. (1951-1959)
- 18 Warren, Pa. (1959-Present)
- 19 New Lisbon, N.J. (1945-1965)
- 20 Pennington, N.J. (1971-Present)
- 21 Laurel, Md. (1939-1961)
- 22 Morgantown, W. Va. (1964-Present)
- 23 Elkins, W. Va. (1946-1965)
- 24 Parsons, W. Va. (1965-Present)
- 25 Princeton, W. Va. (1961-Present)
- 26 Columbus, Ohio (1927-Present) (CSFES Headquarters, 1927-1966)**
- 27 Delaware, Ohio (1957-Present)**
- 28 Berea, Ky. (1954-Present)**
- 29 Penobscot-Bradley, Me. (1950-Present)
- 30 Massabesic-Alfred, Me. (1936-Present)
- 31 Bartlett-Bartlett, N.H. (1928-Present)
- 32 Hubbard Brook-West Thornton, N.H. (1955-Present)
- 33 Lawrence Hopkins-Williamstown, Mass. (1935-1968)
- 34 Paul Smiths-Paul Smiths, N.Y. (1948-1961)
- 35 Finch Pruyn-Newcomb, N.Y. (1933-1961)
- 36 Pocono-Gouldsboro, Pa. (1948-1969)
- 37 Delaware-Lehigh-Monroe and Carbon Co., Pa. (1948-1964)
- 38 Morris Arboretum-Philadelphia, Pa. (1949-1963)
- 39 Standing Stone-Manor Hill, Pa. (1938-1948)
- 40 Kane-Kane, Pa. (1932-Present)
- 41 Lebanon-New Lisbon, N.J. (1934-Present)
- 42 Beltsville-Laurel, Md. (1939-1961)
- 43 Fernow-Parsons, W. Va. (1934-Present)*
- 44 Vinton Furnace-Radcliff, Ohio (1952-Present)**
- 45 Mead-Bear Creek, Ohio (1962-Present)**
- 46 Bald Rock-London, Ky. (1956-Present)**



ADMINISTRATED FACILITY:

- 47 Pinchot Grey Towers-Milford, Pa. (1970-Present)

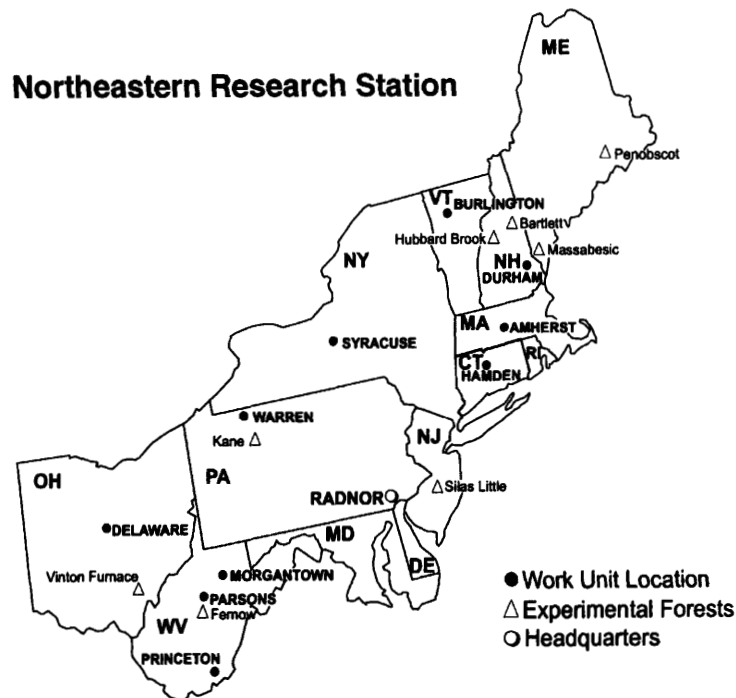


* Acquired from the Appalachian Forest Experiment Station during the reorganization of 1945.

** Acquired from the Central States Forest Experiment Station during the reorganization of 1966.

A 1973 map of the Northeastern Forest Experiment Station's area of responsibility and its research facilities during the first 50 years.

Northeastern Research Station



- Work Unit Location
- △ Experimental Forests
- Headquarters

The present Northeastern Research Station's area of responsibility and its research facilities.

Background

An excellent history of the first 50 years of the Northeastern Forest Experiment Station was published in 1973.¹ The publication traced the Congressional authorization that established the Station in 1923, the consolidation with the Allegheny Forest Experiment Station in 1942, and the addition of research programs in Ohio and Kentucky after the Central States Forest Experiment Station was closed in 1966. The Station's research programs, which covered a 14-state area in 1973, have an extensive and diverse record of accomplishment. Many important research problems were addressed during this period that resulted in significant improvements in forest management on public and private land. The publication also described important Station research activities and accomplishments in timber and watershed management; forest genetics; insects and disease; utilization and marketing; forest survey, economics, and engineering; wildlife habitat; and recreation.

This history covers the period from 1973 to 1998. Much of the information on research and technology accomplishments was obtained from numerous current and former Station employees. Other information was obtained from published Station reports, interviews with all of the respective Station Directors, unpublished records at Station Headquarters and the Washington Office of the Forest Service, and the personal recollections of the author during the time he served as an Assistant Director of the Northeastern Station, Director of the Southeastern Forest Experiment Station, and Associate Deputy Chief for Research in Washington.

¹Schrepfer, Susan R.; Larson, E. vH.; Maunder, E. R. 1973. A history of the Northeastern Forest Experiment Station, 1923 to 1973. Gen. Tech. Rep. NE-7. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 52 p.

Research Administration

Period of Continued Growth

1973 to 1974

Warren T. Doolittle became Station Director in 1970. He trained as a silviculturist and soil scientist, receiving a B.S. degree from Iowa State



Warren T. Doolittle

University, an M.S. degree from Duke University, and a Ph.D. degree from Yale University. He was a research forester with the Southeastern Station from 1946 to 1957 and was a member of the Timber Management Staff in Washington from 1957 to 1959. Doolittle joined the Northeastern Station in 1959 as Assistant Director responsible for research in timber and watershed management, mined-land reclamation, engineering, recreation, and wildlife habitat.

During Doolittle's tenure, the Station grew rapidly. Several new programs were established and new research facilities were built. One of the first programs to be accelerated was gypsy moth research at the Hamden, Connecticut, Laboratory. Senator Robert Byrd of West Virginia, a strong supporter of this research, was instrumental in securing the appropriation in 1971. The new Gypsy Moth Research and Development (R&D) Program pooled the resources of several Station work units. James Bean was named Program Manager, a position that functioned much like an Assistant Director. This was the first R&D program established in the Station (see Special Research Programs). Another program was the Pinchot Institute for Environmental Forestry, which was formalized in 1970 and led by Elwood Shafer. The Pinchot Institute was primarily a cooperative research consortium of nine universities in the Northeast (see Special Research Programs). Under this program, the Station received special funding for water, wildlife, timber, urban forestry, and

watershed research. Part of the money was earmarked for cooperative programs, but no specific portion was identified for cooperative research at specific universities. Such decisions were left to the Station, which formed a board of directors representing the universities that evaluated solicited research proposals and made recommendations to the Station for distribution of research funds. Doolittle also initiated wildlife and urban forestry projects at Amherst, Massachusetts, and a watershed project at Pennington, New Jersey.

Doolittle was successful in securing construction funds for new laboratories at Burlington, Vermont, and Durham, New Hampshire. Also appropriated were funds for new wings at the Morgantown and Princeton, West Virginia, laboratories. New funding was in process for a new laboratory at Berea, Kentucky, when Doolittle left the Station. He worked hard to develop support for the new Station programs among the many outside cooperators and various congressional delegations.

This also was a period of technological growth. During the late 1960's, nearly every laboratory had a computer but most were shared by various users. In the early 1970's, computers became more affordable, and the use of mini-computers and desktop computers was becoming more widespread.

The Station has long enjoyed strong support from many university deans, state foresters, and industry officials. Deans at the State University of New York College of Forestry at Syracuse, Princeton University, and the University of

Massachusetts were prominent in supporting roles for new programs at their schools. Surface-mining associations in West Virginia, Kentucky, and Pennsylvania as well as Pennsylvania Power and Light were strong supporters of emerging research programs on mined-land reclamation. Other valued cooperators were the Mead Corporation in Ohio, Collins Pine and Hammermill in Pennsylvania, International Paper in New York, and several forest industries in Maine. Mead provided two experimental forests in Ohio and the Penobscot Experimental Forest in Maine resulted from close cooperation with the timber industry.

In the early 1970's, collaborative ties were strengthened with the other major branches of the Forest Service—the National Forest System and State and Private Forestry (S&PF). During this period, Doolittle and John Ohman, Director of the North Central Forest Experiment Station worked with Jay Cravens, Regional Forester for the Eastern Region (9), and Phil Thornton and Robert Raisch, Directors of the Northeastern Area S&PF, to include their organizations in research planning and priority setting.

One research location was closed between 1970 and 1974. Much work had been completed on mined-land reclamation at Wilkes-Barre (Kingston), Pennsylvania; however, that program was maturing and a new program was being initiated at Berea, Kentucky. When the Wilkes-Barre location was closed, its leader, Grant Davis, relocated to Berea to lead the program there.

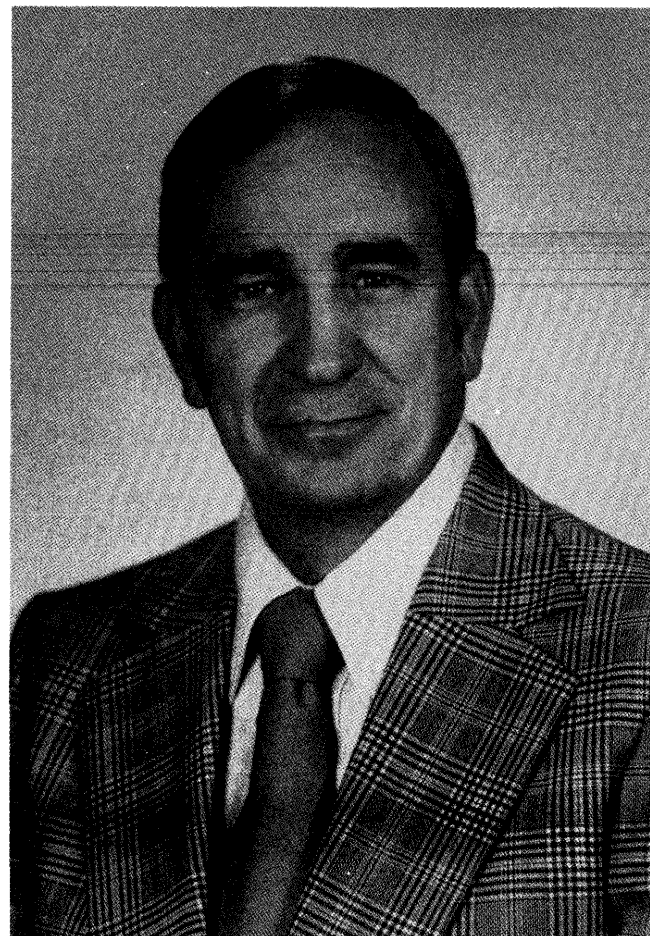
During his last year as Director, Doolittle supervised within the Station a Forest Service-

wide reorganization within Research Administration known as the “geographic assistant director” concept. He never favored this organization because he believed it would result in less contact with his assistant directors, hindering rapid communication and access to his staff. Doolittle left the Station in 1974 to become Director of Timber Management Research and later Associate Deputy Chief for Research in Washington.

1974 to 1979

F. Bryan Clark succeeded Doolittle as Station Director in September 1974. He trained in forestry and botany, receiving a B.S. degree from Purdue University, an M.S. degree from the University of Missouri, and a Ph.D. degree from Southern Illinois University. Clark worked on strip-mine reclamation and hardwood regeneration and management and was adjunct professor of forestry at the University of Missouri and research associate at Southern Illinois University. He also served as leader of research projects at Carbondale, Illinois, and Bedford, Indiana, for the Central States Station. He also served as Assistant Director for timber management research at the North Central Station before joining the Northeastern Station as Associate Director in June 1974.

Clark began his tenure as Director just as the major change in Research Administration noted earlier was being implemented. Formerly, Station assistant directors were located at headquarters and managed functional areas of research generally related to their own professional



F. Bryan Clark

expertise. Under the new concept, the assistant directors, each officially titled “Assistant Station Director for Continuing Research,” would manage research programs in a specific geographic area regardless of the functional research underway in that area. Importantly, the new geographic assistant directors would be relocated to field

offices. The first Station Assistant Directors assigned to field locations were Daniel Schmitt, Samuel Gingrich, and Eldon Ross. Located in Durham, Schmitt was responsible for oversight of research programs in New England and New York. Gingrich, located in Morgantown, was responsible for research in New Jersey, Maryland, West Virginia, and Kentucky. Ross, located in Delaware, Ohio, supervised research in Pennsylvania and Ohio.

The reorganization included new or restructured positions to the Director's staff as well as a Deputy Director and an Assistant Director for Planning and Application. The function of the Assistant Director for Support Services also was restructured. R. Duane Lloyd became the Station's first Deputy Director, Thomas Hamilton was the first Assistant Director for Planning and Application, and Robert Erickson served as Assistant Director for Support Services under the reorganization. The addition of these three positions relieved some of the need to have every member of the Director's staff close at hand. The Deputy Director managed the Station's day-to-day operations, allowing the Director to focus increasingly on external responsibilities, while the Assistant Director for Planning and Application concentrated on program planning, research budgets, and the transfer of research results. The role of research administration was greatly enhanced as the Assistant Director for Support Services became a full participant in the Station's decisionmaking process. Being located in the field enabled the Assistant Directors for Continuing Research to be closer to the research projects they managed and strengthened their working relationship with external clients of the Station's research programs.

Project leaders now had to assume full technical responsibility for their research program. Although some project leaders objected to what they believed was closer scrutiny of their research programs, most developed strong working relationships because the assistant directors became advocates for research in their geographic areas.

A strong advocate of scientific accountability, Clark continually pressed for the highest standards in the conduct of the Station research program, always asking the scientists: "Who needs the research?," "Why do they need it?," and "How will we get the research information to them?" He placed great emphasis on the transfer of research information to users and was the first Station Director to place technology transfer specialists from S&PF in positions associated with research projects, including the Gypsy Moth Research and Development Program and the Mined-Land Reclamation Project.

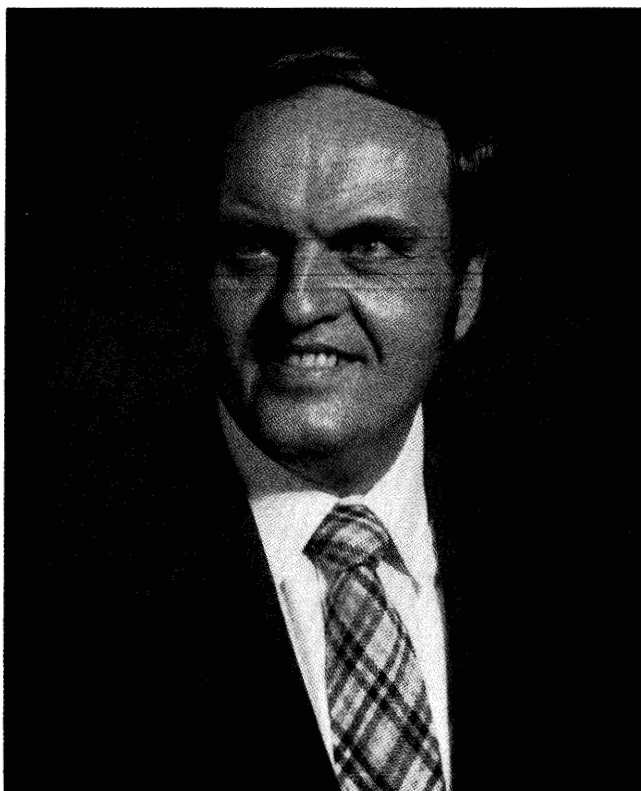
Several new R&D programs and research work units were initiated or accelerated in the mid and late 1970's. The Gypsy Moth Research and Development Program was accelerated by a substantial increase in research funds from the U.S. Department of Agriculture's (USDA) "Big Bug" program. The Spruce Budworms Program was initiated during this period and later was expanded when the United States and Canada established the CANUSA program. Air pollution research also was emphasized when Clark obtained a significant increase in appropriations for this research at Delaware, Ohio. This work spurred the First International Symposium on Acid Rain, which contributed to the later

formation of the National Acid Precipitation Assessment Program.

This also was a time of new and startling research on nutrient cycling and acid precipitation on the Hubbard Brook Experimental Forest in New Hampshire. Much of the work there by Forest Service and cooperating scientists broke new ground that revised the current thinking on the impact of air pollution on water quality. Clark also was able to accelerate, with additional funding, the Station's pioneering research on decay and discoloration in trees at Durham.

While Clark was Director, new wings were added to the laboratories at Morgantown and Princeton, and funding was secured for the construction of an office-laboratory in Berea to house mined-land reclamation research, which had become a part of the National Surface Environment and Mining Research and Development Program, also known as SEAM. Also, Station Headquarters located in Upper Darby, Pennsylvania, had been judged inadequate to meet a growing need for space. In 1978, the Headquarters staff and two research projects relocated to a new leased building in nearby Broomall, Pennsylvania.

In 1975, a field location at Columbus, Ohio, was closed and the timber management, economics, and utilization research units were transferred to the Station laboratory at Delaware, Ohio. At about the same time, the Bald Rock Experimental Forest in Kentucky, having exhausted its potential for additional research, was returned to the Daniel Boone National Forest. Clark left the Station in June 1979, to serve as Director of Timber Management Research and later Associate Deputy Chief for Research in Washington.



David B. Thorud

1979 to 1981

David B. Thorud succeeded Clark as Station Director in the summer of 1979. He trained at the University of Minnesota, receiving a B.S. degree in forestry and M.S. and Ph.D. degrees in forest hydrology. He served for two years on the faculty at the University of Minnesota and in 1966 was appointed associate professor in the Department of Watershed Management at the University of

Arizona. He later became head of that department, and in 1975 became the first director of that University's School of Renewable Natural Resources. Thorud joined the Forest Service in 1977 as an Assistant Director at the Southeastern Station. He was a staff hydrologist with Forest Environment Research in Washington before assuming duties as Director of the Northeastern Station.

Thorud immediately demonstrated considerable organizing and planning skills by assuring that the Station maintained a firm position in the new hardwood research initiative developed by the eastern research stations, and by securing a strong position for the Station in the developing acid rain program. He also directed the development of an economics research plan for the Station and reexamined its insect and disease and wildlife research programs. Thorud completed the phase-down of the CANUSA program, reorganized the watershed research program at Parsons, West Virginia, the program on the ecology of forest insects at Hamden, and the Consortium for Environmental Forestry Studies. He also redefined the mined-land rehabilitation program at Berea. Under his directorship, the following research received both national and international attention: watershed research at Hubbard Brook Experimental Forest led by Robert Pierce; Allegheny hardwoods research at Warren, Pennsylvania, led by Dave Marquis; forest inventory research led by Joe Barnard; research on

insect biocides at Hamden, led by Frank Lewis; and research on tree decay and discoloration led by Alex Shigo at Durham .

Like his predecessors, Thorud enjoyed the strong support of Congressional delegations that represented the various states in the Station's territory. He also had a close working relationship with the Station's cooperators, worked with Al Schacht, Director of the Northeastern Area S&PF on numerous technology transfer programs, and met frequently with representatives of Region 9 to coordinate research programs. Thorud left the Station in June 1981 to become Dean of the College of Forest Resources at the University of Washington.

In 1979, the Office of Personnel Management adopted a new classification system for executive personnel called the Senior Executive Service (SES). Station directors no longer would be classified under the General Schedule classifications. Because of the administrative procedures involved in appointing new members of the SES, the appointment of a new Station Director was delayed for nearly 6 months. During this period, Deputy Director Robert Romancier, who had succeeded R. Duane Lloyd in that post, served as Acting Director. Romancier, who joined the Station in September 1980, continued to implement the programs that had been set in motion, by Thorud. Romancier kept the Station on a productive course, working actively with cooperators and helping establish programs that enhanced diversity within the Station.

Downsizing, Soft Money, and Reinvention 1981 to 1992

In December 1981, Denver P. Burns succeeded David Thorud as Director. Burns was trained in agriculture, zoology, entomology, and public administration, receiving B.S., M.S., and Ph.D. degrees from Ohio State University, and an M.S.



Denver P. Burns

degree in public administration from Harvard University. He first served the Station in the early 1970's as a staff assistant in insect and disease research. Later he was an Assistant Director at the Southern Forest Experiment Station in New Orleans, and then budget staff assistant to the Deputy Chief for Research in Washington. He was Deputy Director of the North Central Station before returning to the Northeastern Station as Director.

