COMPASS

perspectives & tools to benefit southern forest resources from the southern research station

issue 11

Return of the American Chestnut

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Cover photo: *Photo showing the three distinctive nuts contained in the American chestnut burr. (Photo by Joe Schibig, courtesy of The American Chestnut Foundation)*

COMPASS

Science You Can Use!

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perspectives and tools to benefit southern forest resources

COMPASS is published by the Science Delivery Group of the Southern Research Station (SRS), Forest Service, U.S. Department of Agriculture. As part of the Nation's largest forestry research organization—Forest Service Research and Development—SRS serves 13 Southern States and beyond. The Station's 130 scientists work at more than 20 units located across the region at Federal laboratories, universities, and experimental forests.

Future issues can be obtained by returning the postcard included in this issue.

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An American chestnut tree in West Salem, WI, planted outside the chestnut's natural range in the early 1900s by settlers. Under the tree are, from left: TACF president and CEO Marshal Case, Dr. Cameron Gundersen, and Bruce Gabel. (Photo courtesy of Daphne Van Schaick)

American Chestnut and Beyond

by Jim Reaves and Zoë Hoyle

You might wonder why we would devote an entire issue of *Compass* to the American chestnut. As you will read, American chestnut was an important part of everyday life for millions of people almost a century ago, a magnificent tree—tall and spreading—and an integral component of a forest ecosystem that provided habitat and abundant food sources for animals and people. But why should we devote research time and money to a tree that's now mostly a memory?

The death of the American chestnut across the Eastern United States was just the beginning of a series of decimations of great American trees by pathogens and pests not native to our climate and ecosystem. These "nonnative invasives," as we call them right now, are brought in inadvertently—on landscape plants (or as landscape plants), in shipments of goods, inside tires, even on the shoes of travelers. Once here, they're unhampered by the organisms that kept them in check in their native lands, and can move quickly through our forests, laying low chestnut, elm, ash, oak—in some cases, tipping the ecological balance toward yet more invasions.

How will we respond as these invasions continue, possibly accelerated by global climate change? How can we keep our native forests vital and diverse, graced with the tall old trees that we've written and sung about, that built our ancestors' houses, provided shade and food, and nurtured them spiritually? Since the turn of the century, we've lost almost all of the magnificent chestnut trees to the chestnut blight. Monumental strides have been made to bring these trees back to forests. Now that we've been somewhat successful in bringing these trees back, how can we keep them and other foundation species—those that define a forest—intact in the face of further invasions?

"The death of the American chestnut across the Eastern United States was just the beginning of a series of decimations of great American trees by pathogens and pests not native to our climate and ecosystem."

As a result of long years of research and the traditional crossbreeding program started by **The American Chestnut Foundation** (TACF), there will soon be blight-resistant American chestnut seedlings (at least 94 percent pure) available for planting throughout the tree's former range. While breeders were patiently searching forests for pollen-producing trees and pollinating by hand on research farms, the science of genetics and genomics came of age. Genetic research by our own Station scientists is providing growers with diagnostics to make crossbreeding more effective and precise, while genetic studies on the chestnut blight fungus itself—and its relationship with a virus—are providing fundamental information about how the pathogens that invade trees evolve and interact among themselves. Another SRS scientist looks into the very chromosomes of tree cells to find out why a particular hybrid won't grow or reproduce.

While other SRS scientists study how well both pure and hybrid American chestnut seedlings do on a range of sites, they're gathering the data that will guide the planting of trees in the future. They're also adding data to that long-term record of disturbance and regrowth in American forests that the Forest Service started collecting over a century ago—data that's coming into its own in computer models that predict where best to plant trees after a major disturbance. Other models are designed for rapid risk assessment, to let us know about a major invasion such as chestnut blight before it's too late to do anything about it.

