1999 Research and Development Highlights

from the USDA Forest Service's Northeastern Research Station

USDA United States Department of Agriculture

Forest Service • Northeastern Research Station

For more information about the research and other programs of the USDA Forest Service's Northeastern Research Station, contact the office of Dr. Bov Eav, director, by telephone at 610-557-4017; by e-mail to beav@fs.fed.us; or by postal mail to USDA Forest Service, Northeastern Research Station, Eleven Campus Boulevard, #200, Newtown Square, PA 19073.

Cover photographs: *autumn leaves, stream, fungus, and frog (Kenneth Dudzik, Durham, NH); lumber mill (Jan Wiedenbeck, Princeton, WV); and open-top chamber (Robert Long, Delaware, OH).*

The recent millennium festivities and anxieties had many people looking both backwards and forwards, evaluating the past and pondering what the future would bring. Happily, we enjoyed the fireworks and survived Y2K! Although many people say that we are starting the new millennium, others contend that we are in the last year of the old one. Regardless of which is true, we have entered the 2000's and many of us ponder what the new millennium holds in store for us.

We at the USDA Forest Service wonder what will happen to our forest resources. What effects will global change have on our region's vegetation? Will "alien" pests continue to be introduced and devastate our forests? What can we do about acid rain? How can we keep our forests healthy? What can be done to help sustain forest resources for the next thousand years? Can we find ways to use our wood more efficiently? Can trees make cities more liveable? How can we use our parks and forests wisely? How can forests help mitigate the buildup of carbon dioxide in the atmosphere?

Scientists of the Forest Service's Northeastern Research Station are studying these questions, and our research successes in 1999 provide some answers and guidance as well as point to future directions of research and concern. In this time of fiscal accountability and budget tightening, it is important that our clients and our various

publics know what we have accomplished with the taxpayers' money that we have been given to do our work.

The press and other media often trumpet significant scientific "breakthroughs"—X discovery will cure this or that, or Y will fix some terrible problem, etc., etc.—that some time later may be found to be "still only preliminary"! However, some findings do result in new understandings of natural processes and can lead to new products and methods for improving our world. But we seldom hear of the daily grind of science, the results that comprise the endless little steps forward in the slow march toward new knowledge. With this 1999 Research and Development Highlights (which we hope to make an annual publication), we will highlight some of our truly outstanding and significant findings and research syntheses, which we can think of as "keystones," as well as those incremental advances that slowly but surely build up the foundations of knowledge, which we can think of as "building blocks" or "bricks"—that is, the bricks that build the edifice of knowledge. In addition, we have "poured foundations" for several innovations and renovations, reorganizing and revising methods for gathering data for our research and monitoring functions.

***Bov Eav**, director*

Northeastern Research Station

Keystones for Healthy Forests in the Future

What effect will global change have on our region's vegetation?

Potential range shifts of trees in the East in response to five possible global change scenarios have recently been made available to the public in a tree species distribution atlas [available both as a book and as a website at the following URL: www.fs.fed.us/ne/delaware/atlas]. With data on 80 conifers and broad-leaved trees, foresters, scientists, policymakers, and land managers as well as interested members of the public can clearly visualize what could result from increased levels of atmospheric carbon dioxide and increased temperatures. The atlas includes distribution maps and tables for different climate change scenarios, life-history and disturbance attributes, ecological attributes, forest-type maps, and a sorted list of species importance values by state/county for different climate change scenarios for the eastern half of the United States (east of the 100th meridian). The atlas is the result of a modeling effort that involved the use of USDA Forest Service's Forest Inventory Data, numerous environmental variables gleaned from various sources, and climate variables provided by various global circulation models [*Atlas of Current and Potential Future Distributions of Common Trees of the Eastern United States* (GTR-NE-265) by Louis Iverson, Anantha Prasad, Betsy Hale, and Elaine Kennedy Sutherland, unit 4153, Delaware, Ohio].

According to another modeling study, the increasing level of atmospheric CO_2 is already having a positive effect on tree growth and will continue to accelerate growth of many species, even in the face of increasing temperatures [Harry Valentine and others, unit 4104, Durham, New Hampshire].

Will "alien" pests continue to be introduced and devastate our forests?

A new strain of the gypsy moth nuclear polyhedrosis virus with enhanced polyhedra and budded virus production has been isolated and patented, as has a method for isolating such viruses. This virus is specific for gypsy moth, unlike *Bacillus thuringiensis* (which may also affect other species of butterflies and moths) and chemical insecticides (which affect the total environment). The virus has been found to be an effective agent against gypsy moth larvae when sprayed onto forest trees and eaten by caterpillars. Although the virus is already endemic in the wild population, it does not act until large populations of the caterpillars have already devastated forests. This viral strain is the only one that can be produced in cell culture bioreactors, making it of great interest to companies that make baculoviruses for use in agriculture [patents 5,8832,913 & 5,853,982 to James Slavicek and Nancy Hayes-Plazolles, unit 4509, Delaware, Ohio; field studies, John Podgwaite,

Asian longhorned beetle preparing for flight (Roger Zerillo, Hamden/Ansonia, CT).

unit 4502, Hamden/Ansonia, Connecticut].

Study populations of recently introduced non-native insects such as the Asian longhorned beetle and the Asian gypsy moth have recently been established in the NERS quarantine laboratory in Ansonia, Connecticut. The Asian longhorned beetle is a distinctively marked inch-long beetle that has been introduced into metropolitan areas in untreated wooden packing materials from China. Its eggs, laid under the bark of broadleaved trees, hatch into larvae that bore into the sapwood of shade trees such as maples, poplars, and willows (chiefly), as well as horsechestnuts, mulberries, birches, and elms. The emerging adults drill dime-sized holes to exit the trees. After repeat-

Technicians transferring Asian longhorned beetle larvae at the NERS quarantine laboratory (Melody Keena, Hamden/Ansonia, CT).

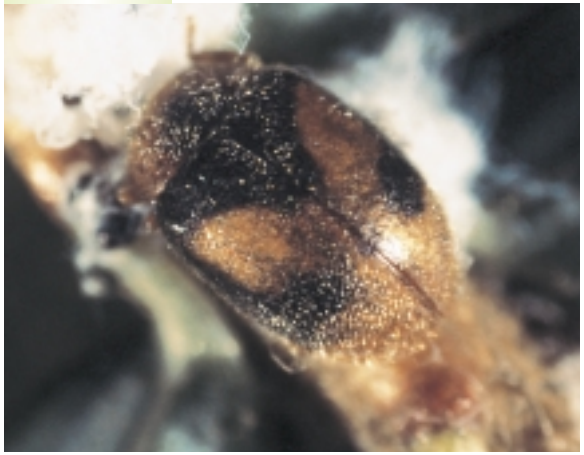
ed attacks, infested trees die. So far, outbreaks have been in cities. It is feared that these beetles could kill up to one-fourth of the shade trees in U.S. cities and urban residential areas. If the beetles become established in the countryside and forests, attacks on sugar maples could have serious economic impacts on the production of maple syrup and on tourism associated with fall color.