Burns' 11-year tenure was a challenging time for station directors throughout the country. USDA Assistant Secretary John Crowell, who had oversight of the Forest Service in the early 1980's, placed less emphasis on research than his predecessors. As a result, there were significant decreases in funding, a number of research programs and facilities were closed, and the number of scientists employed by the Forest Service fell sharply. At the Northeastern Station, appropriated research dollars decreased by slightly more than \$1 million by 1987. However, in constant dollars, the Station actually lost nearly \$5 million by 1986 and returned to the appropriation level of 1982 in 1991 only after a series of general increases.

Also during this period, other factors were at work. The cost of doing scientific research increased several times faster than standard inflation. Pay costs and increased costs associated with the new Federal Employees Retirement System (which replaced the Civil Service Retirement System) were only partially funded in the annual research appropriations. As a result, these costs were absorbed by the research operating account. The number of Station scientists that were funded decreased

from a high of 160 in 1981 to 99 in 1992. At Beltsville, Maryland, a pioneering research unit on mycorrhizae and a basic research project on tree meristems were closed. Also terminated were a recreation research unit at Durham, the Pinchot Consortium, a wildlife research unit at Morgantown, a research unit on sugar maple timber and sap production at Burlington, and the Eastern Spruce Budworms Program. Finally, mined-land reclamation research was discontinued and the relatively new laboratory at Berea was closed.

Despite this discouraging situation, this period was one of opportunity for the Station. Because of emerging needs in other areas, several new research programs were initiated. A biotechnology unit was established at Delaware, a project aimed at the silvicultural control of gypsy moth was initiated at Morgantown, and a project related to decision modeling and forest ecosystems research was established at Burlington. Also, new appropriated funds as well as substantial amounts of funding from other federal agencies, particularly the U.S. Environmental Protection Agency (EPA), flowed into the Station and led to the establishment of the Forest Response, Forest Health Monitoring, and Global Change Research and Development programs. This "soft money" from other agencies changed the direction of several Station research programs and became a contentious issue with some scientists and administrators, who believed "outside" funding had placed their research programs on a course not originally intended. However, others viewed soft money as a means of preserving valuable research talent and facilities that otherwise would be lost for lack of funding.

Late in Burns' tenure, in response to a proposal by Senator Robert Byrd, the Advanced Hardwood

Processing and Technical Resource Center was established at Princeton to assist wood-working machinery manufacturers and end users in testing and evaluating equipment. The Center's staffers also developed commercial and specialized databases on all aspects of secondary wood processing. Funding was provided through the Station but later was transferred to the S&PF budget (see Technology Transfer).

With the assistance of industry, a new technology transfer building was built at the Kane Experimental Forest, and Mead Corporation upgraded its facility at the Vinton Furnace Experimental Forest in Ohio. Also, facilities at the Hubbard Brook Experimental Forest were upgraded. In 1990, the Station Headquarters again changed locations. Working with the General Services Administration, the Station found a new location in Radnor, Pennsylvania, to replace outmoded facilities in Broomall. The new Headquarters was an "open space" facility with few interior walls, which allowed for easy rearrangement of office space.

In the early 1980's, the Forest Service adopted a new means of computer-based electronic communication called the Forest Level Information Processing System or FLIPS. The Northeastern Station was among the first research entities to use this new internal electronic mail system by which individuals eventually were able to communicate with anyone in the Forest Service literally in a matter of seconds. The Data General Corporation supplied both the hardware and software for the system, which became known simply as DG. Along with emerging FAX technology, the DG system greatly accelerated the processing and analysis of some field data.

During this period, the administration of field research programs was reevaluated, particularly the geographic assistant director concept. Greatly improved communications and means of transportation lessened the need for assistant directors to be in the field. Separation of key staff members from Station headquarters became problematic because an insurgence of new R&D programs was overwhelming the resources of the Assistant Director for Planning and Application. As a result, when these new programs were established, their managers were relocated at Headquarters. By 1991, all of the Station's Assistant Directors were headquartered in Radnor.

Burns and his leadership team believed strongly in developing interdisciplinary research programs. Encouragement for such programs came from the office of the Deputy Chief for Research. However, budgeting negotiations between the Washington staff directors who managed the functional research programs and the station directors sometimes led to disagreements on research priorities. The staff directors claimed they were adhering to national priorities but the leadership at the Northeastern Station (and other Stations) maintained that several important research opportunities had been lost.

In the mid-1980's, the Forest Service initiated a pilot program designed to reduce red tape and self-imposed restrictions that after a period of time become interpreted as law. The national program was managed by Associate Chief Dale Robertson, who selected the Northeastern Station as one of two research stations to launch the program. Burns seized this opportunity to initiate a process called Genesis that allowed employees to spurn conventional thinking and make suggestions in a

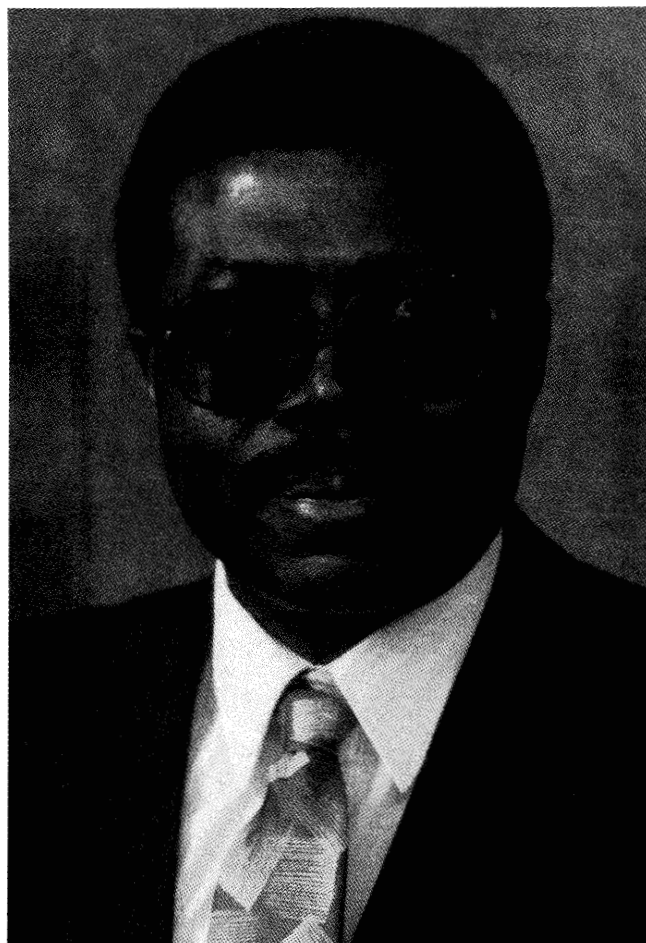
non-threatening environment. Genesis proved highly successful as nearly 300 employee suggestions for improvement were adopted by 1991. Many of these eased the paperwork burden or otherwise simplified the day-to-day work process.

The Genesis program even led to the development of a new research project. The problem of how to manage intermediate stands of hardwoods previously had been identified by the Station's management team, which invited any scientist interested in this problem to attend and contribute to planning meetings. Scientists from 12 projects and many research disciplines became involved in this research problem under the leadership of David Marquis of the Warren laboratory. Under traditional research planning procedures, this problem would have been assigned to a timber management research unit with supporting disciplines playing a minor role or excluded entirely. However, a new leadership and problem-solving approach by participating scientists led to the development of the successful Northeast Decision Model (NED), a collection of software tools for forest management planning. The continuing work on decision modeling in forest ecosystems later was given project status under the direction of Mark Twery at Burlington (see Technology Transfer).

Burns left the Station in 1992 to become Director of the Rocky Mountain Forest and Range Experiment Station at Fort Collins, Colorado, as well as Acting Director of the Intermountain Forest and Range Experiment Station at Ogden, Utah. In 1997, these two stations were consolidated and renamed the Rocky Mountain Research Station with Burns as Director located at Fort Collins.

1992 to 1997

Robert Lewis, Jr. became Station Director in December 1992. He received a B.S. degree in biology from Jackson State University and a Ph.D. degree in plant pathology from Texas A&M University. He began his career with the Forest Service in 1970 as a biological laboratory



Robert Lewis, Jr.

technician with the Southern Station. From 1976 to 1986, Lewis served as a research plant pathologist at that Station's Hardwood Research Laboratory at Stoneville, Mississippi, where he conducted research on canker diseases, forest declines, and oak wilt. He joined the Northeastern Station in 1986 as Assistant Director for Planning and Application and in 1989 was appointed an Assistant Director with responsibility for the research programs in New England and New York. He left the Station briefly from 1991 to 1992 to serve as a staff assistant to the Deputy Chief for Research in Washington before returning to Radnor as Station Director.

Although the Station's budget was \$25 million in 1992, it had declined in real dollars by 18 percent in 1997, resulting in a 10-percent decrease in permanent salaries and a 42-percent decrease in operating funds. Included during this period was a midyear, 5-percent Congressional rescission of appropriated funds in 1995 in an attempt to balance the federal budget. There were additional budget cuts in 1996, with the Global Change Program, economics, recreation, and engineering research absorbing the greatest reductions. Forest Inventory and Analysis was the only program that did not suffer significant reductions. Cooperative research at universities also was hard hit because there was little operating flexibility in the Station's research program. This downsizing precluded the initiation of new research programs and forced Lewis to consider alternative management strategies.

The Station suffered substantial reductions in personnel; administrative positions were reduced by 30 percent and the number of permanent full-time scientist positions was reduced to 85.

Looking to the future despite these severe restrictions, the Station was able to keep five scientists in Ph.D. developmental programs on term appointments; several research work units were consolidated; research locations at University Park, Pennsylvania, and Orono/Bradley, Maine, were closed; and greater emphasis was placed on interdisciplinary research, with scientists assigned to programs that extended across the Station's entire territory. This closer scrutiny of research programs resulted in the development of strategic planning process called RoaDMaP (from Research and Development Management Plan), which provided a conceptual framework for research and development at the Station that complied with the national plan. The Station's strategic planning has since evolved to the point where scientists routinely participate in the current RoaDMaP process.

Despite the decline in funding available for cooperative research, universities continued their strong support for Station research. The University of Vermont and the State University of New York's College of Environmental Science and Forestry have played important roles in the development of Station research programs. Also, the Hardwood Research Council continues to support hardwood research, and the Hardwood Lumber Association supports forest inventory and analysis, economics, and forest products and harvesting research. Cooperation among Forest Service cooperators also continues to grow. The

national forests within Region 9, particularly the Allegheny, White Mountain, Green Mountain, Monongahela, and Wayne National Forests, are working closely with Station scientists on ecosystem management research. Also, the Station and the Northeastern Area S&PF have developed an eastern leadership team to work jointly on a forest health and operations initiative, and currently are collaborating on the establishment of a long-term ecological reserve in an urban area that would incorporate the vast research base of the Station and the extensive work by S&PF on the Chesapeake Bay Restoration Program. Participants would include the Institute for Ecological Studies at Yale University, the University of Connecticut, and an historically black college or university.

The past five years have been marked by efforts to improve the energy efficiency of some Station facilities and by new construction. A headhouse and greenhouse were constructed at Delaware, a greenhouse was built at Burlington, a small office-laboratory was constructed at Bradley, Maine, to accommodate the research staff that had been moved from Orono, and additions were made to facilities at the Hubbard Brook and Bartlett Experimental Forests.

Administration of the research programs at Station Headquarters also has changed since 1993. At present, two assistant directors and two program managers oversee all research work units. The assistant directors now may oversee research units located anywhere in the Station. The manager for the Global Change Program supervises three research units, and the manager for the Forest Monitoring Program supervises the

Forest Inventory and Analysis unit. In 1996, Richard Guldin, Acting Deputy Station Director, was reassigned to Washington. That position has remained vacant as the responsibilities of the Deputy Station Director have been distributed among members of the Management Team.

As noted earlier, the Data General Corp. had provided necessary hardware and software for Forest Service communications and other computing needs. In 1998, the IBM Corp. began providing similar services that also include geographic information systems (GIS) capability. Two years earlier, the Station officially entered the Information Age with its own site on the Internet. Information about Station research programs and other pertinent data are available via the World Wide Web at: <http://www.fs.fed.us/ne/>

Lewis left the Station in March 1997 to become Deputy Chief for Research and Development in Washington. Keith F. Jensen, an Assistant Director, served as Acting Station Director until a new Director was appointed.

1997 to Present

In December 1997, Bov B. Eav was named the new Station Director. He earned a degree in forestry in 1970 from the Universite des Sciences Agronomique, Chumkar Daung, Cambodia; and an M.S. degree in forest biometrics in 1974; and a Ph.D. degree in forest biometrics/remote sensing in 1977 from the State University of New York College of Environmental Science and Forestry,



Bov B. Eav

Syracuse. In Cambodia, he served as forestry inspector for the Ministry of Agriculture, Department of Forests and Water. In the United States, Eav was principal scientist for the Lockheed Corporation in Houston, Texas, where he led mission tasks for several space shuttle scientific payloads, including the IMAX camera project and solid-surface combustion and particle-cloud combustion experiments. He also

supervised Lockheed's timber inventory project sponsored by the Forest Service. In 1985, Eav came to the Forest Service as an operations research analyst for S&PF's Methods Application Group (MAG) in Forest Pest Management at Fort Collins, Colorado. Later, he would become associate director and manager of the Quantitative Techniques Program for MAG. In 1994, he became director of the National Center of Forest Health Management in Morgantown, West Virginia, but soon returned to Fort Collins as director of the Forest Service's Forest Health Technology Enterprise Team.

Special Research Programs

Pinchot Institute of Environmental Forestry Studies

In 1970, the Station announced the formation of the Pinchot Institute, officially chartered as the Consortium for Environmental Forestry Studies, to conduct urban research in the Northeastern United States. Elwood Shafer was the first Program Coordinator. Later, George Moeller, Brian Payne, and Al Foulger served in this role.

Charter members of the nonprofit Consortium were the University of New Hampshire, Massachusetts Agricultural Experiment Station, University of Connecticut, Yale University, State University of New York College of Forestry, Cornell University Agricultural Experiment Station, Princeton University, Rutgers University, and Pennsylvania State University. Princeton later dropped its membership, but the Consortium added Ohio State University, University of Delaware, and University of Vermont. Research proposals by scientists from member universities and the Station were ranked by an executive committee and recommended to the Station, which funded them through grants to individual universities. Working groups related to air quality, amenities, genetics, insects and disease, planning and management, social and behavioral issues, soils, water quality, and wildlife were formed and became the core mechanism for functioning of the Consortium, because they essentially controlled the direction of research in their defined area.

Three Station work units were dedicated to Consortium-related research: urban forestry and wildlife habitat associations at Amherst, structure

and function of urban forest ecosystems at Syracuse, and amenities and municipal watersheds at Pennington and later University Park. During its 15-year lifespan, more than \$2.5 million were granted for research studies, problem analyses, symposia, and technology transfer. The Consortium sponsored 11 major symposia and generated more than 300 scientific papers, reports, articles, and presentations, many of which were landmark accomplishments in urban forestry. This successful program was terminated in 1986.

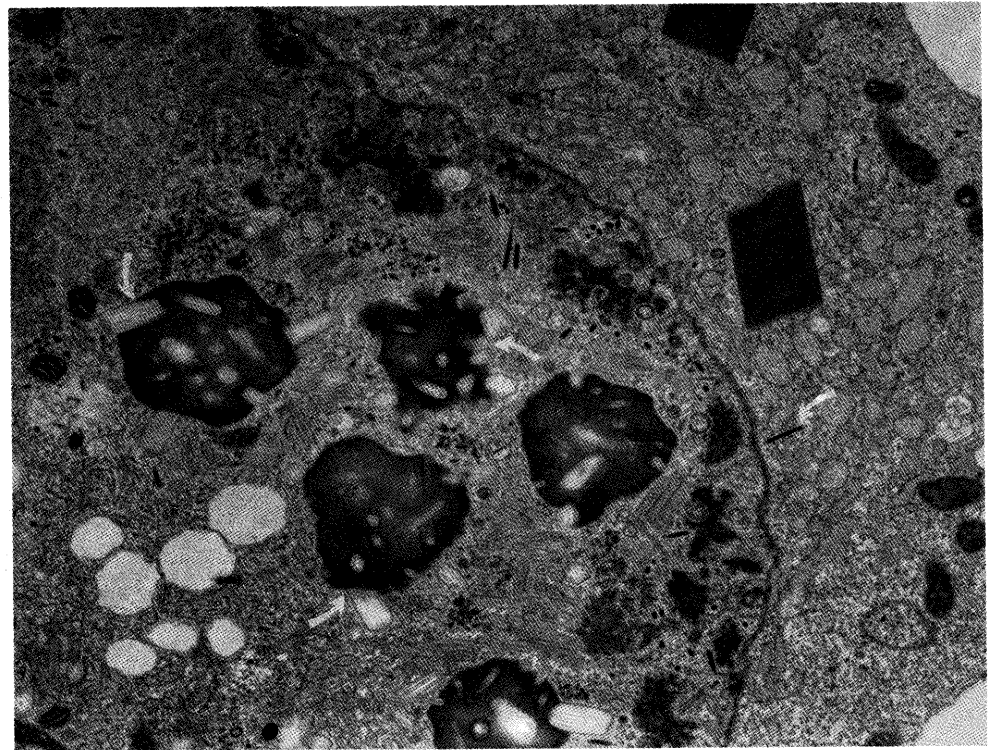


Adult gypsy moth females laying eggs. Egg clusters may contain an average of 750 eggs and are found on tree trunks, frequently on loose bark or under limbs.

Gypsy Moth Research and Development Program

In 1971, the USDA redirected \$1 million for research on the gypsy moth, most of which was designated for cooperative studies with universities and various state agencies. This funding was a response to the tremendous increase in gypsy moth populations between 1968 and 1972. In 1972, the Station initiated the Gypsy Moth Research and Development Program, which was led by James L. Bean. Most of the research was

focused at the Hamden laboratory. Under the direction of Robert Campbell, a series of intensive research plots was established throughout the Northeast to acquire data on the dynamics of this forest pest and its impact on forest resources. Beginning in 1974, gypsy moth research was accelerated through the USDA's Combined Forest Pest Research and Development Program, a coordinated national effort that focused on the management of the southern pine beetle, tussock moth, and gypsy moth and that was supported by a special Congressional appropriation. Michael McManus directed this special program. At the same time, a team of Northeastern Area specialists was relocated to Hamden under the direction of William White, who served as application coordinator. Program scientists were responsible for the following major accomplishments:



Replication of nucleopolyhedrosis virus in a gypsy moth hemocyte. The arrows point to virus particles.

1. Developed a model that simulated the interaction of the gypsy moth and New England forests and predicted the impact of defoliation on tree condition and mortality.
2. Developed a procedure that included measurements of root starch to assess individual tree vigor and predict which trees are most likely to succumb to defoliation.
3. Developed a predictive model that allowed foresters to classify stands that are resistant or susceptible to gypsy moth populations.
4. Registered Gypchek, a safe, viral pesticide specific to the gypsy moth, as well as two new chemical pesticides (Dimilin and Orthene).
5. Synthesized a more potent sex pheromone of the gypsy moth and deployed it in a new pheromone trap that greatly improved population monitoring.

6. Developed an insect mass-rearing prototype facility on Cape Cod, in Massachusetts in conjunction with the USDA's Agricultural Research Service (ARS) and Animal and Plant Health Inspection Service (APHIS).

7. Published "The Gypsy Moth: Research Toward Integrated Pest Management", an exhaustive 784-page synthesis of research on gypsy moth.

The worst gypsy moth outbreak in history occurred between 1979 and 1982. More than 14

million acres were defoliated in 1981 alone. Congress responded by appropriating \$700,000 for gypsy moth research through the Northeastern Station. Beginning in 1984, the Station initiated the Gypsy Moth Research and Development Program for extramural research. The program was led by Gerard Hertel and Garland Mason until 1986 and then by Max McFadden.