Other alien pests are also being studied at the quarantine laboratory. The nun moth, a close relative of the gypsy moth, is a major defoliator of conifers in Europe and Asia and it is considered at high risk for introduction to North America. Scientists at the quarantine facility are doing advanced studies to determine its characteristics, life cycle, and methods for control. Extensive studies on the Asian strain of the gypsy moth have been completed and the colonies continue to be used for additional detailed studies in cooperation with U.S. and international scientists. The quarantine lab is also used to import and evaluate biological controls for the hemlock woolly adelgid, which is devastating native hemlocks in the Northeast. Two species of lady beetles from China, natural predators of this adelgid, are being studied with the hope that they can be released to prey upon it [Kathleen Shields, Melody Keena, and Michael Montgomery, unit 4501, Hamden/Ansonia, Connecticut].

What can we do about acid rain? How can we keep our forests healthy?

The detrimental effects of "acid rain" (more accurately, acid deposition) on U.S. and European forests have been talked about for many years, but the actual extent of the damage and the exact means of injury to trees have been obscure. However, an NERS scientist and collaborators at the University of Vermont have elucidated the biochemical mechanism in red spruce, a tree species that shows definitive injury from acid deposition (mostly highly acidic cloudy water at high altitudes). Their results

Lady beetle imported from China for biological control of hemlock woolly adelgid (Michael Montgomery, Hamden/Ansonia, CT).



High-elevation firs killed by insects (Mark Twery, Burlington, VT).

show that acid deposition leaches membrane-associated calcium, leading to cell membrane destabilization and increased susceptibility to freezing injury. This finding opens up many new directions for studying acid deposition's effects on the health of other species and what could be done to ameliorate its effects [Paul Schaberg, unit 4103, Burlington, Vermont].

Collecting sugar maple leaves for studies of the physiology and development of autumn color (Paula Murakami, Burlington, VT).

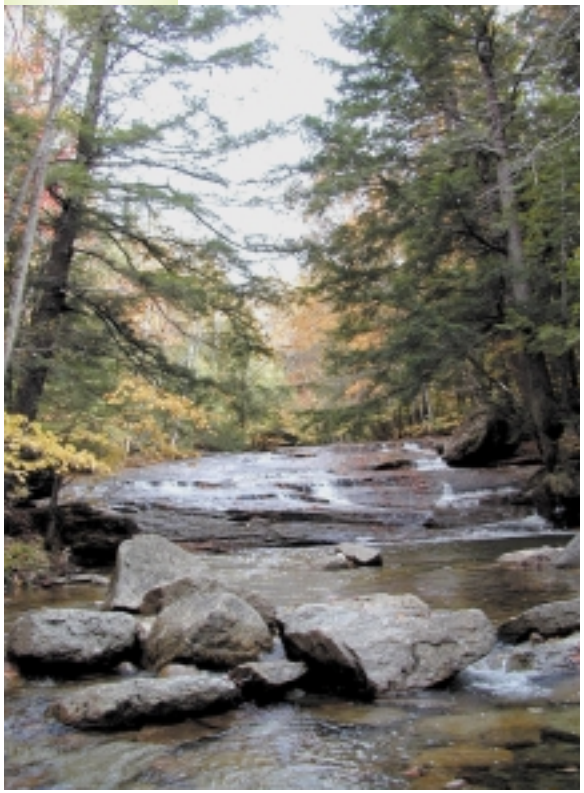
Sugar maple trees have been declining across the unglaciated Allegheny Plateau in northwestern and north central Pennsylvania since the early 1980's. An interdisciplinary team of Forest Service scientists and cooperators has been investigating the complex factors associated with this decline disease. A long-term liming study was established by NERS scientists in cooperation with the Pennsylvania Bureau of Forestry in 1985. Eleven years later, despite the adverse effects of defoliation and drought, it was evident that a single application of 10 tons/acre of dolomitic limestone on sugar maple stands increased flower and seed production, increased foliar concentrations of calcium and magnesium, and improved growth and vitality, as indicated by positive changes in three stress indicators. In addition, despite high levels of inoculum (rhizomorphs) of the Armillaria root disease fungus, this liming also reduced tree mortality. These results suggested that the distribution of base cations on the landscape was important to maintaining sugar maple health. Subsequent research on sites in northern Pennsylvania and southern New York showed that declining stands are those with low foliar magnesium and two or more moderate to

severe defoliations in the past 10 years. Additional research linking a network of 43 stands in Pennsylvania and New York with 40 stands in New England will analyze relationships of soil and foliar chemistry, tree growth, root and twig carbohydrates, and stress indicators. To assist land managers in identifying sites suitable for sugar maple, herbaceous indicator species are being developed from plant surveys in all stands. The station recently published *Sugar Maple Ecology and Health: Proceedings of an International Symposium* (GTR NE-261), which brings together the best information on the causes of a variety of recent declines in sugar maple, including those in Canada, Vermont, and Pennsylvania [Philip Wargo, unit 4505, Hamden, Connecticut; Scott Bailey, unit 4352, Richard Hallett, unit 4155, and Rakesh Minocha, unit 4505, Durham, New Hampshire; Robert Long, unit 4558, Delaware, Ohio; Susan Stout and Stephen Horsley, unit 4152, Warren, Pennsylvania; Betty Wong, unit 4103, Burlington, Vermont].

What can be done to help sustain forest resources for the next thousand years?

Riparian areas, where forests adjoin streams and other water bodies, protect water quality and aquatic habitat (as well as provide a variety of other products and amenities) by protecting the integrity of the soil and shading the streambed. Management of riparian areas has moved to the forefront because of conflicts between protection and the ever-increasing use they receive. Scientists from the Northeastern, North Central, and Southern Research Stations

New England mountain stream lined with hemlocks (Kenneth Dudzik, Durham, NH).