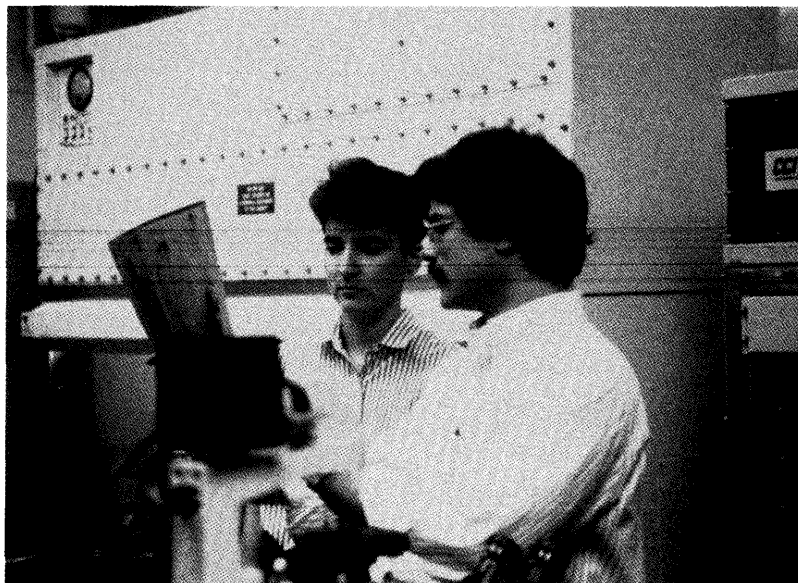
The objectives of this new program were to: (1) determine the effects of gypsy moth on forests; (2) increase our understanding of the biology and

population dynamics of gypsy moth; (3) develop and evaluate management options, particularly the role of selected pathogens as regulators in low-to-medium density populations; and (4) develop models and integrate knowledge.

Contributing to the program were two research units at Hamden, one led by William Wallner and later Michael Montgomery, and one directed by Franklin Lewis and later Michael McManus; a unit at Morgantown led by David Donley, Garland Mason, and Kurt Gottschalk; and a unit at Delaware led by Ming Chang and later Jim Slavicek. Several participating universities, private research institutes, other USDA agencies, state agencies, and private industry added to the body of knowledge about gypsy moth.

A number of microbial agents were identified or refined that can be used to control the gypsy moth. These include the bacterial pathogen *Bacillus thuringiensis*, the fungus *Entomophaga maimaiga*, and the *Lymantria dispar* nucleopolyhedrovirus (LdMNPV). An advantage of LdMNPV is its specificity for the gypsy moth. This trait allows its use in areas containing threatened and endangered species. An isolate of LdMNPV from Connecticut, the "Hamden" isolate, had been evaluated from 1972 to 1977 to determine whether the virus was safe for use as a microbial pesticide. In 1978, the Hamden isolate of LdMNPV was registered by the EPA as a microbial pesticide for use against the gypsy moth under the name Gypchek.

Through a joint effort by researchers with APHIS, ARS, and the Forest Service, in vivo production of Gypchek was developed and a facility was constructed at an APHIS location. Production of

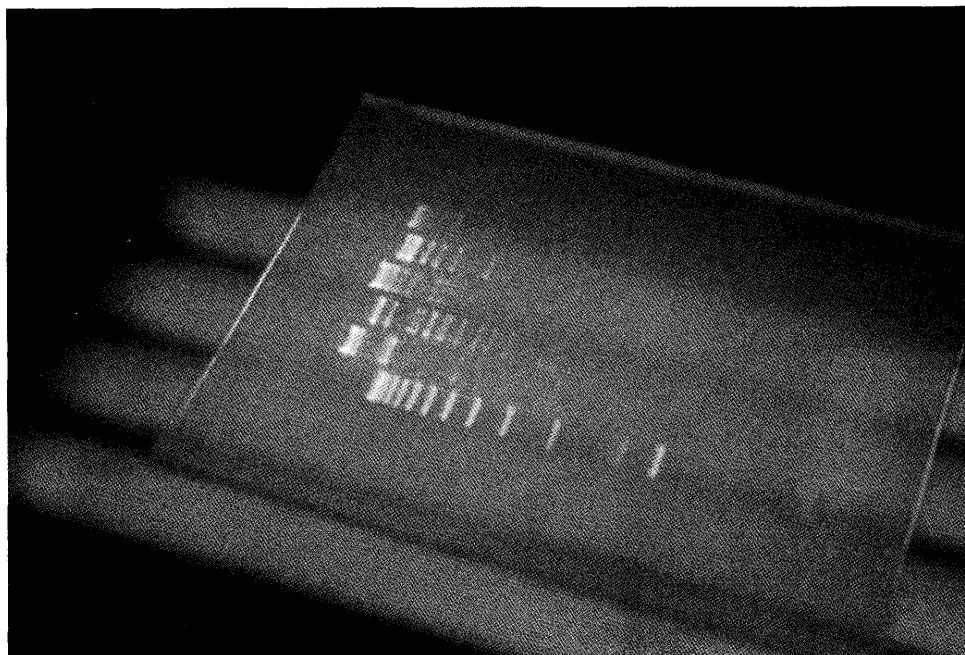


Researchers analyze the expression of viral genes. Through genetic engineering, improved strains of the gypsy moth virus are being developed for use in control programs.

LdMNPV in cell culture is an alternative to production in gypsy moth larvae and has the advantages of greater scale, a more controllable process, and greater product purity. However, during virus production in cell culture, a type of virus mutant that produces little virus often is generated. These "few-polyhedra mutants" prevented the successful production of virus in cell-culture bioreactors. The formation of few-polyhedra mutants in the LdMNPV has been studied extensively at both the organismal and molecular levels. A viral strain derived from Gypchek was developed that was less prone to formation of few-polyhedra mutants. In collaboration with the private sector, efforts

continue to develop improved LdMNPV strains and cell culture bioreactor methods for the commercial production of LdMNPV.

New strains of *Bacillus thuringiensis* with enhanced virulence were identified, tested for aerial application, and placed in use. Concern over the use of this bacterium as an agent for controlling gypsy moth led to extensive studies of impacts on nontarget insects that have produced valuable information on the timing of applications and protection of sensitive species. Research on gypsy moth parasites also received greater attention. Much was learned about the use of tachinid, braconid, and encyrtid parasites. Silvicultural



An agarose gel is stained with ethidium bromide and illuminated by ultraviolet light to visualize DNA fragments. Gypsy moth viral DNA is being analyzed to identify genomic changes that gave rise to a mutant virus. Researchers at Delaware, Ohio, have developed improved gypsy moth viral strains for use in control programs.

methods were developed to reduce damage by gypsy moth, and mathematical models of the gypsy moth life system, a gypsy moth phenology model called GMPHEN, and other models (such as GypsES) that integrated current knowledge into usable management tools were developed (see Technology Transfer).

In 1991, the Asian gypsy moth was introduced accidentally along the Atlantic and Pacific Coasts. Research on this introduced pest was necessary because some life stages differed significantly from those of the European gypsy moth already present

in North America. During this time, extensive joint studies were initiated with scientists in Russia. Researchers learned that Asian and European gypsy moths hybridized readily, making it important to identify and locate the presence of genetic material from the Asian gypsy moth. Scientists at Delaware developed nuclear DNA markers that aided in identifying the Asian gypsy moth.

Although a substantial gypsy moth research program continues in the Station, the R&D program was discontinued in 1995 but not before the original objectives were met. There were

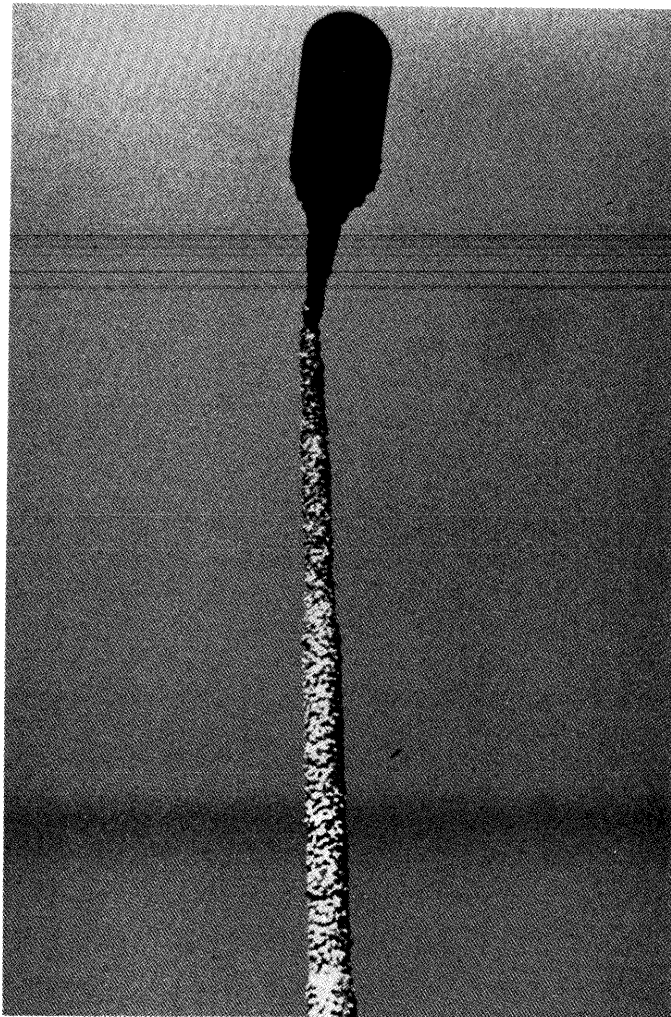
substantial accomplishments in understanding the effects of gypsy moth on forests, biology and population dynamics, gypsy moth management, and model development. Research products generated by these programs were used by the Appalachian Integrated Pest Management Program (established in 1987 and managed by the Northeastern Area S&PF) to reduce the rate of spread and effects of gypsy moth in eastern West Virginia and central Virginia.

CANUSA Spruce Budworms Program

By the mid-1970's, the spruce budworm had become a serious forest pest in the United States and Canada. Nearly 160 million acres were infested, and losses were serious in spruce-fir stands in North America. In 1977, the Canadian Department of the Environment and the USDA initiated an accelerated program to find ways to control spruce budworms in both countries. The Northeastern Station was the lead research unit for the Eastern United States. Daniel Schmitt was appointed program manager for this new effort, known as CANUSA. Increased funding for spruce budworms research was allocated to several Station work units, particularly the project in Orono led by Barton Blum. Much of the Forest Service's long-term silvicultural research related to the CANUSA program was conducted on the Penobscot Experimental Forest near Bradley, Maine. At its completion in 1984, CANUSA research had generated 17 USDA publications that aided foresters in managing outbreaks of spruce budworm.

Eastern Spruce-Fir and Eastern Hardwoods Research Cooperatives

In response to the Acid Precipitation Act of 1980, the Station developed the Eastern Spruce-Fir and



Asian gypsy moth egg masses on a street lamp in the Russian Far East. Females of the Asian strain are attracted to lights and often deposit eggs in harbor areas. Gypsy moths from Asia and Europe are found on commercial and military vessels and their cargo.

Eastern Hardwood Research Cooperatives. Major components of the national Forest Response Program, these cooperatives were initiated to determine whether acid deposition was causing significant forest damage, the mechanisms of acid deposition that contribute to forest damage, and the relationship between air pollutants and forest damage.

The Eastern Spruce-Fir Research Cooperative, led by Gerard Hertel and later Chris Eagar, focused on the high-elevation spruce-fir forests of the Appalachian Mountains. Station scientists and researchers from 14 institutions contributed to this research effort. On several research sites ranging from the Great Smoky Mountains National Park to Howland, Maine, changes in the condition of the spruce-fir forests were compared to pollutant exposure. Also, altered soil nutrient status and physiological processes related to reduced growth, leaching of foliar nutrients, and cold hardiness were investigated in red spruce.

Station scientists and researchers from 20 institutions participated in the Eastern Hardwood Research Cooperative, led by Max McFadden. This program focused primarily on air pollution gradient studies in the Northeast and controlled laboratory and field studies on dose-response effects of atmospheric deposition on hardwood species. This cooperative included the North American Sugar Maple Decline Project, a joint U.S. and Canadian effort that examined sugar maple decline in both countries.

The research information generated by these cooperatives, which were terminated in 1990, supported the following conclusions:

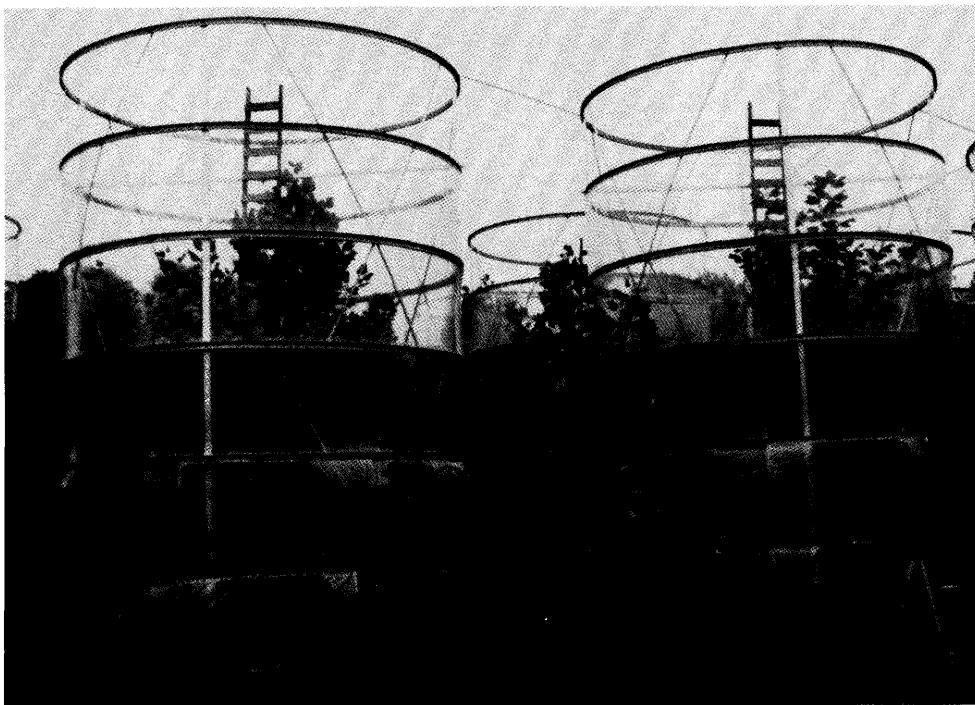
1. There is no evidence of a general, widespread decline of forest tree species due to acid deposition.
2. The potential exists for effects of acid deposition on soils at high elevations in the Southeast because of acidic cloud water and low base saturation of the soils.
3. Tree seedlings can exhibit foliar injury from acid deposition at or below pH 3.
4. Most acid mist treatments affected the susceptibility of red spruce to winter freezing injury.
5. Ozone is the pollutant of greatest concern in rural, near urban, and urban forests in North America.
6. In open-top chamber experiments, ozone caused physiological changes in red spruce foliage and suppressed the growth of several hardwood species.
7. Natural stress factors such as local weather, insects and disease, and stand dynamics have been implicated in observed changes in forest condition, though pollutants cannot be ruled out as causal agents.

Forest Health Monitoring

In the late 1980's and early 1990's, the Station responded to increasing concerns about general forest health by organizing the Forest Health Monitoring Program. It was an outgrowth of the National Vegetation Survey in the Forest

Response Program, which was part of the National Acid Precipitation Assessment Program (NAPAP). The Forest Health Monitoring Program was first conducted in New England in 1990 in cooperation with state foresters and the EPA's Environmental Monitoring and Assessment Program (EMAP). Later in 1991, the Station's forest health monitoring program became part of EMAP. Other participants included the National Association of State Foresters; Tennessee Valley Authority; USDI Fish and Wildlife Service, Bureau of Land Management and National Park Service; and USDA Soil Conservation Service

(now the Natural Resources Conservation Service). The Station's program, headquartered in Radnor and directed by Andrew Gillespie in collaboration with the Northeastern Area and state foresters, remains a significant contributor to the national program. Through a network of permanent monitoring plots, information is gathered regularly to determine trends in the condition of the forest resource. Observations are made on insect and disease conditions and the effects of air pollution, climate, fire, animal damage, floods, and other factors on the long-term productivity of forests.



Growth chambers are used at the Delaware laboratory in global change research.

Global Change Research

When Congress passed the Global Climate Change Prevention Act of 1990, it provided for the U.S. Global Change Research Program, which was established under the direction of the Office of Science and Technology. The Forest Service is a major contributor to this program, which examines processes that are sensitive to physical and chemical changes in the atmosphere, functional changes in ecosystems, and implications for forest management in sustaining productivity, health, and diversity. This national program was initiated when NAPAP was terminated in 1990. The Forest Global Change Program is divided into four regional programs: North, South, Pacific, and Forest Products Laboratory. The Northern Global Change Program (NGCP) is located at Radnor and is directed by Richard Birdsey.

Through 1996, NGCP had generated more than 100 research papers and reported the following major findings:

1. Past and projected changes in climate, air pollution, and acid deposition now can be estimated.
2. Exposure to acidic clouds impairs the cold tolerance of red spruce.
3. Variable responses of some species to elevated levels of ozone alone or in combination with elevated carbon dioxide levels are better understood.
4. Exposure of foliage to increased ozone and carbon dioxide affects the resistance of foliage to insect attack and nutritional value for insect growth.

5. Some conifers, especially larch, can rapidly change their genetic makeup when exposed to a changing environment.
6. There has been a substantial reduction in calcium in the organic soil layers of red spruce forests.
7. Possible nitrogen saturation of soils from atmospheric deposition could lead to nitrate pollution of freshwater and marine water systems.
8. Warmer temperatures can affect carbon and nitrogen dynamics in northern forest soils.
9. In some areas, forest productivity has been reduced by as much as 17 percent due to exposure to ozone.

Highlights of Research Activities and Accomplishments

Forest Environment

Watershed Management/Ecosystem Research

During the early 1970's, the Northeastern Station was conducting watershed management research on 23 small, gauged watersheds—8 on the Hubbard Brook Experimental Forest, 9 on the Fernow Experimental Forest in West Virginia, and 6 on the Leading Ridge Experimental Watersheds in Pennsylvania. Research at Hubbard Brook was led by Robert Pierce and later by Chris Eagar. Research on the Fernow had been led by James Patric, Jim Kochenderfer, Samuel Kunkle, Dave Helvey, and Mary Beth Adams. Research at Leading Ridge, which was associated with the municipal watersheds research headquartered at University Park, was directed by Howard Halverson and later Edward Corbett.

Studies on these watersheds expanded our understanding of how forests and their management affect the hydrologic cycle and streamflow quality. Experimental treatments, including species conversions and a variety of silvicultural practices, revealed long-term impacts on annual and seasonal streamwater yields, snowmelt runoff, flood flows, and low flows. Researchers used these same experiments to determine the effects of treatments on streamwater quality, including sediment, turbidity, temperature, and chemical concentrations. Results were published widely in the literature and continue to serve as a basis for “best management practices,” a series of guidelines and recommendations used by state agencies to protect forest streams and aquatic ecosystems. These



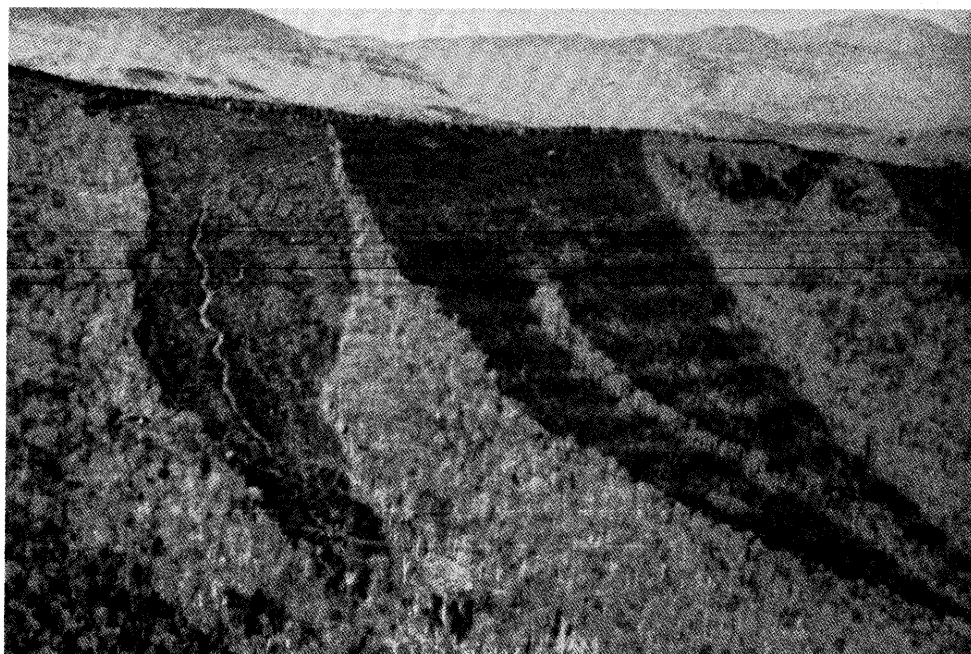
A weir at flood stage at the Hubbard Brook Experimental Forest. Weirs or streamgauging stations like this are used to obtain continuous measurements of streamflow. They are a basic tool for watershed research

watershed studies also provided background and baseline data for the development of BROOK, a hydrologic simulation model that quickly gained widespread application as a research and teaching tool.