Grading hardwood lumber by measuring wood quality and assigning value (Jan Wiedenbeck, Princeton, WV).

recently wrote and edited a book that considers the problems presented by the many kinds of uses and ownerships of riparian areas. More importantly, the book also presents state-of-the-art guidelines for defining and managing riparian areas. Federal and state agencies and industrial and private landowners responsible for riparian resources are finding this book invaluable [*Riparian Management in Forests of the Continental Eastern United States* (New York: Lewis Publishers.) by James Hornbeck (with others), unit 4352, Durham, New Hampshire].

Can we find ways to use our wood more efficiently?

Secondary wood processors such as furniture, cabinet, and dimension manufacturers and wood flooring plants are frequently faced with questions and problems regarding the efficient use of hardwood lumber. These questions cover topics such as equipment setup, lumber grade mix to purchase and process, cutting bills (the list of part sizes and required quantities), and scheduling cutting operations. Until recently, the only way to answer these questions was to conduct mill studies, recording and analyzing data about the lumber processed and the parts produced—a time-consuming and sometimes inexact process. The ROMI-RIP 2.0 and ROMI-CROSS computer software packages allow secondary wood processors to examine many aspects of their operations through computer simulation and identify opportunities to use hardwood lumber more efficiently. More-efficient lumber processing helps to reduce the demands on the hardwood forest by producing more product per tree harvested. These simulators process digitized lumber data that include the location, size, and type of every defect per board, as well as the board's dimensions and grade. Another software package that has been released is the UGRS (ultimate grading and remanufacturing system) program, which processes the lumber databank and trains personnel in the grading of lumber according to the National Hardwood Lumber Association (NHLA) rules. UGRS can also be used to train personnel to optimize the edging and trimming of hardwood lumber, as well as provide a source of graded and/or re-manufactured lumber data to the rough mill simulators. To date, over 800 copies of these three software tools have been distributed to wood-processing firms, university researchers, and wood industry consultants [Edward Thomas and Betsy Porterfield (with university cooperators), unit 4701, Princeton & Morgantown, West Virginia].

Integration of the results from several cable and ground-based logging studies with those from several regeneration studies determined the most effective size of group-selection openings in northeastern hardwood forests. Results

suggest that land managers can maximize financial yields by using group-selection units of 1.25 acres or larger [Chris LeDoux, unit 4751, Morgantown, West Virginia].

The ice storm of 1998 devastated large areas of the northern hardwood forests of Vermont, New Hampshire, and Maine. There was great concern that harvesting damaged trees needed to be done in a timely enough manner that the wood could be used for lumber. However, studies by NERS scientists showed that loss of wood quality due to decay and discoloration resulting from the ice injury was highly localized and would spread at a rate slow enough to allow ample time to plan harvesting. Studies also showed the utility and speed of using digital imaging to record, transmit, and demonstrate the relationship of injury to damage [Walter Shortle and Kevin Smith, unit 4505, Durham, New Hampshire].

■ These advances are just some of the outstanding and significant research findings and technology transfer products finished and published in 1999. NERS scientists continue to carry out the station's mission—to develop and provide scientific information and technology to sustain forests and their uses. We serve our region and our clients by providing scientific leadership that benefits the people and woodlands of the northeastern United States. For over three-quarters of a century, we have served a diverse array of clients from public land management organizations to individual private landowners; non-government organizations to private industry; private forestry consultants to Native American tribal organizations; as well as a diverse array of federal organizations. We also have formed many research partnerships with universities and other research institutions, state departments of natural resources, the USDA Forest Service's National Forest System, and industry. ❖

Trees damaged by the 1998 ice storm (© Robin Twery, Burlington, VT).

Our Region & Its Challenges

The 13-state northeastern region served by the USDA Forest Service's Northeastern Research Station includes New England (Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut) plus New York, Pennsylvania, New Jersey, Delaware, Maryland, West Virginia, and Ohio. These states make up 7% of the nation's total land area (153 of 2,263 million acres) but contain 13% of its forests (93 of 737 million acres). Forests cover 61% (93 of 153 million acres) of the land in the 13-state area, and 6 of the nation's 10 most densely forested states are in the Northeast. Northeastern forests are primarily second- and third-generation forests resulting from historic harvest and agricultural practices. Extensive urban forests, a growing wildland–urban interface, and a high degree of forest fragmentation pose unique problems today.

Northeastern forest habitats range from the coniferous forests of Maine and the alpine mountaintops of Mt. Washington in New Hampshire to the highly diverse mixed mesophytic forests and the economically important oak forests of the Appalachian highlands of New York, Pennsylvania, Maryland, West Virginia, and Ohio. More than 120 tree species form the foundations for habitats that are home to a great diversity of flora and fauna and contribute to air and water quality in the region.

The northeastern region is both the most densely populated and most densely forested part of the country. People in the Northeast interact continually with the forest and its benefits, as water consumers, recreationists, forest dwellers, and in many other ways. The forests shelter watersheds that provide drinking water for the 69 million residents of the Northeast (28% of the U.S. population). The major watersheds in the Northeast include many major river systems: the Penobscot, Connecticut, Hudson, Delaware, Susquehanna, and Potomac Rivers along the Atlantic Coast; the upper reaches of the Ohio River watershed in Ohio, western Pennsylvania, and West Virginia; and smaller rivers along the northern parts of New York and Ohio that drain into the St. Lawrence River watershed.

Nearly 79 million acres (85%) of the northeastern forest are privately owned; of the 2.5 million owners, about half own 10 acres or less and 8,000 owners are industries. Forest industry is predominantly small and medium-sized companies, most of which have no in-house forest research capabilities. Forest-related industry contributes significantly to the economy of the region, and 25% of all forest industry wages in the United States are paid within this 12% of the nation's forested land area.

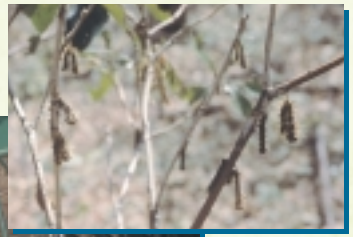
The Northeast's steadily increasing demand for recreation is met by a complex network of federal, state, county, and munici-

pal lands. Public lands are scarce, and the National Forest System plays a crucial role in sustaining dispersed recreation. New technologies have opened the forests for year-round use, and an aging population implies shifting attitudes toward forest management practices as well as changing participation patterns.

The Northeast has the highest proportion of urban land in the United States; 8 of the top 10 most urbanized states are located here. Urban vegetation and its management can significantly influence human health and environmental quality in and around cities. However, relatively little is known regarding these influences and what vegetation designs and management practices will optimize the net benefits to society from urban vegetation.

Demand for wood products from the NERS region is growing due to harvest limits in the West and production limitations in the South. New technologies have increased the use of hardwoods in new products, such as oriented strand board, laminated veneer lumber, and oriented strand lumber, which are direct substitutes for traditional softwood products used in construction applications. Non-industrial private forests provide the majority of timber for these and other uses. In the future, overseas demand for our timber products will increase because the United States is one of the few countries viewed to practice sustainable management in hardwoods. NERS is challenged to provide leadership and information to foster continued sustainable management and use of the forests in our region.

Historically, the Northeast has been the primary port of entry for many exotic forest pests such as gypsy moth, chestnut blight, Dutch elm disease, white pine blister rust, brown-tail moth, and beech bark disease, and more recently, dogwood anthracnose, pine shoot beetle, Asian gypsy moth, and Asian longhorned beetle. (The hemlock woolly adelgid, also a serious pest in the Northeast, invaded the East Coast in Virginia and has spread north.)



Knowledge and Helping Our Publics, Brick by Brick

Many of our research and development activities don't always produce keystones every year. On the contrary, many scientists spend years producing building blocks and laying courses of bricks. Finally, a structure can be discerned and then, wow, the findings can be seen to be part of a much larger whole. Forestry research usually takes several years, and sometimes even decades, to produce data. Here are some recent building blocks—findings that we hope will help us detect, understand, and deal with future conditions and problems.

Eastern hemlock branch infested with the hemlock woolly adelgid (Michael Montgomery, Hamden/Ansonia, CT).

Will "alien" pests continue to be introduced and devastate our forests?

Although the gypsy moth problem in the eastern United States has subsided temporarily, this pest has become increasingly important in the Midwest. Therefore, scientists continue to search for environmentally safe, biologically based technologies that can be used to manage gypsy moth populations throughout the current and projected ranges. Ten isolates of microsporidia, protozoal pathogens that infect gypsy moth larvae populations throughout their endemic range in Europe, have been recovered from nine countries in Europe and are being studied by classical and molecular techniques. Field trials are being conducted jointly with cooperators in the Slovak Republic to evaluate their efficacy. The ultimate goal is to introduce the best microsporidian isolate into gypsy moth populations in the United States to enhance the natural control of this pest [Michael McManus and others, unit 4502, Hamden/Ansonia, Connecticut].

As the gypsy moth continues to spread outside of the Northeast, NERS scientists continue to work to understand how the "spread front" moves forward. A mathematical model (developed by an NERS scientist and a cooperator) showing that isolated colonies jump forward and then coalesce to form a new front was validated by trap data. The model's prediction of 54% decrease in spread rate if isolated colonies were eradicated was closely matched by the 59% decrease in a pilot program that actually did eradicate isolated forward colonies [Andrew Liebhold,and others ,unit 4557, Morgantown, West Virginia].

What can we do about acid rain? How can we keep our forests healthy?

Protecting the health and long-term productivity of forest and aquatic ecosystems is a major goal of forest management and environmental policy. Potential changes in forest productivity and stream quality due to the interactive effects of acidic deposition and timber harvesting are determined by inherent site factors that influence the availability of base cations (that is, calcium and magnesium), aluminum mobilization, and nitrogen dynamics. In a study conducted at Hubbard Brook Experimental Forest and two other sites in New England, the chemical signature of forest streams was found to provide useful indices of nutrient status and cycling processes occurring in forested watersheds. For example, low concentrations of base cations (especially calcium) in streams suggest that watershed stores of this element may be depleted, possibly due to past disturbance or to low contributions from mineral weathering. Forest managers can use this information to help make informed decisions about the intensity and frequency of harvesting and to evaluate susceptibili-

Transporting harvested logs to mill (Kenneth Dudzik, Durham, NH).

ty of forest and stream ecosystems to atmospheric deposition [James Hornbeck and Scott Bailey, unit 4352, Durham, New Hampshire].

How can forests help mitigate the buildup of carbon dioxide in the atmosphere?

The amount of carbon that U.S. forest ecosystems can sequester has been estimated and the forestry implications of the Kyoto Protocol to limit greenhouse gases have been analyzed. The U.S. forest carbon budget is used by the U.S. Departments of Agriculture, Energy, and State, the Environmental Protection Agency, and the Council of Economic Advisors as well as forest industry and others in developing a U.S. policy position [Linda Heath, unit 4104, Durham, New Hampshire; Richard Birdsey, John Hom, and others, Northern Global Change Program, units NE & NC 4455, Newtown Square, Pennsylvania].

Coarse woody debris plays a significant role in the forest ecosystem, from sequestering carbon to providing habitat for smaller organisms and wildlife. A promising new method for quantifying downed coarse woody material—point relascope sampling—has been developed [Jeffrey Gove, unit 4104, Durham, New Hampshire.

Active intensive forest management will be required to sustain healthy forest ecosystems that will provide a multitude of values, to many users, on a shrinking forest land base. Application of proper silviculture techniques that will meet the biological requirements of preferred species will be necessary to sustain species diversity. Culture practices such as crop tree release can be used to regulate species composition and enhance growth rates of desirable trees. Proper use of best management practices (BMP's) during timber harvesting activities will reduce adverse impacts to soil and water resources to acceptable levels [Mary Beth Adams, unit 4353, Parsons, West Virginia].

As people demand many diverse benefits from their forest lands, management decisions are becoming more and more complex. The NED family of software tools are helping landowners and resource managers understand the tradeoffs among their goals of wildlife habitat, watershed protection, recreation, forest health, and timber production. Now in use by hundreds of forestry consultants and others around the Northeast, the NED programs allow users to analyze the benefits provided by the lands they manage. The newly distributed NED-1 program provides ways to analyze alternative strategies on small and large forest lands and is enabling resource managers to make better informed decisions [Mark Twery and others, unit 4454, Burlington, Vermont; Susan Stout and others, unit 4152, Warren, Pennsylvania; and James Hornbeck, unit 4352, Durham, New Hampshire].

The computer simulation model FIBER (forest increment based on ecological rationale) was used as a comprehensive analytical tool to grow the mixed species forests of Maine and construct yields of future wood availability. FIBER provided the baseline growth assessment and followed species succession for different ecological habitats in the *Timber Supply Outlook for Maine, 1995–2045*. Using FIBER, this technical assessment examined the long-term sustainability balance between growth and harvest [Dale Solomon, unit 4104, Durham, New Hampshire].