In later years, watershed studies were expanded beyond water quality and the hydrologic cycle to include the cycling of nutrients and pollutants. The focus now shifted from watershed management research to watershed ecosystem analysis or ecosystem studies. The Station encouraged outside cooperation in ecosystem

studies at both the Fernow and Hubbard Brook. This effort was highly successful, attracting hundreds of participating scientists and students from universities, government agencies, and industry. The Hubbard Brook Ecosystem Study has resulted in more than 1,300 publications and is recognized as a model for such studies.

The ecosystem studies evaluated the impacts of forest disturbances and acid rain on chemical cycling and the subsequent health and productivity of forest and aquatic ecosystems. The greatest concerns centered around clearcutting



Experimental harvests on northern hardwood forested watersheds at the Hubbard Brook Experimental Forest. The watershed on the right has been harvested by progressive strip cutting; the watershed on the left has been harvested by whole-tree clearcutting.

and whole-tree harvesting and whether these practices reduce species diversity, deplete nutrients, and increase erosion. Forest managers countered that intensive harvesting such as clearcutting was necessary to regenerate commercially valuable forests and could be applied without harming productivity or the environment. At Leading Ridge, Fernow, and Hubbard Brook, one or more watersheds were clearcut and contrasted with a nearby, uncut watershed. The impacts of intensive harvesting on regeneration, water quality and quantity, and soil nutrients were quantified. Because of these studies, more

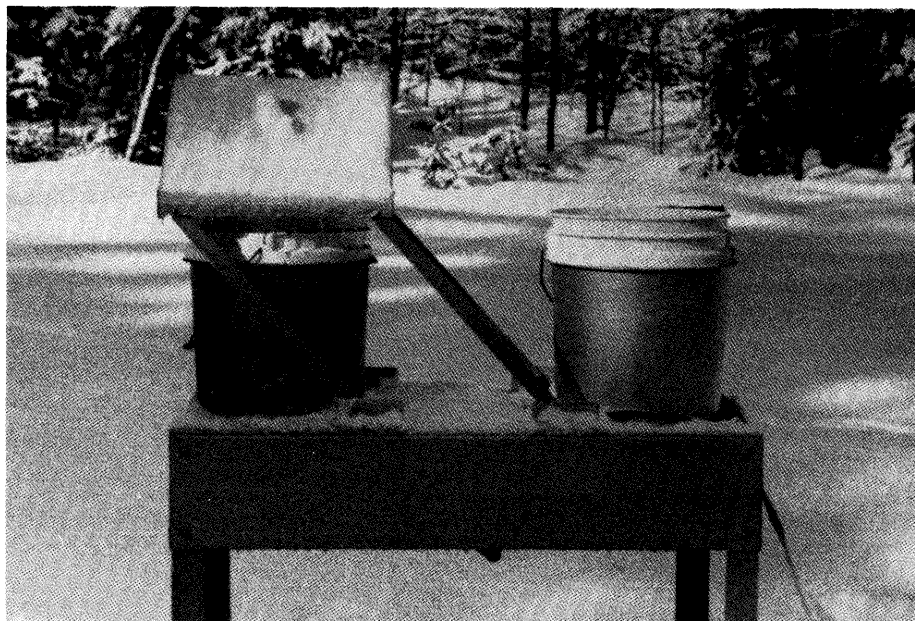
informed decisions are being made by managers of forest ecosystems in the Northeast.

Ecosystem studies also played an important role in documenting the extent and effects of wet and dry deposition. Measurements of precipitation chemistry at Hubbard Brook, begun in 1963, were the first to document the occurrence of acid rain in North America. The continuous record of precipitation chemistry data at Hubbard Brook is the longest in the world. This record has been invaluable in determining long-term variability and trends and in documenting significant

responses to emission controls initiated under the 1973 Clean Air Act. Hubbard Brook, the Fernow, and the Kane Experimental Forest in Pennsylvania, were among 76 initial sampling sites established in 1978 by the National Atmospheric Deposition Program to determine the extent and patterns of acid deposition. Sampling sites were established at the Station's Delaware laboratory, and at Leading Ridge. A gradient of precipitation sampling stations across Pennsylvania plus research at Hubbard Brook using back trajectories and chemical analyses of storm events were instrumental in substantiating the anthropogenic origin and source areas of acid rain.

At the Fernow, acidifying chemicals were applied to an entire watershed to mimic (and also hasten) the effects of acid precipitation on soils, streams, and plants. The objective of this study is to derive strategies for mitigating the effects of atmospheric deposition. Ecosystem studies at Hubbard Brook and satellite sites in New England documented the depletion of cations (especially calcium) and the mobilization of aluminum associated with acid rain, forest harvest, and past agriculture. These studies led to guidelines and recommendations for protecting site nutrient capitals and helped focus future research on nutrient depletion, nitrogen saturation, and mineral weathering rates.

The Station's research work unit associated with Leading Ridge was discontinued in 1995. However, both Hubbard Brook and the Fernow have promising futures because of the recognized value of long-term data maintained on these experimental forests. Since 1987, Hubbard Brook has been supported in part by the National Science Foundation as part of the latter's Long Term Ecological Research Program.



Atmospheric deposition has been sampled by the Northeastern Station at four locations since 1978.

Mined-Land Reclamation

Research on surface-mine reclamation by the Northeastern Station was centered at the Berea laboratory until 1992. Directed by Willie Curtis and later Willis Vogel and Howard Halverson, the Berea unit was part of the national SEAM program, which was established in part because surface mining for coal in the Appalachian Coal Field was devastating the environment.

The major emphasis of research was revegetating mined sites, specifically determining the most

desirable types and species of vegetation that can be established and thrive on mined land. Other studies were conducted to determine the suitability of mined and reclaimed land as habitat for wildlife and to find ways to ameliorate adverse visual effects resulting from the mining and reclamation process. Watersheds were instrumented throughout the Appalachian Coal Field from Alabama to Pennsylvania to document the influence of surface mining and reclamation on streamflow and water quality. Weekly samples collected from more than 100 watersheds

representing unmined, newly mined, and old mined conditions were subjected to rigorous laboratory analyses that determined the levels of some two dozen chemical elements.

Scientists also documented the need to adjust the pH of mined sites to promote the establishment of desirable species. Various types of mulch were identified that enhance plant establishment, development, and growth, and it was found that nitrogen and phosphorus fertilizers should be included in vegetation planning. Black walnut and ash are among the more desirable woody species that can be established under the cover of lesser desirable ones.

One of the more significant findings related to the water-holding capacity of mine spoils compared to unmined land was that during some storms, streamflow peaks were lower from revegetated mined watersheds than from nearby unmined ones. At the same time, base flows were higher and were sustained for a longer time in the mined watersheds. Properly placed impoundments on mined lands were important in reclamation efforts. The use of impoundments was significant in alleviating runoff and the resultant lowering of stormflow peaks. These ponds also provided recreation opportunities by supporting fish and enhancing habitat for a variety of wildlife species.

Wildlife Habitat

Since 1973, there have been noteworthy changes in the Station's wildlife and fish habitat research program. In 1977, wildlife habitat research at Amherst emphasized studies of forest birds, small mammals, and amphibians in northern hardwoods and related forest types on the White Mountain



Data on white-tailed deer foraging in a clearcut area are recorded to determine plant species selected and the estimated weights of those eaten.

National Forest in New Hampshire and Maine. This cooperative work helped the Forest respond to requirements of the National Forest Management Act of 1976. A major outcome was the 1986 publication "*New England Wildlife: Habitat, Natural History, and Distribution*," which summarized the natural histories of all species of terrestrial New England vertebrates and related their occurrence to a standard forest-vegetation classification. In 1992, a second volume in the series, "*New England Wildlife: Management of Forested Habitats*," described

the relationships between habitat structure and New England forest wildlife and described silvicultural prescriptions for managing that region's forests for wildlife diversity.

The West Virginia wildlife unit at Morgantown, which operated from 1965 to 1982 under the leadership of John Gill, focused on understanding the effects of uneven-age forest management on wildlife, with an emphasis on game species such as white-tailed deer, ruffed grouse, gray squirrel, and

wild turkey. Those studies led to a basic understanding of the gray squirrel's need for tree cavities and provided descriptions of the formation and abundance of natural cavities in several forest types. Other studies developed techniques for studying the wild turkey and described its requirements for winter range and brood rearing habitat.

When the Morgantown and Amherst wildlife units were combined in 1982 under the direction of Richard DeGraaf, research was expanded to include New England's oak forests. Studies of the relationships among timber harvest, understory development, and small-mammal abundance revealed that gypsy moth defoliation along with annual variation in acorn crops greatly influenced the dynamics of oak ecosystems. This discovery led to joint research by which scientists discovered important interactions among acorn crops, small mammals, and gypsy moth populations that may be useful in predicting gypsy moth outbreaks.

Wildlife habitat research was a substantial part of the CANUSA program in Maine. This research, conducted from 1978 to 1991, resulted in important advances in our knowledge of predation by birds on spruce budworm. In 1991, the Amherst wildlife unit broadened its research to address the effects of forest management and global change on amphibians. Included were studies of both terrestrial red-backed salamanders and aquatic-breeding, temporary pond species and their habitats. Another new research area begun in 1994 involves the early life history of Atlantic salmon, which once thrived in the Connecticut River and Merrimack River drainages. In 1995, scientists at Amherst also began analyzing people's



The hemlock woolly adelgid poses a new threat to northeastern hemlock forests.

perceptions, values, and sentiments concerning wildlife resources. In 1996, researchers investigated wildlife resource and habitat relationships in hemlock-dominated forests in response to concerns about the damaging effects of the hemlock woolly adelgid. Today, wildlife habitat research is conducted as part of silvicultural research projects at Durham, Warren, and Parsons, and wildlife habitat resource tables are now included in state resource bulletins

generated by the Station's Forest Inventory and Analysis unit.

Forest Management

Forest Genetics

Some of the most significant hardwood breeding programs in the world have been conducted at the Northeastern Station. Ernie Schreiner initiated a poplar hybridization project in 1934 that was the

first large-scale breeding project devoted exclusively to the improvement of forest trees. Following Schreiner's retirement in 1970, Peter Garrett continued the genetics research program at Durham. A number of NE clones are still widely planted around the world. Jonathan Wright, author of the first textbook on forest tree improvement, and Frank Santamour, currently with the National Arboretum, did pioneering genetics work with pine, spruce, birch, oak, and other species. In 1959, provenance trials with eastern white pine provided valuable information on growth rates and hardiness of seed sources across the natural range of this species. Later work by Ron Wilkinson provided information on weevil resistance in several white pine species. In 1963, Silas Little started the first large-scale interspecific hybridization program with pines at New Lisbon, New Jersey. Millions of his pitch $\times$ loblolly hybrids are planted each year on industrial, state, and national forest lands.

In 1962, William Gabriel at Burlington began searching for maples with high sap-sugar concentrations. This program was expanded into a general study of the species that included progeny and provenance trials. This work is continuing at Ohio State and Cornell Universities. The genetics project at Durham was terminated in 1985, though a research unit there continues to monitor many of the plantings, which should prove valuable in long-term studies on atmospheric deposition and global change. Current tree-improvement work by Station scientists is concerned with the development of cold hardiness, herbicide tolerance, and pest resistance through molecular technologies. This work is being directed by James Slavicek at the Delaware laboratory.



A major emphasis of research on mined-land reclamation at Berea, Kentucky, was revegetating mined sites to enhance aesthetic appeal, slow erosion and stream siltation, and return mined land to productivity. This pitch x loblolly hybrid pine is one of several species evaluated on surface-mine spoil.

Northern Hardwoods

Research on northern hardwoods has been conducted at Durham under the supervision of William Leak, Stanley Filip, Carl Tubbs, and Peter Garrett. The early to mid-1970's marked the beginning of a new era in timber management throughout the United States. In 1962, most commercial forest land in the National Forest System was under even-age (clearcutting) management. By 1975, however, increasing concerns by environmentalists over the alleged

overuse of clearcutting led to a shift toward uneven-age systems and was the driving force behind the Station's research on northern hardwoods in New England.

Initial concerns related to this switch to uneven-age management was regeneration. It was well-known that single-tree selection provides opportunities for trees to reach their optimum biological/financial condition, but also that regeneration could be good (sugar maple, ash, and

spruce) or less than desirable (beech and red maple). To address this problem, the White and Green Mountain National Forests in collaboration with the Station developed a series of land-capability studies to determine the influence of soils, landform, and vegetation on successional processes, eventually leading to the concept of the ecological land types and forest habitats that comprise the smaller units in the hierarchical ecological classification system now being advocated nationwide.

In northern hardwoods in New England, the logical alternative to clearcutting was group selection at a scale small enough (openings up to 1 acre in size) to qualify as uneven-age management. Previous research showed that group selection produced excellent regeneration and provided a means for concentrating the cut on mature/defective groups of trees. Several years of practice on National Forest System lands provided efficient ways to mark stands under group-selection systems. Some practitioners began making greater use of shelterwood systems in northern hardwoods, borrowing from experience in the Great Lakes area. However, stand damage was a problem in certain areas, and the final removal cuts looked suspiciously like clearcuts. Greater emphasis was placed on deferred shelterwoods, borrowing from research in the Appalachian region, where a minimal volume is left standing after the preparatory or seed cuts. These trees are not removed until the first commercial entry into the newly regenerated stand—perhaps 50 or more years later.

The scientific response to the movement away from clearcutting in northern hardwoods came from wildlife research showing that unbroken

forest canopies provide necessary habitat for only a limited number of wildlife species. In particular, many neotropical migrant birds (some apparently declining in abundance) require openings (clearcuts), sometimes large ones. The current wisdom is that wildlife diversity is maximized in landscapes containing a sustainable range in forest types; stand age classes; forested and nonforested openings; water sources; and within-stand features such as midstory layers, woody debris, mast, and ground cover. Watershed research and aesthetic considerations have provided a means for designing clearcuts that are environmentally sound components of a productive landscape. Today, this landscape approach to multiresource management is known as ecosystem management.

Allegheny Hardwoods

Most organizations that manage eastern hardwood forests, including the National Forest System, switched to even-age silvicultural systems in the 1960's following research that showed that other methods failed to regenerate shade-intolerant species such as black cherry, yellow-poplar, and paper birch. In most hardwood types, even-age systems worked well. However, this was not true in the Allegheny hardwood forest. Many years of excessive deer browsing had altered ecological succession in this forest type, leading to a buildup of interfering understory plants and direct damage to tree seedlings. As a result, forest regeneration failed to develop under any management scheme.

The Station's laboratory at Warren was reorganized in the early 1970's to attack this problem. The multifunctional timber and wildlife research unit established there, led by David Marquis and later Susan Stout, eventually became

one of the Station's largest. Scientists at Warren were able to:

- ◆ Document the adverse effects of deer browsing on forest regeneration and understory development.
- ◆ Determine deer population levels that were compatible with various intensities of forest management.
- ◆ Devise methods to protect regeneration from browsing damage.
- ◆ Develop herbicide treatments to control interfering understory plants.
- ◆ Formulate silvicultural techniques to secure successful regeneration under a wide range of conditions.

Many of these silvicultural techniques are used widely throughout the Allegheny region and beyond. By analyzing the regeneration potential of individual stands, forest managers can choose the most appropriate treatment, for example, shelterwood cutting aimed at circumventing deer browsing, shelterwood in combination with herbicide treatment of the understory, or two-age management schemes. In addition, the attention focused on deer browsing has resulted in efforts by state wildlife agencies to establish deer population goals and reduce herds to levels compatible with sustainable forestry.

Scientists at Warren also conducted experiments to determine thinning regimes and management strategies for optimizing sawtimber and value growth in this forest type, which is dominated by fast-growing, high-value species such as black cherry, white ash, red oak, and maple. A major accomplishment was the development of stocking guides that recognized that different species

require different amounts of growing space and provided an accurate means of evaluating stand density in mixed stands. Another accomplishment was the recognition that partial cuttings of any kind must control stand structure and species composition as well as density to achieve desired objectives. This was followed by the development of practical techniques for prescribing and controlling structure as part of the management process. By reopening stand-culture experiments from 1930's research and combining long-term data with new studies, researchers were able to develop a computer stand-growth simulator that enables foresters to compare a variety of management strategies on specific stands and develop a complete set of management guidelines for existing stands.

Perhaps the most significant accomplishment of the Warren unit in the 1970's and 1980's was the synthesis of all the research knowledge accumulated over the years into a stand-analysis and prescription procedure called SILVAH. With this system, scientists are able to collect data on stand and site factors and then use this information to analyze a stand's potential for growth and regeneration. In combination with a set of decision tables or charts, the analysis is used to select the most appropriate silvicultural treatment for the stand that meets specific landowner objectives. A computer program by the same name automates much of the process and combines it with the stand-growth simulator to provide a complete decision tool for forest managers (see Technology Transfer).

Appalachian Hardwoods

Research on Appalachian hardwoods was conducted by scientists at the Parsons laboratory

on the Fernow Experimental Forest. This work was directed by Richard Trimble and later H. Clay Smith. The mid-1970's to the mid-1990's was a period of intense public and political interest in the management of hardwoods in the central Appalachian region. This interest led to efforts by Station researchers to develop practical guidelines for managing and reproducing central Appalachian hardwood stands for a range of products, benefits, and landowner uses while maintaining the quality and diversity of the hardwood resource. This was a difficult challenge because the forests of the central Appalachians are noted for their variability in topographic features, growing sites, accessibility, ownership patterns, and land-use history. The existing forest stands have been greatly influenced by past logging, agriculture, and fire, and there are a variety of tree species with different biological requirements.

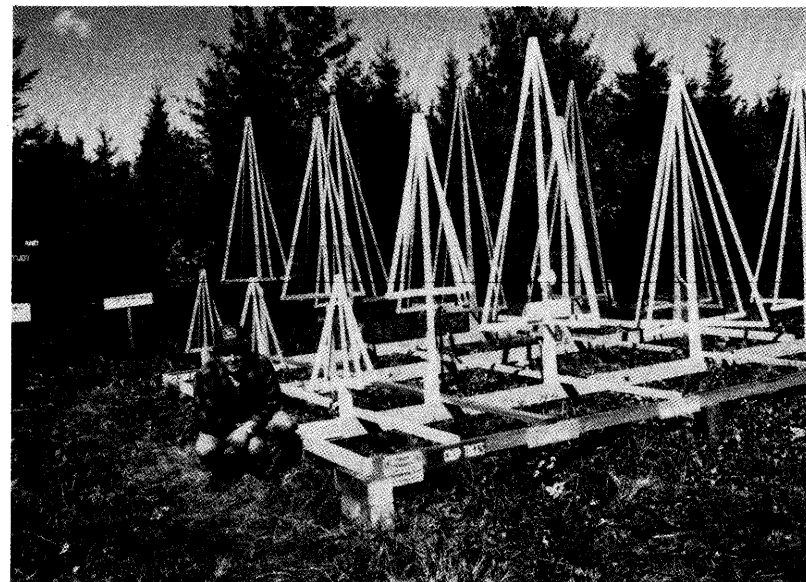
During the 1970's, research objectives were to develop silvicultural guidelines for central Appalachian hardwood stands that emphasized the production of high-quality sawtimber products. These objectives were later modified to emphasize the production of wood products in conjunction with other resource uses and benefits and that recognized multiple landowners objectives. In 1994, the forest and watershed management projects at Parsons were combined. The new project's objectives were to explain the role of natural and human-induced factors on the sustainability of the central Appalachian forest ecosystem and provide guidelines for managing this valuable resource for a range of products and benefits while maintaining the productivity and diversity of the soil, water, and other values. Scientists also developed guidelines for controlling

grapevine and managing crop trees, as well as alternatives to clearcutting and single-tree selection practices.

Spruce-Fir

The spruce-fir forests in the East are found in northern Maine, northern New Hampshire, the Adirondacks of New York, and to a lesser extent the mountains of the southern Appalachian chain. This forest type is one of the most important not only because of wood products it generates but also because its water, recreation, and wildlife resources are enhanced by their proximity to large population centers. A stand is classed as spruce-fir if a majority of the trees in the overstory are red, white, or black spruce and balsam fir. Northeastern spruce and balsam fir are shade tolerant and survive many years under a dense tree canopy.