Can we find ways to use our wood more efficiently?

A recent study that examined what hardwood inventory statistics actually mean, compared to how such statistics are interpreted by industry and academic users, found two major inconsistencies. Inventory statistics only include trees that are or have the potential to be sawtimber. Cull trees, cull portions of trees, and tree tops are not included. Much of the material excluded from inventory can be used by fiber-based industry, the fastest-growing segment of the market. Therefore, any analysis of the impact of fiber-based industries on the eastern forest must first account for this material. Another statistic that is commonly misinterpreted is the growth–drain ratio. This ratio represents long-term averages and not current harvesting activities. Because harvesting activity has increased over time, this long-term average tends to underestimate the effects of current harvesting levels on the hardwood sawtimber inventory [William Luppold, unit 4805, Princeton, West Virginia; William McWilliams, unit 4801, Newtown Square, Pennsylvania].

Few furniture, cabinet, and millwork producers manufacture products that utilize sound, naturally occurring wood characteristics, also know as "defects." Furniture designers have traditionally driven market preferences by limiting their wood product designs to clear wood elements with specific colors and grain patterns. Our research findings indicate that significant increases in lumber utilization rates are achievable (3 to 11% higher product yields) when sound character marks are retained in wood sections for incorporation into furniture and other such wood products. These findings were based on comprehensive yield studies using the ROMI-RIP and ROMI-CROSS programs. These results were recently substantiated in a case study in a modern mill. By discovering and describing how large the yield increases due to character-mark inclusion in parts can be, we hope industry will seek opportunities to produce furniture parts with character-marks. Because the furniture and related industries utilize about 30% of all harvested roundwood, the resource impact of improved utilization of lumber as it is

Portable sawmill (Kenneth Dudzik, Durham, NH).

cut up into furniture parts is very important [Jan Wiedenbeck and Edward Thomas (with university cooperators), unit 4701, Princeton, West Virginia].

What do consumers think of character-marked wood products? Results of a survey suggest that many consumers find other cabinet attributes such as wood species and color to be more important to product evaluations than the presence of character. This suggests that opportunities exist for increased use of character-marked wood. However, for a smaller subset of consumers, the presence of character was quite important to product evaluations. Opportunities among this group seem to be limited to use of light of subtle character [Cynthia West (formerly with unit 4803) and Matthew Bumgardner (with university cooperators), unit 4803, Princeton, West Virginia].

Can trees help make our cities more liveable?

Modeling the effects of increased urban tree cover on ozone concentrations from Washington, DC, to central Massachusetts revealed that urban trees generally reduce ozone concentrations in cities but tend to slightly increase average ozone concentrations in the overall modeling domain, particularly downwind of cities. Interactions of the effects of trees on the physical and chemical environment demonstrate that trees can cause changes in pollution removal rates and meteorology (particularly air temperatures, wind fields, and boundary layer heights), which, in turn, affect ozone concentrations [David Nowak, Daniel Crane, and others, unit 4952, Syracuse, New York].

How can we use our parks and forests wisely?

The Northeast is one of the most densely populated regions of the country, with a high demand for recreation creating numerous and increasing management challenges. The Northeast is filled with significant recreation resources, including the White Mountain and Green Mountain/Finger Lakes National Forests and the Adirondack Park, and recreation is a key component of the economy in many northeastern states. Recently, the unit has determined that user fees increase the public's expectations about the level of services provided; developed basic categories for describing human responses to recreation activities; determined that 85% of the economic value of eastern wilderness is attributable to non-use values (existence, option, and bequest values); and developed frameworks for understanding the public's ethical concerns associated with wildlife management [Thomas More, unit 4454, Burlington, Vermont]. ❖

The Mission of Forest Service Research and Development

The Northeastern Research Station is one of six regional research groups—the North Central, Northeastern, Pacific Northwest, Pacific Southwest, Rocky Mountain, and Southern Research Stations—as well as the Forest Products Laboratory and the International Institute of Tropical Forestry that are the Research and Development arm of the USDA Forest Service (FS R&D).

FS R&D is one of the world's leading forestry research organizations, conducting and sponsoring basic and applied research. The research generates credible, relevant knowledge and exciting new technologies that can be used to sustain the health, productivity, and diversity of the nation's forests and rangelands to meet the needs of present and future generations. Creating and communicating knowledge and technology to private landowners so they can better sustain the health, productivity, and diversity of their lands is as important to FS R&D as is serving the needs of public land managers.

The Goals of Northeastern Research Station

We have recently reframed our mission and goals and are moving forward with new projects as well as continuing with on-going projects and the invaluable decades-long ecosystem studies and environmental monitoring carried out on the northeastern experimental forests. In doings so, we are working within the framework of the following five goals:

- Goal I: Develop and deliver guidelines to help landowners and timber users sustain the aesthetic, ecological, fish and wildlife, recreation, timber, and water values of the mostly-privately-owned northeastern forest.
- Goal II: Develop and deliver basic and applied information about the effects of single and multiple stressors, such as air pollution, global change, and insect and disease problems, on watershed and ecosystem processes.
- Goal III: Develop and deliver information about the relationships between urban forests and quality of life.
- Goal IV: Develop and deliver information about social and economic values and their relationships to forest resource management and use.
- Goal V: Inventory and continue to monitor status, trends, and health of the northeastern forest and its use by forest industry.

Renovating Old Assignments, Laying the Foundations for New Projects, and Looking to the Future

Open-top chambers used to study the effects of ozone and carbon dioxide on tree growth (Robert Long, Delaware, OH).

In this past year, a number of organizational and physical "renovations" have been completed. They range from physical relocation to organizational merger, from establishment of a new monitoring network to involving the public in the decision about the future of an experimental forest. All these accomplishments, which involved considerable effort and personnel, have laid the foundations of new and revised activities and research that will produce real results in the future.

The USDA Forest Service's Northeastern Research Station headquarters was moved to a new building in Newtown Square, Pennsylvania. The director's office, administration staff, the Northern Global Change unit, and the Forest Inventory Analysis and Forest Health Monitoring units have recently settled into a new office building that is shared with the headquarters staff of the USDA Forest Service's Northeastern Area of State and Private Forestry.