Research on this forest type has been conducted by scientists at Orono led by Barton Blum and later John Brissette. Since the 1980's, this multifunctional research unit has focused on the need to refine silvicultural techniques and evaluate predators of the spruce budworm in the context of silvicultural systems. The goal was to accurately predict growth and yield responses to silvicultural systems and spruce budworm damage, soil fertility, site productivity, and the nutrient requirements of major species. The relationships among

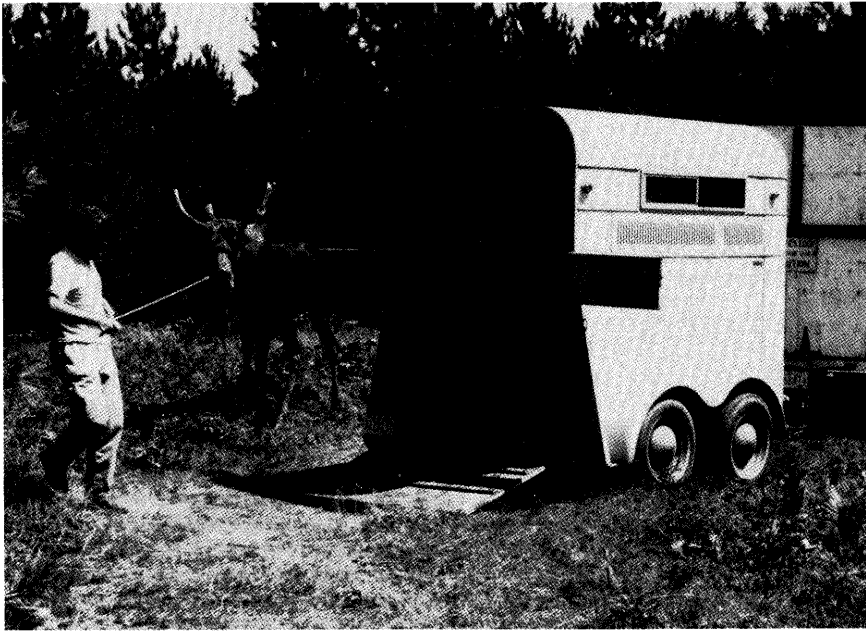


Three-dimensional model illustrates growth responses of red spruce and balsam fir 10 years after spacing on the Penobscot Experimental Forest.

silvicultural prescriptions, spruce budworm damage, and wildlife habitat were also studied. The Orono unit also was the Station's lead member of the CANUSA program. Much of the unit's research was conducted on the Penobscot Experimental Forest. Since 1994, the forest has been managed jointly by the University of Maine and a Station unit formerly located in Bradley and now in Durham. The Penobscot is the focus of the unit's technology transfer efforts and regularly hosts visiting professional and academic forestry groups from New England.

Sugar Maple

The Station launched a sugar maple research program in 1956 to increase maple sap production



A bull moose is loaded into a horse trailer for transport to a spruce-fir research study area. Moose have been used to determine forage selection and plant nutrient values on disturbed forest sites.

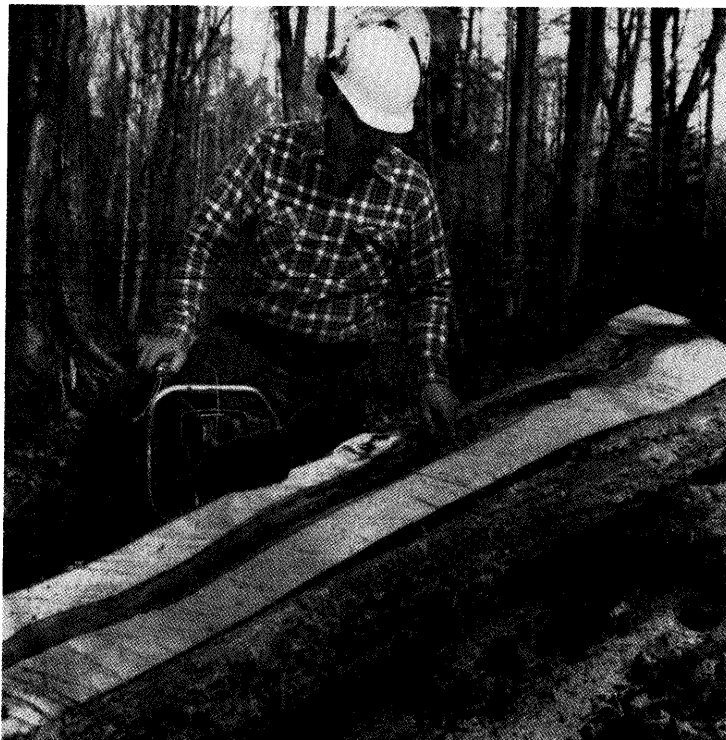


This environment station in a sugarbush is used to monitor solar radiation, soil temperature, sapflow and tree pressure, snow depth, windspeed and direction, soil moisture, humidity, temperature, atmospheric pressure, and precipitation.

through silvicultural manipulation and genetic improvement. In 1969, the program was expanded because maple syrup production continued to decline despite the high demand for syrup and a steadily increasing inventory of sugar maple trees. Competition from Canadian producers was perceived as a risk to the industry because the U.S. tariff on imported maple syrup products was scheduled to be abolished in 1972. Scientists expanded studies on sugar maple genetics, propagation techniques, and sap collection

methods, and initiated new research on maple products marketing, cost of sap and syrup production, and methods of syrup production. The expansion culminated in 1973 with the dedication of the George D. Aiken Sugar Maple Laboratory in Burlington. A strong cooperative program in syrup production technology developed between Station scientists and researchers at the University of Vermont. Research results were quickly transferred to the industry through frequent workshops, meetings, and

publications, and in 1975 resulted in the establishment of the International Maple Syrup Institute through which the maple products industries in the United States and Canada promoted their products and funded new research. In 1982, the Station published "*Sugar Maple Research: Sap Production, Processing, and Marketing of Maple Syrup*," which summarized results of sugar maple research conducted by scientists at Burlington.



Northeastern Station scientists revised the century-old theory of the decay process in trees. Their extensive research involved the dissection and study of thousands of trees.

Forest Protection

Decay and Discoloration

Alex Shigo, a senior scientist, and his research team at Durham conducted pioneering research on the discoloration and decay in living trees, studying the decay process and genetic resistance to decay and developing procedures to prevent tree decay. Significant accomplishments of this project included the development of a concept that describes a process by which an injured tree develops boundaries to resist the spread of pathogens, and a

model called CODIT (Compartmentalization of Decay in Trees) that depicts the process. Shigo's research, which entailed the dissection and study of thousands of trees, revised the century-old theory of decay in trees. He also developed a technique to evaluate the relative vigor of trees and the condition of wood by interpreting patterns of electrical resistance with a pulsed-current meter called the Shigometer. The latter has been used to determine the presence of decay in utility poles, the relative vigor of trees in plantations and urban environments, the presence of hazard trees in urban and recreation environments, the growth potential on spruce-fir sites, and the decay resistance and durability of wood (see Technology Transfer).

Insect Research

During the past 25 years, the Station's insect research has been focused primarily on gypsy moth, European elm bark beetle, and spruce budworm. Other insect research was conducted at the Hamden and Delaware laboratories. Before gypsy moth became the primary focus of research at Hamden, some research was conducted on white pine weevil and the impact of defoliating insects on northeastern forests. At Delaware, scientists studied the European pine



A trap baited with elm bark beetle pheromones is being installed in a field study at the Delaware, Ohio, laboratory.

shoot moth, but the emphasis was on insects that damage or otherwise affect the regeneration of high-value hardwoods—the red oak borer, acorn weevils, insects that transmit oak wilt, and those that degrade black cherry.

Dutch Elm Disease

Research on Dutch elm disease was carried out at Delaware by work units led by Tom Jones, John Peacock, and Garold Gregory. Research on the sex attractant of the European elm bark beetle led to the development of a patented formulation, Multilure, which was evaluated as a tool for surveying bark beetle populations. Multilure-baited traps proved effective in surveying beetles in areas where their presence was unknown. Although the attractant-trapping system trapped hundreds of thousands of beetles yearly at numerous locations, it was ineffective in reducing the incidence of Dutch elm disease in any of the study areas.

However, studies on the use of systemic fungicides to control Dutch elm disease culminated in the development of a fungicide injection system that can be used in the prophylactic and therapeutic treatment of American elms. Prophylactic injection of the systemic fungicide Lignasan BLP® resulted in a significant reduction in disease rates, and therapeutic injections of Lignasan into diseased elms in conjunction with the early removal of symptomatic branches greatly increased the survival of diseased trees. Recent studies have focused on bacterial isolates that inhibit the activity of the Dutch elm disease pathogen. An antifungal isolate of *Bacillus subtilis*, first reported in 1988 and recently identified as *Bacillomycin L_c*, has inhibited the disease fungus in the laboratory.

Studies with the insecticide methoxychlor have demonstrated its efficacy in preventing feeding by bark beetles on healthy elms. The average incidence of Dutch elm disease remained stable in



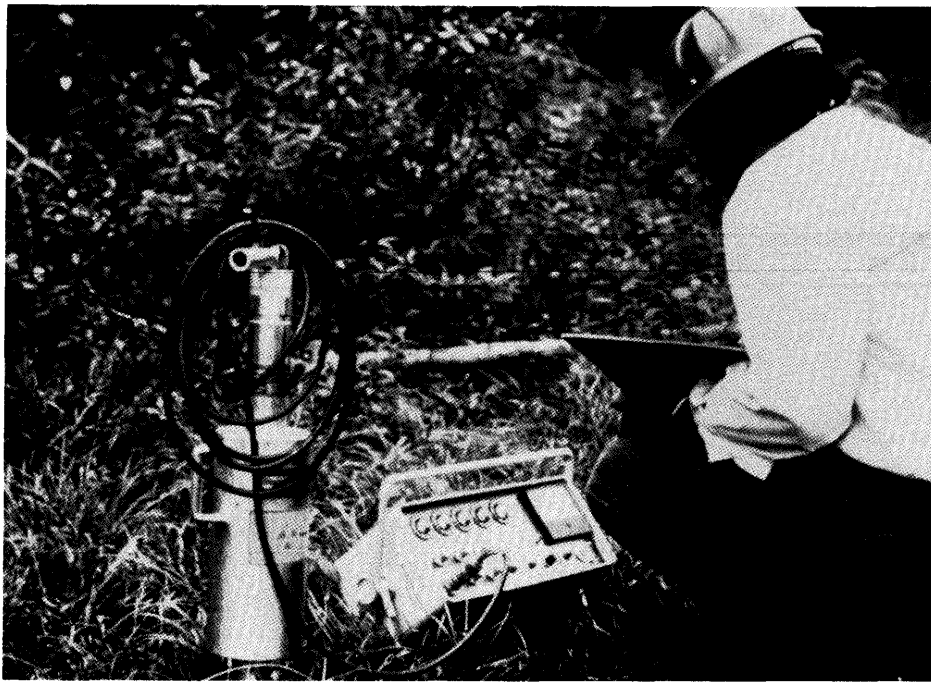
Open-top growth chambers are used to study the impact of air pollutants on tree growth at the Delaware laboratory.

areas sprayed with methoxychlor, whereas disease levels rose in untreated control areas. Variation in spray coverage was a significant factor in the degree of disease control.

Air Pollution, Atmospheric Deposition, and Global Change

Research on the effects of air pollution, atmospheric deposition, and global change on forest health has been carried out by work units at Delaware led by Leon Dochinger, Keith Jensen, and Robert Long. In the early 1960's, evidence was mounting that environmental damage was occurring because of industrialization and the

rapid expansion of the nation's transportation system. This evidence included leaf and needle chlorosis, early leaf and needle abscission, and reduced growth in eastern white pine. Numerous white pine seedlings in Christmas tree plantations in central Ohio exhibited these symptoms and were identified as having "chlorotic dwarf disease." Over a period of 10 years, studies documented that air pollution was the cause of this disease. This research was the beginning of the Northeastern Station's program to investigate the impact of environmental pollution on forest ecosystems.



Equipment used to measure soil moisture in Allegheny hardwood studies on the Kane Experimental Forest.

Researchers next focused on determining the susceptibility of a wide range of tree species to air pollution. The objective was to identify the tree species that could be planted in areas with polluted air. By selecting tolerant species, the cost of tree replacements in cities could be reduced significantly. Scientists also studied the effect of ambient levels of air pollution on the growth and seedling health of various forest species. This research revealed that even very low levels of pollution can reduce growth. This information has been used extensively by the EPA in establishing and supporting National Ambient Air Quality Standards.

By the early 1970's, another environmental stress related to air pollution, acid deposition, or acid rain, had been identified. Acid rain forms when pollutants such as sulfur dioxide and nitrogen oxide combine with water in the atmosphere. The initial questions about acid deposition were: How acidic is rain? and Is it getting more acidic? The Station played an important role in answering these and other questions. The only historical data available on the acidity of rain in the Northeast have been collected at Hubbard Brook Experimental Forest since 1963. These data provided the preliminary basis for the acid

deposition program that followed (see Watershed Management/Ecosystem Research).

The Station operates four long-term monitoring sites that were established in 1978 when the National Atmospheric Deposition Program was initiated. They are located at Delaware, Parsons, the Kane Experimental Forest in Pennsylvania, and Hubbard Brook Experimental Forest. These and other sites in the monitoring network have identified the regions that are most affected by atmospheric deposition and how deposition has changed over time. The National Dry Deposition Network, designed to monitor the effects of dry deposition, was established in 1988 and includes sites at Parsons and Hubbard Brook.

By the early 1990's, research on air pollution or atmospheric deposition changed again with the recognition that these pollutants may be affecting the world's climate. This led to the establishment of the Global Change Program, which was concerned primarily with the impact of air pollutants on forest ecosystems and the possible effects of global warming on forests. Another issue that resurfaced in 1996 is the impact of atmospheric deposition on forest soils. Preliminary studies suggest that nutrients are being leached from the soil in areas of high deposition. This process also may be playing an important role in the decline of maple species.

Calcium Depletion

During the early 1980's, there was growing public concern about the impact of air pollution on the health of forests in the Eastern United States and in much of Europe. The threat of acid deposition was of particular interest to the Northeastern



Electron micrograph of a pitch pine needle from a seedling in an aluminum toxicity study. Visible are the tonoplast, plasma membrane, separations in chloroplast membranes, and disrupted cytoplasm.

United States and the Federal Republic of Germany because of the low nutrient status (base cations) of northern coniferous forests. To address this concern, the Northeastern Station and the University of Hamburg initiated a joint research project in 1984. The group's working hypothesis was that aluminum, the most common metal cation in the mineral soil beneath the forest floor of much of the spruce-fir forests, was being mobilized and exchanged with calcium and magnesium on binding sites in forest-floor materials, especially the nonwoody root tips that absorb essential nutrients from the floor. Replacing calcium and magnesium with aluminum leads to growth suppression of roots.

Roots that cannot move into new areas of the forest floor to absorb nutrients soon starve and die, making conditions favorable for attack by pathogens. Loss of roots below ground leads to premature shedding of needles in the crown to reduce water loss from trees with a shrinking root system. Cambial activity becomes suppressed as roots and shoots are lost. Less wood and bark is formed, which reduces the transport, storage, and defense functions of these tissues in mature trees. Stress increases steadily in mature trees during periods of environmental change until a new balance is reached or until life systems fail and some of the mature tree

population dies. Mortality relieves stress within the stand and regeneration begins among the survivors.

In 1988, an innovative research effort by Shortle, Kevin Smith, and Rakesh Minocha at Durham and by cooperating scientists confirmed this hypothesis. This research has helped show how acid deposition might be linked to the essential base status of the floor of northern coniferous forests.

Stress-Induced Diseases

For the past three decades at the Hamden laboratory, David Houston and Philip Wargo have spearheaded research on the ecological and physiological nature of the causes, patterns of occurrence, spread, and development, and management of forest tree diseases, particularly those initiated by stress. Ecological and physiological studies of such diseases—the diebacks and declines—have spawned a conceptual model or framework for investigating and describing the chronology of the events, interactions, and consequences involved when trees affected adversely by environmental stress are attacked and killed by opportunistic organisms.

Early on, scientists unraveled the complex etiology of a lethal basal canker disease of white pine that occurred in plantations established on abandoned farmland on the Tug Hill Plateau in New York. The disease resulted when bark that was damaged by secretions of formic acid by the black meadow ant and by snow and ice was invaded by bark-killing fungi. Researchers at Hamden also investigated how forest trees that are stressed by

such factors as defoliating and sucking insects, drought, or air pollutants were rendered susceptible to attacks by secondary-action organisms, for example, root and twig pathogens and bark borers. In a series of studies, scientists were able to:

1. Develop predictive models of stand susceptibility to gypsy moth defoliation.
2. Characterize the anatomical and physiological responses of sugar maples defoliated by the saddled prominent and of oaks defoliated by gypsy moth.
3. Relate these defoliation-triggered host changes to the requirements of and lethal attack by the root rot pathogen *Armillaria* spp.

It was learned also that when defoliation and drought stresses occur simultaneously or consecutively, mortality rates can increase dramatically, and that disturbance by harvesting just before or after defoliation episodes can markedly increase mortality—presumably by causing increases in the amount and vigor of *Armillaria* in oaks and the abundance of twolined chestnut borer. A practical output of work with defoliation-triggered declines was the development of a visual field method for assessing the content of root starch. With this method, forest managers can accurately risk-rate trees and stands stressed by defoliation.

The lethal vascular disease of sugar maple known as sapstreak was investigated as part of the maple decline complex. It was found that sapstreak disease is strongly associated with human activities. Studies revealed that most diseased trees are located adjacent to haul roads or skid trails

and that injuries to root and buttress roots of trees—but not tapholes—are the primary infection sites. It was found that the sapstreak pathogen can move from diseased to healthy trees through root grafts, that the disease can be detected in roots of nonsymptomatic trees by measurements of electrical resistance, and that trees infected by the sapstreak pathogen rarely succumb unless they also are infected by *Armillaria* spp. or *Xylaria* sp.

A long-term program of research was conducted on beech bark disease (BBD), which results when bark is fed upon by the introduced beech scale insect (*Cryptococcus fagisuga*) and predisposed to attack by the bark-killing fungi *Nectria galligena* and *N. coccinea* var. *faginata*. The disease continues to spread south and west from Nova Scotia, where the scale was introduced. Studies showed that in long-affected forests, defect-causing bark cankers accumulate slowly on young trees as they invade forests where the scale and fungi are present. The rate of canker production is correlated with periods of extreme winter cold and heavy autumn rainfall that presumably adversely affect scale populations.

Studies of possible biological control agents showed that a mycoparasite of *Nectria* spp., *Nematogonium ferrugineum*, is found in a high percentage of *N. galligena* cankers on other hardwood species, and often on beech trees with BBD. Although *Nectria* artificially infected with this mycopathogen produced small cankers bearing few spores, the pathogen is not effective in reducing the disease in nature. Not only can the mycoparasite attack both *Nectria* species but also the *Nectria* species can attack scale-infested beech and cause BBD. In outbreaks occurring in advance of the disease front, the native *N.*

galligena can build up and cause BBD. However, when *N. coccinea* var. *faginata* arrives, it gradually replaces *N. galligena* in the pathosystem. Population genetics studies indicated that *N. coccinea* probably was introduced, most likely along with the beech scale.

When spruce decline in high-elevation montane boreal forests was studied as part of the NAPAP program, researchers found that decline, especially in the higher elevation stands of red spruce, was not associated with *Armillaria* even though this root disease was severe in low-elevation stands. Also, the occurrence and abundance of *Armillaria* in these high-elevation stands was significantly less than in lower elevation stands. The decreases were associated with high levels of lead in the forest floor, the result of atmospheric deposition.

Diseases of High-Value and Other Hardwoods

In addition to the disease research being conducted at Durham and Hamden, three work units at Delaware were studying vascular diseases of trees, particularly Dutch elm and oak wilt diseases discussed earlier, virus and mycoplasma diseases of trees, and diseases of high-value hardwoods. The latter research culminated in 1983 with a guide and handbook for reducing decay losses in high-value eastern hardwoods (oaks, cherry, maple, ash, birch, and black walnut). The 1980's also were marked by renewed interest in chestnut blight following the discovery of a hypovirulent strain of the pathogen. The Station participated in a cooperative research program with West Virginia University that was coordinated through the silviculture unit at Parsons.

Forest Products and Harvesting

Forest products research was conducted at Burlington, Princeton, and Columbus, Ohio. The latter unit moved to nearby Delaware, in 1975. Engineering research was conducted in Morgantown.

Log and Tree Grades

The Delaware unit, led by Robert Brisbin, focused much of its research on developing systems for predicting volume and weight yields of lumber, veneer, ties, and pulp chips from mature timber. This unit developed widely adopted log and tree grade methods and completed its work in 1982.

Timber quality can be defined as a composite of tree and wood characteristics that makes a tree useful for one or more products. Systems for measuring timber quality are important for extending the timber resource because they can be used to determine the optimum use of a tree or stand, predict volume yields of end products, and determine tree or stand value based on predicted end-product yields.

Quality classification of mature trees and logs.—The Northeastern Station's hardwood log and tree grade research was organized in 1966. Initial efforts were concentrated on refining Forest Service hardwood log grades that were developed in 1949. The unit's work resulted in a guide to hardwood log grading that was published in 1973 and lumber grade-yield tables for 18 hardwood species that were published in 1980. The tables provided average percent lumber-grade yields by species and log-scaling diameter. The log-grade and lumber-yield information has been used by the National Forest System to determine the potential value of timber sales.