As mandated by the 1998 Congress, the Forest Inventory and Analysis (FIA) and Forest Health Monitoring (FHM) units have been reorganized. The detection function and plot network of FHM (which made up 90% of FHM activities) are now part of the FIA inventory function. This allows FHM personnel to concentrate on their research activities, which are (1) evaluation of problems, (2) intensive site monitoring of problem sites, and (3) research on monitoring technology. In response to the needs of users and the mandate of the Congress, the now-enhanced FIA has just completed the reorganizing necessary to begin annual inventories of U.S. forest resources. Previously, inventories of several entire states in the region were taken each year, at 10-year intervals. Each year the staff inventoried several states and released reports every 10 years. The resultant data were thus only accurate for a few years, and then of declining value until the next inventory. Reports were thus off-schedule, inconsistent nationally, and late. Now, 20% of the lands of each state in the region are inventoried each year and the data are compiled annually. Reports of all the data will be released every 5 years. In addition, because all the lands in the states will be inventoried, the report will give users a much-improved sense of the total picture [Charles Scott and staff, FIA & FHM, Newtown Square, Pennsylvania].

Despite the fact that the majority of the U.S. population lives in metropolitan areas, cities and their surrounding suburban and rural lands have not been studied as ecosystems. To gain better understanding of this important part of our environment, scientists from the Northeastern Research Station, in partnership with the Institute of Ecosystem Studies, the University of Maryland, Baltimore County, and numerous other cooperators, are now working together as

the Baltimore Long-Term Ecosystem Research Program, sponsored by the National Science Foundation. The study will examine how metropolitan Baltimore works ecologically and sociologically over the long term [Kenneth Belt, Gordon Heisler, David Nowak, Richard Pouyat, and Wayne Zipperer, unit 4952, Syracuse, New York; Morgan Grove, unit 4454, Burlington, Vermont; and John Hom, Northern Global Change Program, Newtown Square, Pennsylvania].

As the largest block of public land in southern Maine, the Massabesic Experimental Forest is the subject of much local interest. The scientists who administer and conduct research there, in cooperation with the Maine Forest Service, the York County Soil & Water Conservation District, LaValley Lumber Co., and the Town of Alfred's Conservation Commission, have developed a series of trails and trail guides. Demonstrations of good forestry practice have been integrated into the research program. Recently, local residents have volunteered to assist in taking baseline inventories of all the plants in recently established permanent plots [John Brissette and others, unit 4155, Durham, New Hampshire].

Three research units of the NERS are now partners with the USDA Forest Service's State & Private Forestry in the newly formed Institute of Hardwood Technology Transfer and Applied Research. The institute works to (1) provide a resource center and clearinghouse for technology transfer and training programs; (2) foster collaboration for problem-solving and applied research; (3) carry out applied research in wood utilization that supports sustainable forestry, forest industries, and rural communities. Research results of these units are described above [units 4701, 4803, & 4805, Princeton, West Virginia].

Conclusions

In closing, we hope that we have built for you a booklet that helps you to understand the services that we at the USDA Forest Service's Northeastern Research Station provide with your support. We hope to produce this report on the station's research and development work annually. We appreciate your comments—let us know if the issues, content, and format have been informative and helpful (or not!) and if there are any other topics that you would like to know about. ❖

Field Research Sites

The USDA Forest Service's experimental forests are dedicated to long-term research on ecosystem processes, silviculture and forest management options, wildlife habitat characteristics and forest growth and development. The Hubbard Brook Experimental Forest, with its 43-year-old data sets on watershed hydrology and nutrient cycling, has been designated by the National Science Foundation as 1 of only 19 long-term ecological research sites in the world. Other experimental forests have 50-year-old environmental data (Fernow EF) and 60-year-old silvicultural data (Bartlett EF). Many scientists from the Northeastern Research Station and a large number of cooperating scientists conduct research the following experimental forests in the Northeast.

- Bartlett Experimental Forest, New Hampshire
- Fernow Experimental Forest, West Virginia
- Hubbard Brook Experimental Forest, New Hampshire
- Kane Experimental Forest, Pennsylvania
- Massabesic Experimental Forest, Maine
- Penobscot Experimental Forest, Maine
- Silas Little Experimental Forest, New Jersey
- Vinton Furnace Experimental Forest and Raccoon Ecological Management Area, Ohio

The Northeastern Research Station and the Eastern Region (9) of the National Forest System jointly administer the following six research natural areas:

- The Bowl, Alpine Gardens, and Nancy Brook Research Natural Areas, White Mountain National Forest, New Hampshire
- Reas Run Research Natural Area, Wayne National Forest, Ohio
- Tionesta Research Natural Area, Allegheny National Forest, Pennsylvania
- The Cape Research Natural Area, Green Mountain National Forest, Vermont

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Resources:

No. of research work units (RWU's): 22
No. of research locations: 12
No. of paneled scientists: 82
No. of scientist-years (SY's): 90

Productivity:

Percent of FIA phase 2 and phase 3 plot measured annually: 11

No. of RWU publications (refereed + non-refereed): 349

No. of tours given to educational and professional groups: 164

No. of short courses/training sessions given to educational or professional groups (for example, workshop presentations, demonstrations): 132

No. of videos and/or slide presentations made on research findings: 198

Quality:

No. of publications in refereed journals: 130

No. of non-refereed publications (for example, NERS general technical reports, research papers, resource bullletins, research notes, and newsletters): 219

No. of invited presentations before scientific societies: 127

No. of presentations to lay organizations: 120

No. of leadership posts held in scientific societies*: 31

R&D participation (percentage of effort) in technology transfer activities (including workshops, presentations, training sessions, field visits, assessments): . .17.2

Development of new inventory technology (SY's or effort, technologies developed and applied): 1.4

Number of research products, tools, and technologies transferred to users: 552

*** Key societies:**
Entomological Society of America
Connecticut Entomological Society
West Virginia Partner-In-Flight
Soil Science Society of America
International Union of Forest Research Organizations (IUFRO)
Urban Ecosystems (associate editor)
Natural Areas Journal (associate editor; book review editor)
American Society of Plant Physiology
Society of American Foresters
Pennsylvania Forestry Association (board member)
Association of American Geographers
Ecological Society of America
International Association of Landscape Ecologists

Our Station's Organization, Facilities, and People

At research sites in 10 states—Hamden/Ansonia, CT; Amherst, MA; Durham, NH; Baltimore, MD; Bradley, ME; Syracuse, NY; Warren and Newtown Square, PA; Delaware, OH; Burlington, VT; and Morgantown, Parsons, and Princeton, WV—90 permanent (plus 14 temporary & term) scientists (in 28 scientific specialties) supported by 113 technical and professional and 62 management and administrative personnel work to carry out our research goals.