Because log grades and associated lumber-grade yields are difficult to apply to standing timber, researchers began work on developing tree grades for predicting factory lumber yields. As a result of this research, a grading system was developed that separates trees into high-, medium-, and low-quality groups on the basis of predicted lumber-grade yield. In addition to equations for predicting lumber yield, equations were developed for estimating cubic-foot yields of lumber, sawdust, and chippable residue from the sawing process. These equations, coupled with those for lumber yield by tree grade, provide a more complete evaluation of the volume of products that the sawtimber portion of a tree yields when it is converted to lumber.

Detailed studies of defect overgrowth indicators also were conducted to document their effect on underlying wood quality. This information was summarized in a number of publications, including the USDA Agricultural Handbook "Defects in Hardwood Timber." In another series of studies, multivariate regression techniques were used to develop estimates of lumber-grade yield by species and log grade.

Once research was completed on the relationship of tree and log quality to end-product yields, work began on integrating these models into a form that can be used to predict volumes and values from the tree through mill processing. The Forest Resources Systems Institute awarded Station scientists a grant to develop microcomputer software that could be used by woodland owners, wood-processing managers, timber buyers, and utilization specialists to appraise timber, maintain mill inventories, and predict product output. Research was conducted to model the

relationships among the quality prediction equations so that consistent predictions of product volume and quality could be obtained from the timber stand to the final primary product. This research resulted in an integrated software package that estimates end-product yield and value from timber-cruise or scaled-log data.

Quality classification in young timber stands.—When timber production is important in managing hardwood stands, the objective is to produce high-value sawlogs and veneer logs in the shortest possible time. To accomplish this objective, the growth rate must be increased and the quality potential at harvest must be maintained or improved. For medium- and high-value hardwood stands, quality change over time is as important as changes in volume growth because of the variability in value of potential end products. Researchers investigated different potential quality-related tree characteristics and examined their occurrence and variation in natural and culturally treated young stands. This research showed that thinning treatments significantly affected the number and size of limb-related defects in the more valuable portion of hardwood trees. Also, research results for central hardwoods showed that thinning more than 40 percent of the stand basal area can be detrimental to potential quality because the development of epicormic branches is stimulated and the crown ratio of the trees increases.

Low-Grade Hardwood Utilization

At Princeton, a unit led by Charles Gatchell focused on the utilization of low-grade hardwoods, developing efficient utilization systems and methods for processing low-grade hardwoods into high-value end products. In conjunction with this research, the

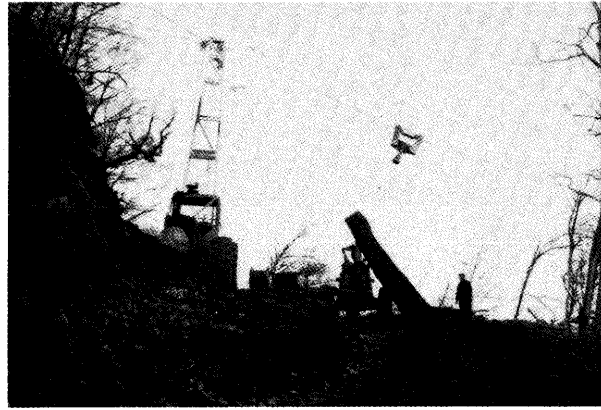
unit developed information on the influence of ripping width on yield for gang-ripping low-grade lumber and systems for manufacturing panel products from low-grade lumber using a process called Serpentine End Matching (see Technology Transfer). Generally, low-grade logs could not be

converted to lumber at a profit, and low-grade lumber could not be economically processed into parts with conventional technology. This work led to the System 6 technology to produce high-quality furniture and cabinet parts that has been adopted widely by industry (see Technology Transfer). As this

research program evolved, new studies focused on economical integrated conversion systems from the sawmill log deck through the rough deck and quantitative and qualitative yields of high-value product parts.

Scientists at Princeton also developed computer programs that generate production cost information and simulate general rough-mill operations (MILLSIM), determine requirements for blanks (BLANKS), and simulate operations of hardwood sawlog sawmills (DESIM). In 1989, under the direction of Robert Brisbin and later Jan Wiedenbeck, researchers next focused on improved processing technology for hardwoods. They developed techniques for evaluating production economics, procedures, and test criteria for evaluating computer numerically controlled machinery and tooling. This unit also produced valuable information to help purchasers

make more informed decisions on investments in automated woodworking machinery, established a decisionmaking process for wood-products manufacturers to respond quickly to customer demands, developed modeling and decision-support tools for a rough-mill gang-rip-first simulator (ROMI-RIP) and a compatible, crosscut-first simulator (ROMI-CROSS), and created an on-line data base that could be accessed interactively to respond to queries by industrial managers and technical personnel.



Cable logging research engineering units at Morgantown, West Virginia, emphasizes harvesting applications on steep terrain in eastern hardwood forests.



Forest Engineering

Forest engineering research has made significant progress in developing stump-to-mill, logging-cost estimating software for cable logging systems. Since 1973, several cable yarders have been studied and their productivity and cost documented by the engineering unit at Morgantown led by Harry Gibson and later Penn Peters. Studies showed that cable logging technology can be used to harvest hardwoods on steep terrain, reduce the amount of forest roads needed, and minimize the effects of logging on soil and site. About 26 percent of the forested land in the 14-state region of the southern Appalachians is located on side slopes that exceed 30 percent.

Also at Morgantown, a research unit directed by Chris LeDoux integrated time study data into an efficient, user-friendly computer program (ECOST) that estimates the productivity and cost for several small, medium, and large cable yarders operating under a range of forest site and stand conditions. This program also is currently being used by the National Forest System, private industry, and university customers. ECOST also was used for assessments of timber supply and demand by the Forest Service's Southern and Eastern Regions.

Other research results suggest that a substantial area and volume of the southern upland hardwood forests on slopes of 30 percent or greater can be logged profitably with cable technology, and that medium-size yarders should be used to maximize profitability.

Researchers also found that contemporary harvesting practices require the use of silvicultural treatments such as single-tree and group selection, shelterwood, and thinnings, and documented

operational efficiencies, cost and productivity, and soil/site effects of alternative cable and ground-based machines. Research continues on computerized systems for estimating cost, productivity, and site impact for such silvicultural treatments that will result in more economical logging operations.

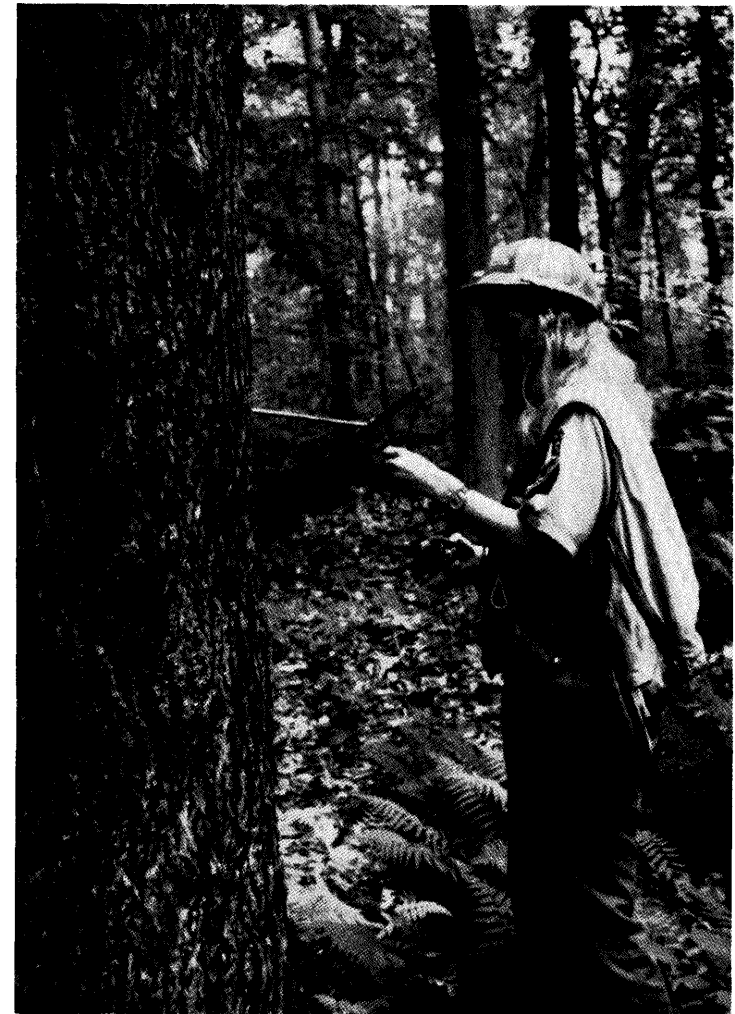
As part of efforts to integrate harvesting with resource management, scientists at Morgantown also have developed a computer program called MANAGE to estimate the costs and benefits of managing hardwoods, and an expert system called FOREX that integrates harvesting information with other resource management objectives in a decision-support system.

Resource Analysis Research

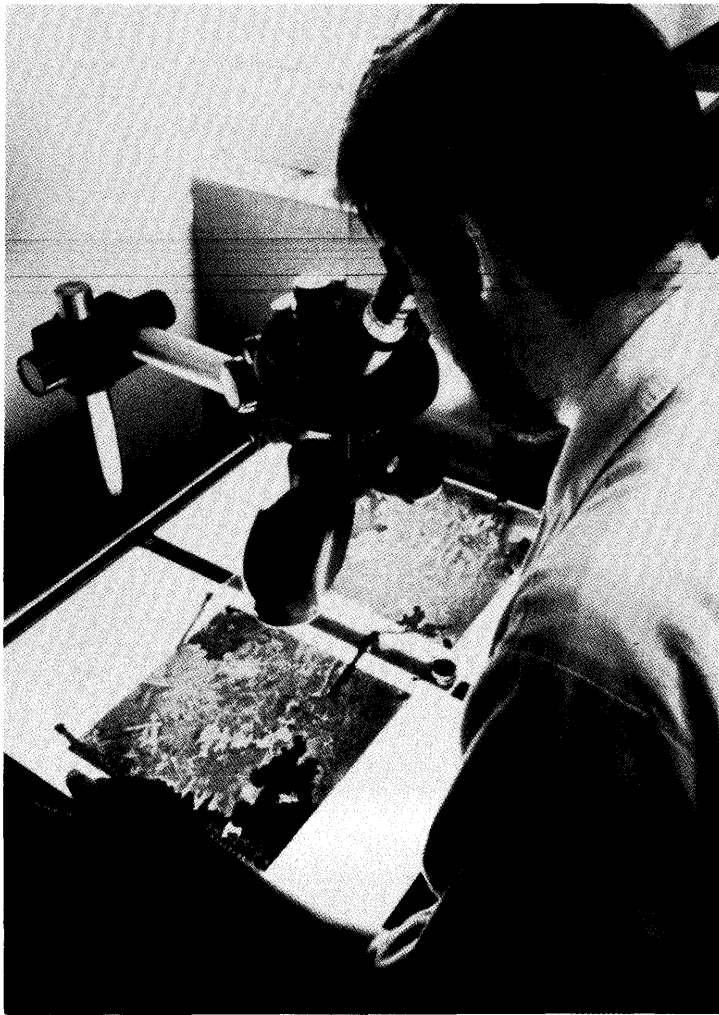
Forest Inventory and Analysis

The McSweeney-McNary Act of 1928 authorized an appropriation of \$3 million to inventory the forests of the United States and its territories and possessions. The Secretary of Agriculture delegated the mission to the Forest Service, which, in turn, delegated the work to its experiment stations. The first inventories or forest surveys were completed in the Lake States.

The Station's forest survey unit was formed in 1946 under the direction of Frank A. Ineson, Chief of the Division of Forest Economics, who



Field data are collected by members of the Northeastern Station's forest inventory unit.



Interpretation of aerial photography is a critical part of the forest inventory process.

had oversight of two inventory units within Station territory—the Northern Project (led by Karl D. Henze) and the Southern Project (led by Carl J. Holcomb). The Northern Project worked

in Elk, Forest, McKean and Warren Counties in Pennsylvania; the Southern Project worked in Pendleton, Pocahontas, and Randolph Counties in West Virginia. In 1947, Harry W. Camp replaced Henze. Field work continued in West Virginia and commenced in New Hampshire. The first statewide survey reports were issued in 1952 and were coauthored by John McGuire, who later would become the 10th Chief of the Forest Service. Norman Griswold replaced Camp and was succeeded by Carl Mayer, who led the Forest Survey unit from 1958 to 1980. Joseph Barnard held the position from 1980 to 1985 when he was succeeded by John Peters.

Until 1973, inventories were focused almost entirely on timber resources. Since then, several laws enacted by Congress, especially the Renewable Resources Planning Act of 1974, have called for information on other renewable forest resources in addition to timber. As a result, the name of the Forest Survey unit was changed to Renewable Resources Evaluation and then to Forest Inventory and Analysis (FIA). To improve efficiency and address new information needs, FIA used several sampling methods and

field plot designs, and developed landowner studies that associate owner attitudes and objectives with the resource base. The project works closely with other regional FIA units to develop standard sampling protocols, data bases, and information retrieval systems.

In 1999, all 13 states now served by the Northeastern Station will have been inventoried four times, and three states will have been surveyed five times. It has been standard practice to seek cooperation from and partnerships with state and other federal agencies to provide more precise forest statistics more frequently. New technology, equipment, projection models, and cooperative ventures are revolutionizing the inventory from planning to analyzing data to getting information to those who need it.

Economics and Marketing

Research on forest economics and marketing was conducted primarily at Delaware, Princeton, Burlington, and Station Headquarters. The Delaware unit, led by David Worley, evaluated forest management alternatives in hardwood stands of the Northeast, income potentials from managed hardwood stands, value and price information needed to plan forest protection programs, and forest management for nontimber uses. Data were generated that integrated economics and silviculture such that small-woodland owners were able to determine rates of value increase and financial maturity of trees, the cost effectiveness of management practices, and methods for assessing the economic impacts and risks associated with forest insect pests. The work of this unit was completed in 1982.

At Headquarters, a unit led by David Gansner was concerned primarily with regional forest resource economics, studying trends in forest resource use and availability and developing guidelines for selecting among management alternatives and competing uses of the forest resource. This unit also analyzed the structure and changes in northern forest industry, trends in recreation, the

effectiveness of federal Cooperative Forestry Assistance programs, the economic potential of pitch $\times$ loblolly pine hybrids, and cutting opportunities in oak-hickory forests. Especially important was research that enabled managers to assess and predict the impact of gypsy moth in northeastern hardwood forests. The work of this unit was terminated in 1985.

At Princeton, a project led by the late Don Cuppett investigated the marketing of primary manufactured products and methods for increasing supplies of hardwood raw materials. Researchers studied the kinds and amounts of marketable products that can be recovered from intermediate cuttings and logging residues; integrated systems for harvesting the mixes of roundwood products; methods and systems for producing lumber, cant-type products and chips from bolts and small logs; opportunities for large-volume use of non-sawable hardwood residues and thinnings for wood fuels; and product yields and comparative economic returns from short-rotation forest management regimes. This unit also developed useful information on the commercial recovery and use of hardwoods from thinnings and logging residue, including quantity, yield, and suitability for alternative marketable products.

Responding to the oil crisis in the late 1970's, scientists at Princeton studied the availability, harvesting efficiency, and seasoning for wood fuel; conversion of oil and gas boilers to wood; costs associated with harvesting wood fuel; and storage of particulate wood fuel. Computer programs were developed to aid logging operators (WEAK LINK) and mill managers (SOLVE II). Following Cuppett's death in 1982, William Luppold led the

unit until 1984 when its work was terminated. However, emphasis shifted to another area of research, lead by Luppold, that centered on an economic analysis of hardwood product use in furniture and pallet industries and the related hardwood stumpage markets. Researchers studied the factors affecting furniture manufacturers' demand for hardwood lumber and hardwood panel products; the demand for timber inputs by the pallet industry; stumpage supply and demand; and the effect of technology, capital costs, wage rates, and log costs on the supply of hardwood lumber. Also examined was the impact of wage rates, furniture prices, currency exchange, and level of international economic activity on hardwood demand, and the effect of national and international demand on the price of hardwood lumber.

This unit also provided information on stumpage demand, developed methods for developing hardwood log statistics, and studied the effects of Pacific Rim and other international imports on U.S. competitiveness in the furniture market. A computer program called OPTIGRAMI was developed to optimize the use of hardwoods in manufacturing hardwood dimension. Also developed were decision models that link manufacturing at each level of production and simulation and optimization models for determining and implementing optimal sawmill production schedules. Luppold led the unit until 1993 when Cynthia West was appointed project leader. Also at Princeton, David Martens conducted research on marketing secondary manufactured wood products and later the economics of consumption, distribution, and production of secondary manufactured wood products. This work continued until 1978.

In 1994, Luppold initiated research aimed at enhancing the performance and competitiveness of the U.S. hardwood industry. He studied the structure, conduct, and performance of various hardwood products; alternative intervention approaches to remedy externalities from production and processing timber; and strategies that help hardwood-processing firms and industries to remain competitive. He provided information on regional changes in product demand, volume, quality, and tree species that affect the hardwood lumber industry; employment opportunities in secondary forest product industries through value-added manufacturing; and the relationship of increased industry concentration to competition in the log and stumpage markets.

Another Princeton unit led by Gil Dempsey studied economic opportunities for improving the productivity of the primary forest industry. This unit quantified the interrelationships of hardwood product supply and demand, studied ways to improve hardwood resource consumption and use relationships and ways to improve the mix of labor and capital supply and productivity in the primary hardwood industry, and examined methods for stimulating the development of nonindustrial forest land. Responding to the expected increase in hardwood demand, researchers developed econometric models of hardboard, insulation board, and pallet markets, and generated price-quantity information on the nature of future consumption. They also developed models to simulate strength of structure, devised procedures for low-grade hardwood log conversion related to pallet production, and studied timber productivity on nonindustrial private forest land. This work continued until 1983.



Research at Princeton, West Virginia, on the construction, supply, and demand for wooden pallets has contributed significantly to the success of the pallet industry.

By 1984, world trade in forest products had become so important that scientists began analyzing international trade for hardwood products. They developed information on economic and institutional factors that influenced international demand, product standards and product alternatives in international trade, and technical and economic information to help producers and entrepreneurs evaluate opportunities and risks associated with export marketing. They also studied the structure, conduct, and performance of various hardwood products; alternative intervention approaches to

managing the external factors related to production and processing timber; and strategies to help hardwood processing firms and industries remain competitive. This work continued until 1985.

A Burlington unit led by Dave Garrett and later Paul Sendak initially developed information on maple sap and syrup quality controls, product development and market expansion, and guidelines for maple syrup producers in selecting alternatives for improving efficiency of water removal from maple sap. However, in 1978, the

unit began studying the economics of wood energy as the Nation looked to other sources of energy to reduce its dependence on imported petroleum. The Burlington program focused on the cost of producing wood for energy and of generating energy from wood, marketing systems for wood energy, and effects on the forest from increased harvesting due to increased demand for wood for energy.

Recreation

During this period of the Station's history, recreation research was conducted at Syracuse, Durham, and Burlington. A research unit at Syracuse led by George Moeller and later Alan Wagar studied recreation demand. A unit at Durham led by Wilbur LaPage conducted research on indicators of outdoor recreation trends, designed and tested data systems to index trends in outdoor recreation activity, and evaluated existing data series as indicators of the quantity and quality of selected outdoor recreation experiences. The unit also developed regional indicators of the types, numbers, and volumes of use of developed outdoor recreation enterprises. A major problem in public and private recreation planning was the lack of reliable trend data on recreation participation. Researchers characterized the size of the camping market and its growth rate in four major regions of the United States and, with the National Campground Owners Association, developed and tested a working model to monitor campground use. They also devised methods for determining how well recreation resource managers meet the expectations of recreationists, and proposed standardized data collection methods for analyses of recreation trends.

Another Durham unit led by Raymond Leonard conducted research on dispersed forest recreation in backcountry areas and focused its work on the biological capacity of remote ecosystems to support use by recreationists under current management systems, information for effective means of managing use in these areas, and criteria and methodology for designing capacities for dispersed recreation areas. The recreational benefits of remote and undeveloped areas of forests became popular in the 1970's. In the Northeast, 14,000 miles of trails and more than 300 overnight shelter facilities provided a variety of recreational opportunities for vacationers as well as the 50 million people who live within easy driving distance. Responding to concerns about biological land capacities and recreationist desires, scientists developed a design capacity concept for planning dispersed recreation lands. They also provided techniques for understanding the durability of different types of understory plant communities, bin composting methods for human waste and garbage, techniques for measuring baseline conditions at backcountry campsites, and design criteria for dispersed recreation areas.

By the mid-1980's, much of the work assigned to the two units in Durham had been completed, and a new recreation research unit was established in Burlington under the direction of Herbert "Skip" Echelberger. Scientists focused on determining the costs of forest recreation opportunities, factors that affect the perceived quality of forest recreation, and the relationships between costs of provision and perceived quality. As this program matured, investigations centered on the human dimensions of tourism, fish,

wildlife, and outdoor recreation. Researchers studied the role of forest recreation and tourism on the quality of life and economic stability in rural communities; interactions among economic, psychological, and social dimensions of ecosystem management; and ecosystem management for high-quality recreation and site access. They also developed guidelines on cost and efficiency of day-use facilities; the application of differential and cost-based fees for commercial campgrounds, state parks, and federal campgrounds; and determined the costs of providing fish, wildlife, and other recreational opportunities as well as the values that constitute a "quality recreation experience."

Urban Forestry

The research unit at Amherst conducted research on both urban forestry and wildlife habitat. Urban forestry studies centered on quantifying the scenic qualities of urban forest vegetation; identifying the benefits of natural places for urban residents and alternative outdoor recreation areas and activities; developing techniques for integrating scenic recreation, wildlife, and other values of urban forests in land-use decisions; and improving the well-being of people through proper management of scenic, recreational, and wildlife values provided by forest cover in and around densely populated areas.

In 1981, work by this unit shifted to research on wildlife habitat as urban forestry research was transferred to a Syracuse project led by Rowan Rowntree. Studies centered on the quantitative influence of various types and intensities of urban development on the ecological functioning of urban forests, integration of urban forestry into urban and regional planning, quantitative

description of the structure and function of urban forest ecosystems, and understanding how the presettlement forest structure and function is changing due to urbanization.

Working with investigators and cooperators in major U.S. urban centers, Rowntree's team developed models to help cities manage their natural resources for maximum benefit at minimum cost. The project provided an understanding of how different land uses determine the distribution, ecological functioning, and individual physiology of a system of vegetation, and produced the first quantitative cost-benefit analysis of open space in urban forests. In 1984, the unit focused on methods to quantify the structure and related characteristics of urban forests. Much of this work led to the "Chicago Urban Forest Climate Study," which described the carbon sequestration, energy savings, and carbon emissions related to reduced consumption of fossil fuels for heating and cooling.

Technology Transfer

During the 1970's, the Forest Service placed considerable emphasis on the transfer of technology related to scientific research. In the mid-1980's, under Forest Service Chief Max Peterson, technology transfer activities were included in scientists' performance and grade evaluations. At the same time, a technology transfer specialist or possible user of the new technology was seated as a voting member on scientists' grade evaluation panels.

The ultimate objective of the Station's research programs is to produce sound information that advances the level of science and is useful to society. Technology transfer can take many forms, including meetings, publications, seminars and workshops, computer programs, video tapes and slides, classroom instruction, and field demonstrations. In this respect, every research program in the Station has contributed to technology transfer in some form. Individually or in teams, scientists frequently call upon specialists in the written, visual, and electronic media to aid them in making research results available to the public. They also form working partnerships with universities, private industry, consultants, national forests, states, and other federal agencies. The following are examples of successful technology transfer programs carried out by Station scientists and cooperating organizations in recent years.

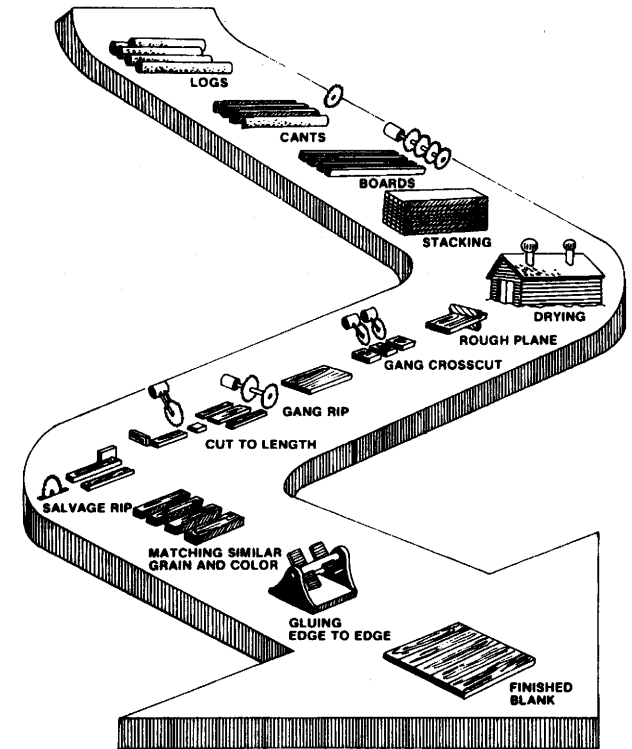
Decay and Discoloration of Trees

At the Durham laboratory, Alex Shigo led a team of scientists conducting research on discoloration and decay in trees. Their work led to new concepts

of the processes of decay and how they can be managed to minimize tree damage. This research was groundbreaking and Shigo's technical transfer effort became something of a personal crusade. Besides publishing hundreds of scientific reports and popular articles on the dynamics of tree discoloration and decay, Shigo addressed numerous forestry and arboricultural organizations and enlisted the aid of illustrators and information specialists to help describe his groundbreaking work. Today, many of the tree-care practices developed by Shigo have been adopted by arborists throughout the world.

System 6 and Serpentine End Matching

The second-growth hardwood forests of the Eastern United States contain large quantities of low-grade material that previously could not be processed and utilized economically. At Princeton, a team led by Charles Gatchell developed System 6, which converts low-grade logs and boards into high-quality end products. Researchers also developed a process called Serpentine End Matching (SEM) that is used in producing high-quality furniture or cabinet parts from raw materials that otherwise would not be used. In 1982, cooperative agreements were initiated with the University of Massachusetts, University of Minnesota, Hardwood Research Council, and S&PF to convert this new technology to practical processes that can be used by industry. A series of workshops led to the widespread use of this research: by 1984, seven System 6 facilities had been constructed and five others were planned. System 6 and SEM technology also have been highlighted in numerous industry publications.



This schematic of System 6 technology illustrates how low-grade logs and boards are converted to high-quality end products.

SILVAH

SILVAH, an acronym for Silviculture of Allegheny Hardwoods, is a computer-based, systematic and quantitative procedure for stand inventory, analysis, and prescription for hardwoods in the Allegheny region. Alone, this system would have been a valuable tool for professional foresters, but in 1976, through the efforts of Station researchers at Warren led by David Marquis and the

Cooperative Extension Service of Pennsylvania State University, training sessions were held on the Kane Experimental Forest to demonstrate the use of SILVAH to practicing foresters. The initial sessions were so popular that they are now conducted two to four times each year. Eventually, a new classroom facility was built to accommodate these successful technology transfer sessions, which have been attended by members of virtually every forest-management organization in the Northeast.

New England Wildlife

Sustainable management of New England's forests has been an elusive goal because of their biological and physical diversity and equally diverse ownership. Managers also have been impeded by incomplete and/or scattered information on the characteristics of the vegetation, wildlife habitat, and land capability of this region's forested ecosystems. Such was the case in the early 1990's when the Forest Service implemented ecosystem management as a standard practice. Scientists at Durham and Amherst, led by William Leak and Richard DeGraaf, respectively, along with research with the White Mountain National Forest undertook the daunting task of assembling the available data on these forests and their management, including the natural history, habitat, and distribution of 338 wildlife species in New England, into a form that can be used easily by forest managers and owners. This massive technology transfer effort produced two major volumes of work describing New England wildlife species as well as forest management strategies that meet a variety of landowner objectives. The work of this team was so successful that it received

national recognition in the form of the Chief's Technology Transfer Award.

Mined-Land Reclamation

Results from the mined-land reclamation research program led by Willie Curtis at Berea were disseminated in Station guides and handbooks, journal articles, and papers at meetings of professional organizations, including the American Society for Surface Mining and Reclamation. Founded by Curtis in 1984, the Society became the cornerstone for transferring mining and reclamation technology throughout the Nation. Other technology transfer efforts included a series of seminars sponsored by universities within the mining region, and handbooks and manuals prepared by Berea scientists for the USDI Office of Surface Mining and Enforcement.

Logging Road Design

Land managers have long recognized that the bare soil exposed on roads and landings is the source of most of the sediment originating from logging operations. Consequently, the Station has included logging-road design as part of its research program for decades, with most of this work being performed on the Fernow Experimental Forest by scientists at the Parsons laboratory. During the 1950's, research on the Fernow focused on evaluating different roading practices and developing guidelines for controlling erosion on logging roads in the steep mountainous terrain of the Appalachians. With the advent of wheeled skidders in the early 1960's, research focused on the dense road systems associated with their use. In 1974, researchers began evaluating a skyline cable system called Urus as part of a program to

develop alternative logging systems that cause less environmental damage than wheeled skidders. In 1980, scientists developed the "minimum-standard truck road" concept, a road built to the lowest standard that will provide a desirable level of utility and environmental protection in Appalachian forests at an acceptable costs. Minimum-standard roads have been accepted widely by private landowners. Many publications pertaining to erosion control on logging roads and culvert sizes have been published by the Station. Much of this information is used in many best management practices (BMP) manuals for minimizing the adverse impact of logging operations on soil and water resources. Since the early 1970's, Station researchers have participated in numerous workshops designed to train loggers and others in implementing BMP's. More recently, educational videotapes and supplemental booklets have been produced in cooperation with West Virginia University and the State of West Virginia. These training aids are used widely at BMP workshops.

NED

NED, originally an acronym for Northeast Decision Model, is a collection of software tools developed in 1987 to help resource managers identify goals, assess current and future condition, and produce management plans for forests in the Eastern United States. NED is unique in that over the years it has captured the collective expertise of scientists at several Station locations. The original goal was to develop a computer program that combined all the growth-and-yield models developed independently by various Station researchers. Early efforts focused on developing a



This minimum-standard road was used to remove a half million board feet of timber from a 96-acre Appalachian watershed.

decision-support system for management problems at the stand level. As more complex problems involving several resources were identified, NED was expanded to include landscape scales. The revised goal was to develop a single, easy-to-use computer program that provides summary information and expert prescriptions for every forest type in the Northeast. At Burlington, a unit led by Mark Twery developed the software tools and is coordinating the continuing development of NED in cooperation with other research units in the Northeastern, North Central, and Southern Stations. Many state and educational institutions are continuing participating in the ongoing development of NED.

Today, the software emphasizes the analysis of inventory data for various forest resources on management areas as large as several thousand hectares. The resources addressed include visual quality, ecology, forest health, timber, water, and wildlife. NED also allows users to evaluate how an individual stand or an entire management unit can provide conditions for specific objectives. Thousands of copies of the NED program have been distributed to landowners, university forestry schools, public

schools, consulting and state service foresters, and public land-management agencies. Also, workshops on the use of NED are conducted regularly by the state extension agencies at Cornell and Pennsylvania State Universities.

Advanced Hardwood Processing and Technical Resource Center

In 1988, researchers at Princeton initiated an ambitious technology transfer program with the creation of the Advanced Hardwood Processing and Technical Resource Center, a series of online data bases that encompass the collection, evaluation, and dissemination of information on all aspects of secondary wood processing. The Center serves as a centralized source of otherwise fragmented industry data that can be easily addressed by machinery and wood-products manufacturers, industry consultants, plant managers, researchers, and others. The data bases currently comprise a global listing of nearly 4,000 manufacturers of woodworking machinery, including computer numerically controlled equipment, information on various machine models and U.S. dealers, listings of training schools for woodworkers as well as computer software associated with the wood industry, data on the properties of tree species, domestic and international trade data on forest products, hardwood market statistics, and results of relevant past and current forest-products research. The woodworking equipment data base is the only one of its kind in the world. To ensure that the data bases incorporate the most recent industry innovations and advances, the Center's staff members regularly attend machinery fairs and trade expositions around the Nation and abroad.

GypsES

At Morgantown, a research unit led by Kurt Gottschalk developed GypsES, a powerful decision-support system for managing the gypsy moth. By integrating computer models of insect phenology, defoliation, stand damage, hazard rating, spray drift and deposit, and related knowledge bases, GypsES allows pest managers to select the most appropriate and cost-effective methods for controlling the most serious insect defoliator in the Northeastern United States. The successful transfer of this highly popular technology, which is the culmination of several decades of research, has been achieved through the coordinated efforts of members of Gottschalk's team and researchers with several other Station units, S&PF, the Southern Region, and the Washington Office's Forest Health Technology Enterprise Team located at Davis, California.

Chronology of Station Work Units

The following chronology of Northeastern Station research work units from 1973 to 1998 is organized by location, research subject, project leader, and date.

Research Subject	Project Leader	Date
Amherst, Massachusetts		
Environmental forestry	J. W. Thomas	1973
	B. R. Payne	1974-1977
Urban forestry	B. R. Payne	1977-1978
	R. M. DeGraaf	1978-1983
Wildlife habitat associations	R. M. DeGraaf	1983-1987
Wildlife communities and habitat relationships in New England forests	R. M. DeGraaf	1987-present
Atlantic salmon habitat restoration ecology and management	R. M. DeGraaf (Acting)	1995-present
Beltsville, Maryland		
Physiology of growth, wood, formation and aging in forest trees	J. A. Romberger	1974-1978
Development and physiology of vegetative and shoot reproductive meristems	J. A. Romberger	1978-1982
Physiology of mycorrhizae of forest trees	E. Hacskeylo	1974-1982
Berea, Kentucky		
Strip-mined area restoration	G. Davis	1973-1974



Forestry Sciences Laboratory at Berea, Kentucky.

Research Subject	Project Leader	Date
	W. R. Curtis	1974-1978
Reclamation of surface-mined areas	W. R. Curtis	1978-1985
	W. G. Vogel	1985
	H. G. Halverson	1985-1989
Reclamation and hydrology of eastern coal mine areas	H. G. Halverson	1989-1991
Burlington, Vermont		
Sugar maple sap production	A. G. Snow, Jr.	1973-1974
	H. W. Yawney	1974-1978



George D. Aiken Sugar Maple Laboratory at Burlington, Vermont.

Research Subject	Project Leader	Date
Production of sugar maple sap and wood products	H. W. Yawney	1978-1981
Sugar maple timber and sap production	H. W. Yawney	1981-1982
Maple products marketing	L. D. Garrett	1973-1978
Maple syrup products marketing and wood energy research	L. D. Garrett	1979
	P. E. Sendak	1979-1986
Economic impacts of wood energy and economics of maple syrup production	P. E. Sendak	1986-1989

Research Subject	Project Leader	Date
Economic potential of forest production in the North	P. E. Sendak	1989-1993
Impacts of acid deposition on physiology, growth, wood formation, and aging in trees	R. A. Gregory	1983-1984
Role of environmental stress on tree growth and development	R. A. Gregory	1984-1988
	D. T. Funk (Acting)	1988-1990
	B. L. Wong (Acting)	1990
	R. Wilkinson (Acting)	1990
	M. Tyree	1990-present
Indicators of outdoor recreation trends	H. E. Echelberger	1982-1984
Forest recreation investment research	H. E. Echelberger	1984-1993
Human dimensions of tourism, fish, wildlife, and outdoor recreation	H. E. Echelberger	1993-1995
Interdisciplinary approaches to managing northeastern forest ecosystems	L. M. Tritton	1991-1992
Integrating the ecological and social dimensions of forest ecosystem management	L. M. Tritton	1992-1994
	M. Twery	1994-present
Columbus, Ohio		
Timber measurement and planning procedures for eastern hardwoods	S. F. Gingrich	1973-1974
	M. E. Dale	1974-1975

Research Subject	Project Leader	Date
Quality and grade of hardwood timber	R. L. Brisbin	1973-1975
Economics of timber growing	D. P. Worley	1973-1975
Delaware, Ohio		
Quality and grade of hardwood and northeastern softwood timber	R. L. Brisbin	1975-1982
Timber measurement and planning procedures for eastern hardwoods	M. E. Dale	1975-1982
Economic evaluation of forest management alternatives on hardwood timber tracts in the Northeast	D. P. Worley	1975-1982
Forest tree virus diseases	C. E. Seliskar	1973-1978
Virus and virus-like diseases of native trees	C. E. Seliskar	1978-1982
Insect behavior	D. E. Donley	1973-1976
Shade tree insects	T. W. Jones	1973-1974
Vascular and virus diseases	T. W. Jones	1973-1974
Insect vectored vascular wilts of forest tree species	T. W. Jones	1974-1977
	J. W. Peacock	1977-1980
	G. F. Gregory	1980-1981
Integrated methods to prevent and suppress Dutch elm disease and identify other insects and diseases of high-value hardwoods	G. F. Gregory	1981-1985



Forestry Sciences Laboratory at Delaware, Ohio.

Research Subject	Project Leader	Date
Insect-vectored diseases of trees	G. F. Gregory	1985
Hardwood cankers, heartrots, and root diseases	F. H. Berry	1973-1976
Insects and diseases of high-value hardwoods	F. H. Berry	1976-1982
	D. E. Donley	1982-1983
Biology and management of insects affecting oak regeneration	J. W. Peacock	1983-1988
Relationship of air pollution to forests of the Eastern United States	L. S. Dochinger	1973-1985
	K. F. Jensen	1985-1991

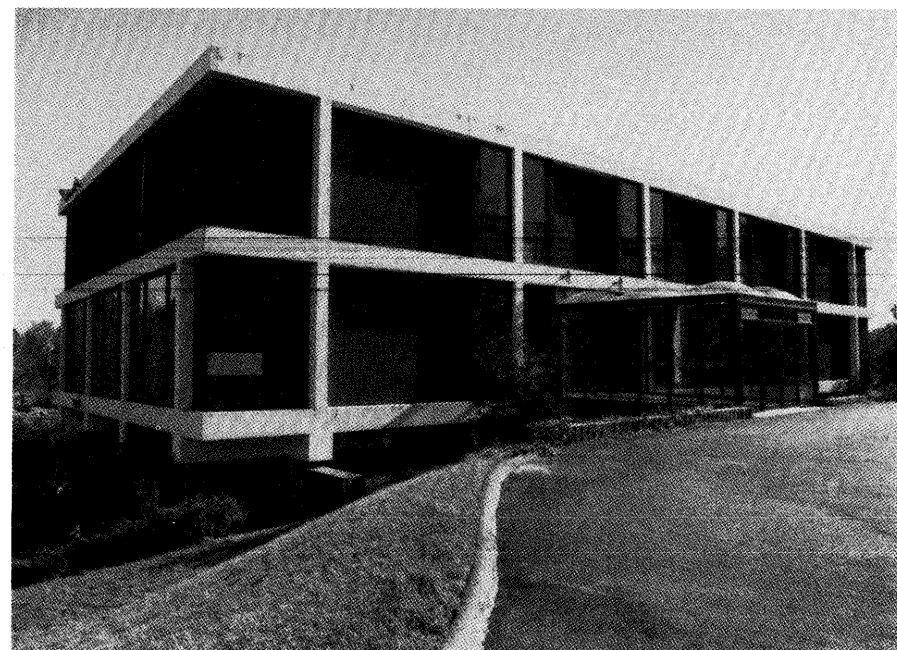


Louis C. Wyman Forestry Sciences Laboratory at Durham, New Hampshire.

Research Subject	Project Leader	Date
	J. Rebbeck (Acting)	1992
Impact of atmospheric deposition and global change on forest health and productivity	R. Long	1992-present
Develop management and utilization guidelines for forest-land owners	N. P. Kingsley	1983-1984
Management and utilization alternatives for nonindustrial private forests	N. P. Kingsley	1984-1988
	D. E. Hilt	1988-1990
Growth, yield, and value	C. Scott	1990-1992

Research Subject	Project Leader	Date
development of northeastern forest types		
Quantitative methods for modeling ecosystem response	C. Scott	1992-present
Application of biotechnology in forest pest management	M. T. Chang	1986-1990
Development of biologically based controls for forest insect pests and diseases through molecular technologies	J. Slavicek	1990-present
Durham, New Hampshire		
Discoloration and decay in living trees	A. L. Shigo	1973-1985
	W. C. Shortle	1985
Physiological and biochemical mechanisms of tree response to injury and infection	W. C. Shortle	1986-1991
Tree response to injury and infection in a changing environment	W. C. Shortle	1991-1995
Growth composition and culture of northern hardwoods	W. B. Leak	1973-1974
	S. M. Filip	1974-1977
Ecology and management of northern hardwood forests in New England	S. M. Filip	1977-1978
	C. H. Tubbs	1978-1986
Ecology and management of beech-birch-maple types in the Northeast	C. H. Tubbs	1986-1990
	P. W. Garrett	1990-1993

Research Subject	Project Leader	Date
Ecology and management of northern hardwoods and associated ecosystems	P. W. Garrett	1993-1996
Ecology and management of northern forest ecosystems	J. C. Brissette	1996-present
Water yield improvement	R. S. Pierce	1973-1974
Water quality and quantity in hardwood ecosystems	R. S. Pierce	1974-1978
Impact of forest management on nutrients in soil and water	R. S. Pierce	1978-1986
Impact of forest management and acid precipitation on nutrients in soil and water	R. S. Pierce	1986-1990
Dynamics of atmosphere, vegetation, soil, and water in mature and harvested forests in New England	R. S. Pierce	1990-1991
	C. Eagar	1991-present
Genetic improvement of northeastern trees	E. J. Schreiner	1927-1967
	P. W. Garrett	1967-1985
Marketing problems of outdoor recreation enterprises	W. F. LaPage	1974-1977
Indicators of outdoor recreation trends	W. F. LaPage	1977-1982
	H. G. Echelberger	1982
Dispersed forest recreation in backcountry areas	R. E. Leonard	1976-1984
Methods for measurement,	D. S. Solomon	1989-present



Center for Biological Control of Northeastern Forest Insects and Diseases at Hamden, Connecticut.