NERS scientists work in a wide variety of research sites all over and even outside the Northeast. They conduct research in 8 experimental forests, including several with long-term data sets that are unique to science, and in 6 research natural areas, sited on National Forest System lands (see page 20). Also unique to the NERS is the Forest Service's only primary quarantine laboratory on the continental United States (at the Hamden/Ansonia, CT, Center for Forest Health Research), a facility certified for biological control research on exotic forest pests and their natural enemies (see pages 4–5).

CONNECTICUT

Hamden/Ansonia

The Role of Forest Insect Biology and Biocontrol in Maintaining Forest Health (NE-4501) Kathleen Shields, project leader, USDA Forest Service, Northeastern Research Station, Northeastern Center for Forest Health Research, 51 Mill Pond Road, Hamden, CT 06514-1703; tel: 203-230-4330; e-mail: kshields@fs.fed.us

Pathology and Microbial Control of Insects That Impact the Health of Eastern Forests (NE-4502) Michael L. McManus, project leader, USDA Forest Service, Northeastern Research Station, Northeastern Center for Forest Health Research, 51 Mill Pond Road, Hamden, CT 06514-1703; tel: 203-230-4322; e-mail: mlmcmanus@fs.fed.us

Disturbance of Eastern Forest Ecosystems by Stressor/Host/Pathogen Interactions (NE-4505) (2 scientists at Hamden, CT, plus 3 scientists at Durham, NH) Philip M. Wargo, project leader, USDA Forest Service, Northeastern Research Station, Northeastern Center for Forest Health Research, 51 Mill Pond Road, Hamden, CT 06514-1703; tel: 203-230-4304; e-mail: pwargo@fs.fed.us

MASSACHUSETTS

Amherst

Wildlife and Fish Habitat Relationships in New England Forests (NE-4251) Richard M. DeGraaf, project leader, USDA Forest Service, Northeastern Research Station, University of Massachusetts, Holdsworth Hall, P.O. Box 34230, Amherst, MA 01003-4230; tel: 413-545-0357; e-mail: rdegraaf@fs.fed.us

NEW HAMPSHIRE

Durham

Measurement, Analysis, and Modeling of Forest Ecosystems in a Changing Environment (NE-4104) Dale S. Solomon, project leader, USDA Forest Service, Northeastern Research Station, Louis C. Wyman Forestry Sciences Laboratory, 271 Mast Road, Durham, NH 03824-0640; tel: 603-868-7666; e-mail: dsolomon@fs.fed.us

Ecology and Management of Northern Forest Ecosystems (NE-4155) John Brissette, project leader, USDA Forest Service, Northeastern Research Station, Louis C. Wyman Forestry Sciences Laboratory, 271 Mast Road, Durham, NH 03824-0640; tel: 603-868-7632; e-mail: jbrissette@fs.fed.us

Ecological Processes: A Basis for Managing Forests and Protecting Water Quality in New England (NE-4352) Christopher Eagar, project leader, USDA Forest Service, Northeastern Research Station, Louis C. Wyman Forestry Sciences Laboratory, 271 Mast Road, Durham, NH 03824-0640; tel: 603-868-7636; e-mail: ceagar@fs.fed.us

Disturbance of Eastern Forest Ecosystems by Stressor/Host/Pathogen Interactions (NE-4505) (2 scientists at Hamden, CT, plus 3 scientists at Durham, NH) Philip M. Wargo, project leader, USDA Forest Service, Northeastern Research Station, Northeastern Center for Forest Health Research, 51 Mill Pond Road, Hamden, CT 06514-1703; tel: 203-230-4304; e-mail: pwargo@fs.fed.us

NEW YORK

Syracuse

Effects of Urban Forests and Their Management on Human Health and Environmental Quality (NE-4952) David J. Nowak, project leader, USDA Forest Service, Northeastern Research Station, c/o SUNY—CESF, 5 Moon Library, Syracuse, NY 13210-2778; tel: 315-448-3212; e-mail: dnowak@fs.fed.us

OHIO

Delaware

Quantitative Methods for Modeling and Monitoring Response of Northeastern Forest Ecosystems to Management and Environmental Stresses (NE-4153) Daniel A. Yaussy, project leader, USDA Forest Service, Northeastern Research Station, 359 Main Road, Delaware, OH 43015-8640; tel: 740-368-0101; e-mail: dyaussy@fs.fed.us

Development of Biologically Based Controls for Forest Insect Pests and Diseases Through Molecular Technologies (NE-4509) James M. Slavicek, project leader, USDA Forest Service, Northeastern Research Station, 359 Main Road, Delaware, OH 43015-8640; tel: 740-368-0033; e-mail: jslavicek@fs.fed.us

Multiple Stress Interactions and Their Effects on Forest Health and Sustainability (NE-4558) Robert P. Long, project leader, USDA Forest Service, Northeastern Research Station, 359 Main Road, Delaware, OH 43015-8640; tel: 740-368-0050; e-mail: rlong@fs.fed.us

PENNSYLVANIA

Newtown Square

Forest Inventory and Analysis and Forest Health Monitoring Charles T. "Chip" Scott, program manager, USDA Forest Service, Northeastern Research Station, USDA Forest Service, 11 Campus Boulevard, #200, Newtown Square, PA 19073; tel: 610-557-4021; e-mail: ctscott@fs.fed.us

Northern Global Change Research Program (NE-4455 & NC-4455) Richard A. Birdsey, program manager, USDA Forest Service, Northeastern Research Station, USDA Forest Service, 11 Campus Boulevard, #200, Newtown Square, PA 19073; tel: 610-557-4092; e-mail: rbirdsey@fs.fed.us

Warren

Understanding and Managing Forest Ecosystems of the Allegheny Plateau Region (NE-4152) Susan L. Stout, project leader, USDA Forest Service, Northeastern Research Station, Forestry Sciences Laboratory, P.O. Box 267, Irvine, PA 16329-0267; tel: 814-563-1040; e-mail: sstout@fs.fed.us

VERMONT

Burlington

The Role of Environmental Stress on Tree Growth and Development (NE-4103) Mel T. Tyree, project leader, USDA Forest Service, Northeastern Research Station, George D. Aiken Forestry Sciences Laboratory, P.O. Box 968, Burlington, VT 05402-0968; tel: 802-951-6771, ext. 1310; e-mail: mtyree@fs.fed.us

Integrating Social and Biophysical Sciences for Natural Resource Management (NE-4455) Mark J. Twery, project leader, USDA Forest Service, Northeastern Research Station, George D. Aiken Forestry Sciences Laboratory, P.O. Box 968, Burlington, VT 05402-0968; tel: 802-951-6771, ext. 1040; e-mail: mtwery@fs.fed.us