Research Subject	Project Leader	Date
analysis, and modeling of forest growth and structure		
Hamden, Connecticut		
Insect genetics and physiology	P. A. Godwin	1973
Impact of insects on northeastern forests	R. L. Talerico	1973-1975
Etiology, epidemiology, and physiology of diebacks, declines, and physiogenic disorders of northeastern trees	D. R. Houston	1973-1984



Forestry Sciences Laboratory at Morgantown, West Virginia.

Research Subject	Project Leader	Date
Etiology, epidemiology, and physiology of stress-regulated host-pest interactions	D. R. Houston	1984-1989
	P. M. Wargo	1989-1995
Disturbance of eastern forest ecosystems by stressor-host pathogen interactions	P. M. Wargo	1995-present
Insect pathology and microbial control	F. B. Lewis	1973-1986
Pathology and microbial control of insects defoliating eastern forest trees	M. McManus	1986-present

Research Subject	Project Leader	Date
Population dynamics and forest insect pests	M. McManus	1974-1975
	P. A. Godwin	1975-1976
	W. E. Wallner	1976-1978
Ecology and management of northeastern hardwood insect pests	W. E. Wallner	1978-1991
	M. E. Montgomery	1991-1995
Forest insect biology and biocontrol	K. Shields	1995-present
Silvicultural decisions and actions for forest management	S. G. Boyce	1980-1981
Biological potential for timber production	S. G. Boyce	1981

Morgantown, West Virginia

Engineering systems for the Appalachian area	H. G. Gibson	1973-1974
Appalachian hardwood timber harvesting	H. G. Gibson	1974-1979
	C. J. Biller	1979
	P. A. Peters	1979-1984
Forest engineering research-timber harvesting systems and equipment for steep terrain	P. A. Peters	1984-1994
Management of small game and deer habitat in Appalachian forests	J. D. Gill	1973-1974
Wildlife habitat management in the central Appalachians	J. D. Gill	1974-1982

Research Subject	Project Leader	Date
Culture of northern Appalachian hardwoods	H. C. Smith	1974-1975
Silvicultural options for the gypsy moth	D. E. Donley	1982-1984
	G. Mason	1984-1987
	K. Gottschalk	1987-present
Systems to integrate harvesting with other resource management objectives	C. LeDoux	1986-present
Orono, Maine		
Culture of northeastern conifers	B. M. Blum	1973-1978
Culture of northeastern spruce-fir forests	B. M. Blum	1978-1991
	P. W. Garrett (Acting)	1991-1992
Ecology and management of northern conifers and associated ecosystems	J. Brissette	1992-1996
Parsons, West Virginia		
Culture of northern Appalachian hardwoods	G. R. Trimble, Jr.	1973-1974
	H. C. Smith	1975-1978
Culture of central Appalachian hardwoods	H. C. Smith	1978-1985
Growth and culture of central Appalachian hardwoods	H. C. Smith	1985-1994
	G. Miller (Acting)	1994
Floods and water yield	J. H. Patric	1973-1974



Timber and Watershed Laboratory at Parsons, West Virginia.

Research Subject	Project Leader	Date
Protecting water quality and improving water yields from forested lands in the central Appalachians	J. H. Patric	1974-1979
	J. N. Kochenderfer	1979
	S. H. Kunkle	1979-1980
Water resource protection in central Appalachian forests	J. D. Helvey	1980-1989
	J. N. Kochenderfer	1989-1990
	M. B. Adams	1990-1994
Sustainable forest ecology in the central Appalachians	M. B. Adams	1994-present

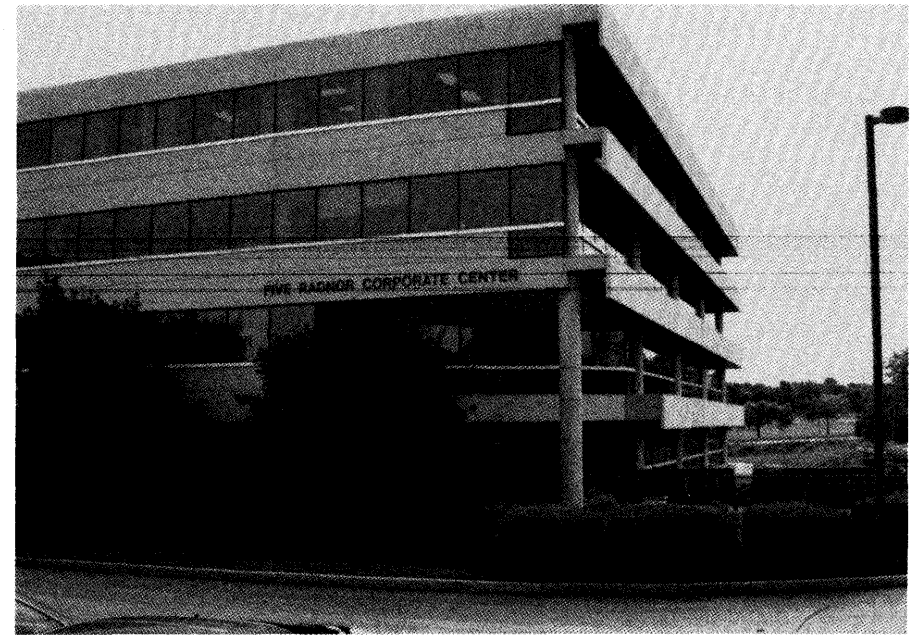


Forestry Sciences Laboratory at Princeton, West Virginia.

Research Subject	Project Leader	Date
Pennington, New Jersey		
Amenities and municipal watersheds	S. Little, Jr.	1973-1975
	H. G. Halverson	1975-1978
Princeton, West Virginia		
Hardwood product improvement	C. J. Gatchell	1973-1978
Low-grade hardwood utilization	C. J. Gatchell	1978-1986
Increasing use of eastern hardwoods through better processing with improved technology	C. J. Gatchell	1986-1989
	R. L. Brisbin	1989-1990

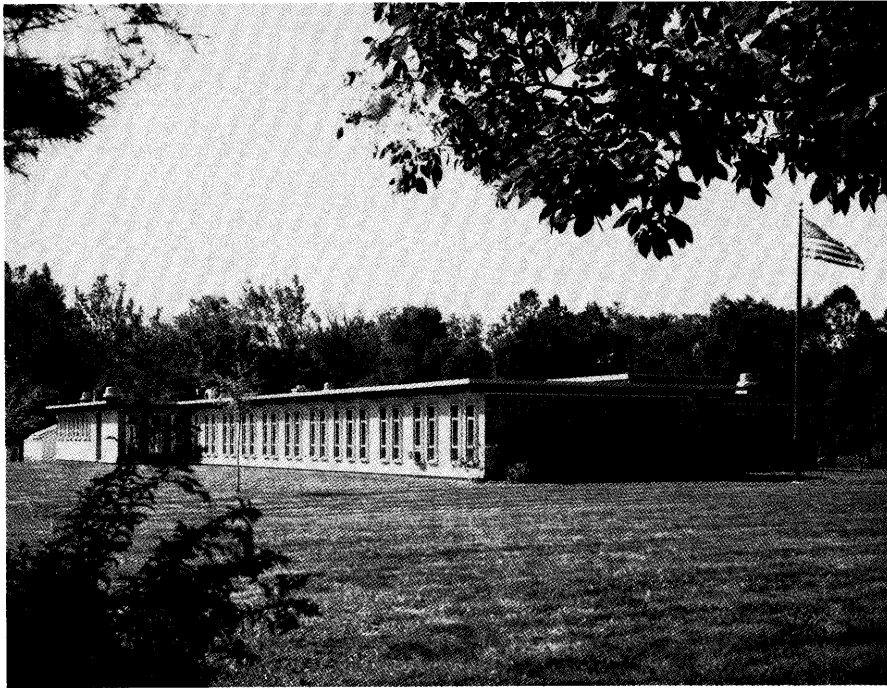
Research Subject	Project Leader	Date
Improved processing technology for hardwoods	R. L. Brisbin	1990-1994
	J. Wiedenbeck	1994-1996
	J. Baumgras (Acting)	1997-present
Marketing timber and roundwood products	T. W. Church, Jr.	1973-1977
Marketing primary manufactured wood products	D. G. Cuppett	1973-1978
Increased supply of hardwood raw material	D. G. Cuppett	1978-1982
	W. G. Luppold	1982-1986
Marketing secondary manufactured wood products	D. G. Martens	1973-1977
Economics of consumption, distribution and production of secondary manufactured wood products	D. G. Martens	1977-1978
Economic opportunities for improving productivity	G. P. Dempsey	1973-1979
Economic opportunities to improve productivity of the primary forest industry	G. P. Dempsey	1981-1983
Analysis of international trade for hardwood products	G. P. Dempsey	1983-1984
Analysis of domestic and international demands for hardwood lumber and veneer and domestic supply of these products	W. G. Luppold	1986-1992
Analysis of domestic and	W. G. Luppold	1992-1993

Research Subject	Project Leader	Date
international hardwood product markets	C. West	1993-1996
	B. Hansen (Acting)	1996-present
Enhancing performance and competitiveness of the United States hardwood industry	W. G. Luppold	1993-present
Syracuse, New York		
Forest recreation demand	G. H. Moeller	1973-1975
	J. A. Wagar	1975-1977
Integrating recreation with other forest uses	J. A. Wagar	1977-1978
Planning for management of urban forest ecosystems	R. Rowntree	1979-1985
Structure and function of urban forests	R. Rowntree	1985-1997
	D. Nowak	1998-present
Station Headquarters		
Regional production economics	D. A. Gansner	1973-1977
Regional forest resource economics	D. A. Gansner	1977-1985
Forest survey	C. E. Mayer	1973-1975
Resources evaluation	C. E. Mayer	1975-1980
	J. E. Barnard	1980-1982
Forest inventory and analysis	J. E. Barnard	1982-1985
	J. R. Peters (Acting)	1985
	D. A. Gansner	1985



Northeastern Research Station headquarters at Radnor, Pennsylvania.

Research Subject	Project Leader	Date
	(Acting)	
Forest inventory, analysis, and economics	J. R. Peters	1985-1990
Forest inventory and analysis	J. P. Peters	1990-present
University Park, Pennsylvania		
Amenities and municipal watersheds	H. G. Halverson	1978-1986
Physical amenities and water supplied by urban and community forests and municipal watersheds environment	E. S. Corbett	1986-1990



Forestry Sciences Laboratory at Warren, Pennsylvania.

Research Subject	Project Leader	Date
Enhancement of the human habitat through management of natural environments	E. S. Corbett	1990-1995
Warren, Pennsylvania		
Ecological aspects of wildlife and timber production	J. S. Jordan	1973-1974
Wildlife habitat management in Allegheny hardwoods	J. S. Jordan	1974-1977
Silviculture of Allegheny hardwoods	D. A. Marquis	1973-1978

Research Subject	Project Leader	Date
Ecology and management of cherry, maple, and oak forests in the Alleghenies	D. A. Marquis	1980-1990
Silvicultural decision systems for eastern hardwood forests of the Middle Atlantic region	S. L. Stout	1990-1995
Understanding and managing forest ecosystems in the Allegheny Plateau region	S. L. Stout	1995-present

International Forestry Programs

The Forest Service has long valued its membership in the International Union of Forestry Research Organizations (IUFRO). Northeastern Station scientists in nearly every discipline have collaborated on numerous research projects with scientists from many nations through their association with IUFRO. Initially, an international research program administered by the USDA and supported by funds made available by Public Law 480 resulted in scientific exchanges with countries such as Egypt, India, Pakistan, Poland, and Yugoslavia. Later, the USDA Office of International Cooperation and Development (OICD) provided funding for cooperative research with a number of countries. These and other associations have resulted in significant advances in the management of forest ecosystems in the United States.

Former Soviet Union

Exchange visits between U.S. scientists and researchers from the former Union of Soviet Socialist Republics that began in the early 1970's emphasized the integrated management of forest insect pests, particularly the gypsy moth. In addition, several teams and individuals with the Station observed and participated in research projects designed to integrate treatment with *Bacillus thuringiensis* and bird management (deployment of nest boxes) to control the oak leaf roller. This cooperative effort included joint studies on small-mammal predators of gypsy moth in areas such as the Ukraine, central Siberia, and the Russian Far East. In 1989, William Wallner of the Center for Biological Control of Northeastern Forest Insects and Diseases at Hamden spent six

months in the former Soviet Union studying forest insects, including the bioecology and behavior of the gypsy moth.

More than 15 visits by Wallner and other Station scientists to research institutes in Moscow, Kiev, Krasnoyarsk, Kharkov, Kharbarovsk, Irkutsk, and Tbilisi generated useful contacts as well as valuable scientific information on a variety of insect pests and other aspects of forest health and productivity. In 1991, cooperating scientists developed a pest risk assessment for Siberian larch, which was proposed for importation into the United States. This achievement led to the first risk assessment for insect pests associated with unprocessed wood. Station researchers have developed similar risk assessment programs with scientists in Chile, Mexico, and New Zealand.

Cooperative research between U.S. and Russian scientists on the Asian gypsy moth proved valuable when this serious forest pest hitchhiked to North America (Oregon, Washington, and British Columbia) in 1991 on Russian grain ships. Armed with the knowledge that female gypsy moths capable of flight were attracted to lights in Russian ports and laid egg masses on ship cargoes, scientists were able to develop a variety of control procedures ranging from biocontrol agents to monitoring and protocol systems for Russian and other foreign vessels.

Increasing pressure on harvesting Russia's Siberian forests have raised international concerns about the sustainability of forest practices in that part of the globe. In 1993, the International Forestry staff in Washington entered into an agreement with the Russian Federal Forest Service

to establish the Central Siberian Sustainable Forest Management Project near Krasnoyarsk. Through demonstrations of sound forest management operations and techniques, participants in this pilot project hope to promote economically and ecologically sustainable forests in this region. Currently, scientists with the Northeastern Station and Region 9 are participating in monitoring activities on this pilot installation.

People's Republic of China

Cooperation between the Forest Service and Northeastern Station with the People's Republic of China began with a fact-finding trip to that country in the late 1970's. This was followed by numerous scientific exchanges during the 1980's and 1990's that included joint studies on a variety of forest insects. This cooperative research resulted in the development of biological agents for controlling the gypsy moth, hemlock scale, and mites, and the identification of predators of the hemlock woolly adelgid. The latter is native to the People's Republic and recently was introduced accidentally to the Eastern United States. Scientific exchanges between U.S. and Chinese researchers continue today as part of formal agreements supported by the Forest Service, OICD, and the Foreign Agricultural Service.

Europe

Efforts to develop additional biological agents to control the gypsy moth led scientists at Hamden to participate in intensive collaborative research with scientists in Austria, Bulgaria, the Czech and Slovak Republics, Germany, Poland, and Romania. This resulted in the collection of a

number of isolates of protozoan pathogens (microsporidia) of the gypsy moth. The infectivity and pathogenicity of these isolates, many of which are new species that await taxonomic classification, are being assessed to determine their usefulness in controlling the North American strain of the gypsy moth.

Air Pollution and Global Climate Change

In 1975, the Northeastern Station cosponsored the First International Acid Rain Conference that was attended by more than 300 scientists from the United States and 12 countries. The published proceedings of that conference reported for the first time the relationship between acid deposition and industry emissions as well as the effects of acid precipitation on forest ecosystems. This landmark conference has since been repeated at intervals of approximately 5 years at various locations around the world. Station scientists and researchers from the former Soviet Union also participated in a technical exchange program that investigated the interactions between air pollution and forest ecosystems. The program fostered several important international meetings and symposia.

In 1984, Walter Shortle of the Durham Laboratory began working with a colleague in Germany to develop a better understanding of the impact of acid precipitation on a variety of soils. In 1987, they were joined by scientists from Canada, Japan, and Norway, and Slovenia in studies that compared declines in silver fir on acid soils in Germany with firs dying on karst soils in Slovenia. This research later was expanded to include the effects of these declines on overall forest health, including the response of individual trees and wood quality.

As global climate change became the focal point of scientific debate during the late 1980's, attention was focused on potential impacts on the world's boreal forests, which had been virtually ignored in previous ecosystem studies. In 1991, the Forest Service joined the International Boreal Forest Research Association, whose membership consists of scientific organizations from the United States, Canada, Russia, Finland, Norway, and Sweden. For Station and other U.S. scientists, the Association is a convenient forum for coordinating research programs on the boreal forest ecosystems within the member countries.

Awards and Recognition

During the past 25 years, significant contributions by Northeastern Station scientists to the advancement of research in forestry and related disciplines have been recognized widely by numerous national and international organizations and societies. In addition, outstanding research accomplishments by the following individuals and teams within the Station have been honored by the Secretary of Agriculture and Chief of the Forest Service with distinguished and superior service awards.

USDA Superior Service Award

Alex Shigo, Durham, 1974, “for internationally recognized leadership and contributions to research on the discoloration and decay process in trees.”

Glenn Gammon, Delaware, 1975, as Station representative on the Sawmill Improvement Program team based at the Forest Products Laboratory in Madison, Wisconsin, “for notable contributions in extending the softwood sawtimber supply of the United States.”

Silviculture of Allegheny Hardwoods research unit, Warren, 1977, “for exemplary team effort and contributions to research on the silviculture of Allegheny hardwoods.”

Insect Pathology and Microbial Control research unit, Hamden, 1979, “for research leading to the development and registration of nucleopolyhedrosis virus for use in controlling the gypsy moth.”

Wilbur LaPage, Durham, 1982, “for outstanding research contributions to the American commercial outdoor recreation industry.”

Forest Inventory and Analysis research unit, Headquarters, 1983, “for substantial contributions to the economic well-being of the Northeast through an efficient program of research, inventory, and analysis of the region’s forest resources.”

Walter Wallin, Princeton, 1985, “for superior research leadership in improving the design and use of wooden pallets and the application of pallet technology in materials handling and related manufacturing industries.”

William Wallner, Hamden, 1993, “for initiating an aggressive program of education and technical planning that provided guidance to the Forest Service and Department of Agriculture for addressing the Asian gypsy moth problem.”

USDA Distinguished Service Award

Rowan Rowntree, Syracuse, 1992, “for leadership in building a cohesive and credible body of knowledge and a cadre of productive scientists in the new science of urban forest ecology.”

Forest Service Forest Insect and Disease Award for Excellence

Walter Shortle and **Kevin Smith**, Durham, 1993, “for describing aluminum-induced deficiency syndrome and its link to dieback and decline in red spruce through exceptional, high-quality research.”

Andrew Liebhold, Morgantown, 1994, “for outstanding research efforts on the development and application of spatial analysis and geostatistics of forest pest population dynamics, prediction, and management.”

James Slavicek, Delaware, 1995, “for outstanding research efforts in developing new gypsy moth virus strains for use in controlling the gypsy moth and developing markers for differentiating between the Asian and North American gypsy moth strains.”

Forest Service Chief’s Award for Excellence in Technology Transfer

Richard DeGraaf, Amherst, **William Leak** and **Mariko Yamasaki**, Durham, and **Richard Guldin**, Headquarters, 1993, “for outstanding accomplishments in demonstrating ecosystem management using silvicultural treatments to provide habitat opportunities for more than 330 wildlife species in New England.”

Forest Service Research Superior Science Award

David Marquis, Warren, 1991

James Hornbeck, Durham, 1993

Forest Service Research Distinguished Science Award

Melvin Tyree, Burlington, 1996

Forest Service Chief’s Award for Customer Service

Northeastern Forest Experiment Station, 1996, “for providing leadership in implementing the Forest Service’s pledge to improve service to the public.”

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