WEST VIRGINIA

Morgantown

Disturbance Ecology and Management of Oak-Dominated Forests (NE-4557) Kurt W. Gottschalk, project leader, USDA Forest Service, Northeastern Research Station, 180 Canfield Street, Morgantown, WV 26505-3101; tel: 304-285-1598; e-mail: kgottschalk@fs.fed.us

Forest Engineering Research: Systems Analysis to Evaluate Alternative Harvesting Strategies (NE-4751) Chris B. LeDoux, project leader, USDA Forest Service, Northeastern Research Station, 180 Canfield Street, Morgantown, WV 26505-3101; tel: 304-2851572; e-mail: cledoux@fs.fed.us

Parsons

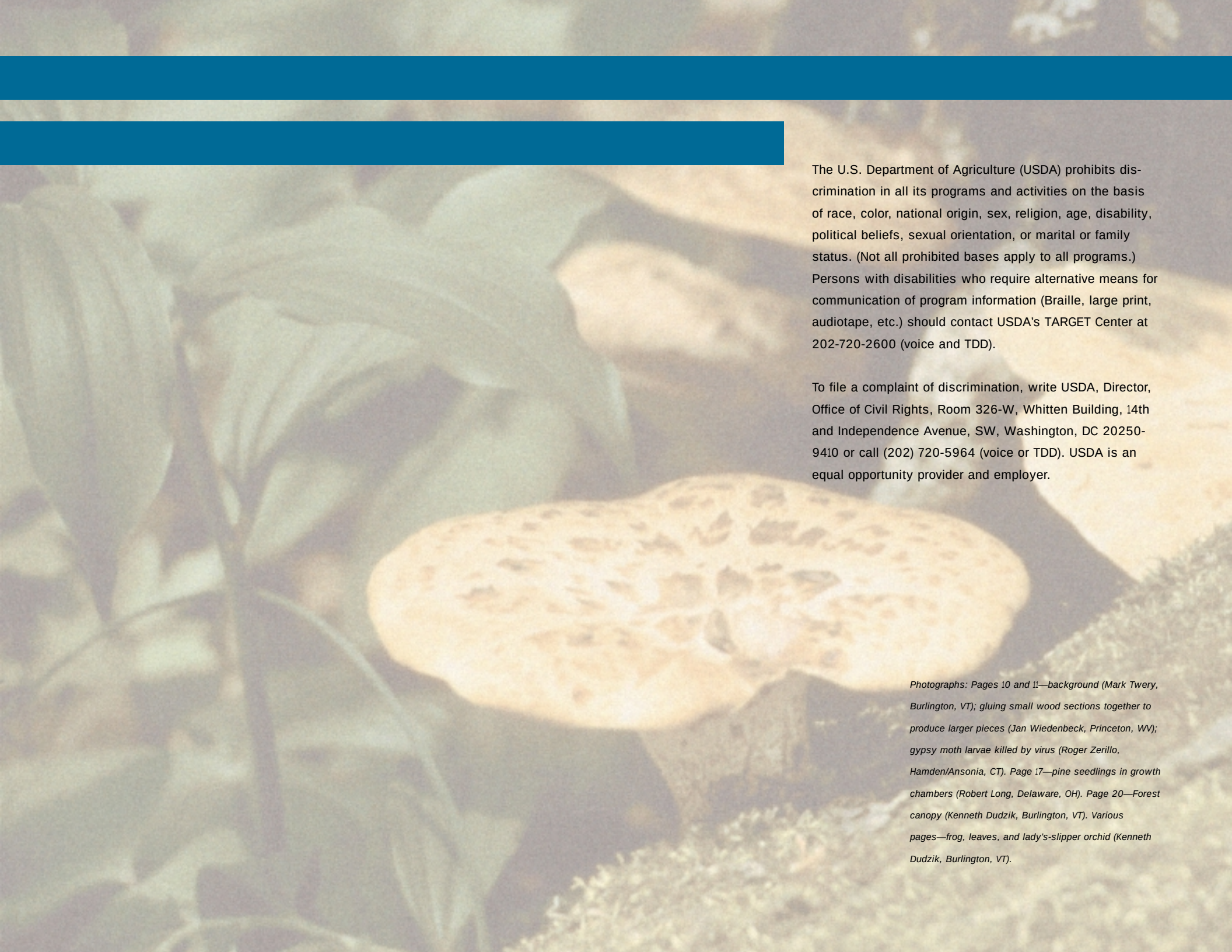
Sustainable Forest Ecosystems in the Central Appalachians (NE-4353) Mary Beth Adams, project leader, USDA Forest Service, Northeastern Research Station, Timber and Watershed Laboratory, P.O. Box 404-Nursery Bottom, Parsons, WV 26287-0404; tel: 304-478-2000; e-mail: mbadams@fs.fed.us

Princeton

Efficient Use of the Northern Forest Resource (NE-4701) John Baumgras, project leader, USDA Forest Service, Northeastern Research Station, Forestry Sciences Laboratory, 241 Mercer Springs Road, Princeton, WV 24740-9628; tel: 304-431-2701 or 304-285-1575; e-mail: jbaumgras@fs.fed.us

Economics of Eastern Forest Use (NE-4803) Bruce G. Hansen, project leader, USDA Forest Service, Northeastern Research Station, Forestry Sciences Laboratory, 241 Mercer Springs Road, Princeton, WV 24740-9628; tel: 304-431-2739; e-mail: bghansen@fs.fed.us

Enhancing the Performance and Competitiveness of the U.S. Hardwood Industry (NE-4805) William Luppold, project leader, USDA Forest Service, Northeastern Research Station, Forestry Sciences Laboratory, 241 Mercer Springs Road, Princeton, WV 24740-9628; tel: 304-431-2770; e-mail: wluppold@fs.fed.us



Photographs: Pages 10 and 11—background (Mark Twery, Burlington, VT); gluing small wood sections together to produce larger pieces (Jan Wiedenbeck, Princeton, WV); gypsy moth larvae killed by virus (Roger Zerillo, Hamden/Ansonia, CT). Page 17—pine seedlings in growth chambers (Robert Long, Delaware, OH). Page 20—Forest canopy (Kenneth Dudzik, Burlington, VT). Various pages—frog, leaves, and lady's-slipper orchid (Kenneth Dudzik, Burlington, VT).

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