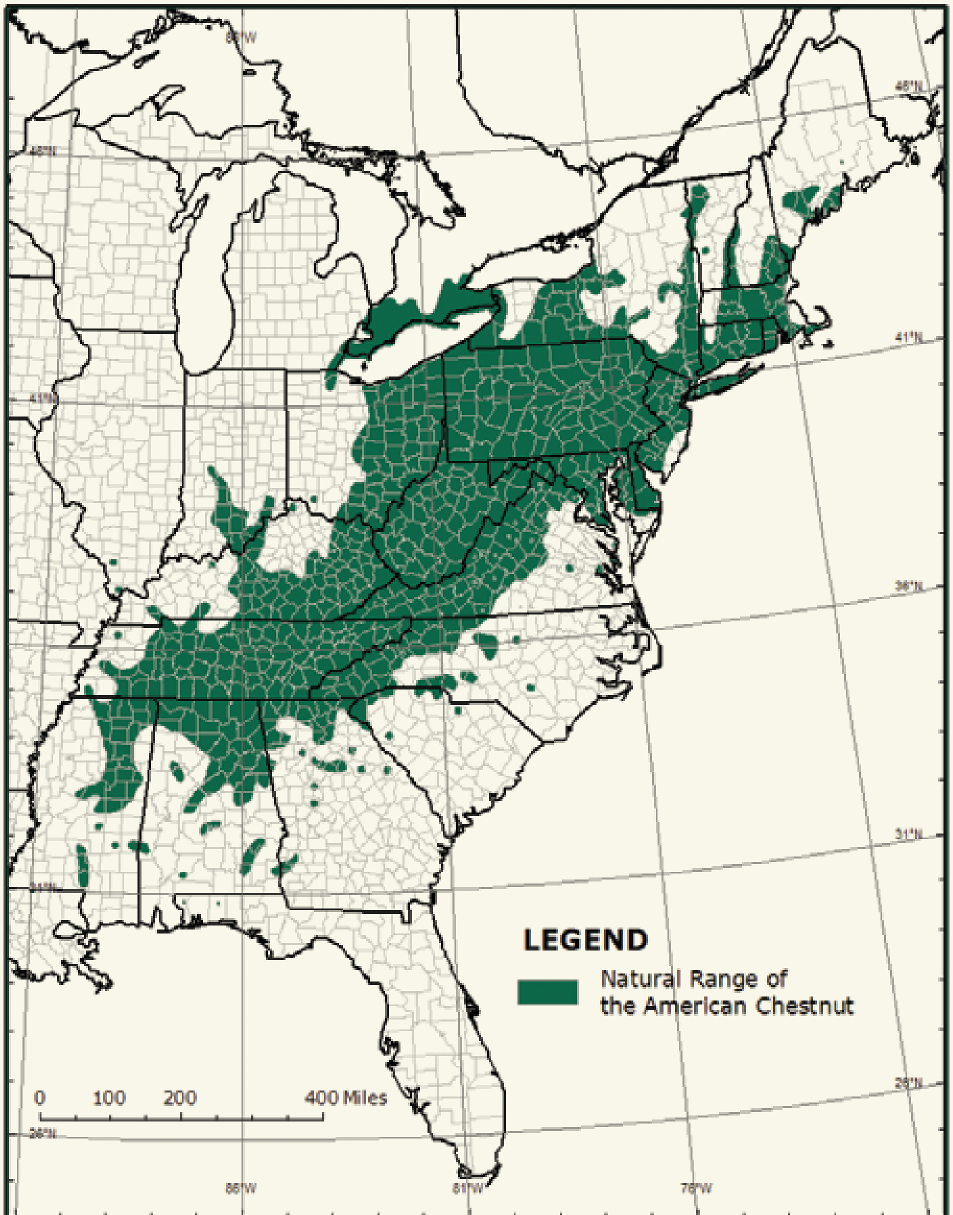
This issue of *Compass* celebrates the 25th anniversary of TACF, itself the culmination of decades of effort by thousands of individuals. We hope that what we've learned about bringing back this great American tree, especially what we're learning in the accelerating world of tree genetics, can help us figure out how to move more rapidly in the future—how to keep chestnut, hemlock, oak, ash, and elm in our forests as the invasions and disturbances continue.

The American Chestnut Foundation

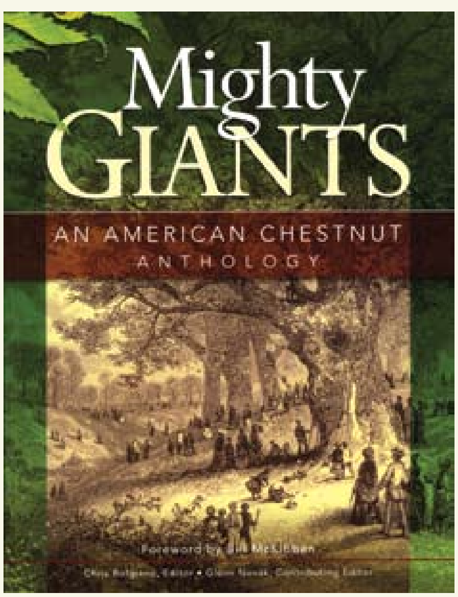
The goal of **The American Chestnut Foundation** (TACF) is to restore the American chestnut tree to its native range within the woodlands of the Eastern United States using scientific research and the breeding program developed by its founders. TACF harvested its first blight-resistant nuts in 2005, and will begin reforestation trials with blight-resistant American-type trees before the end of this decade. The return of the American chestnut to its former niche in the Appalachian hardwood forest ecosystem is a major restoration project which has involved research and sustained funding, but most importantly, the hopes and service of thousands of dedicated members and individual volunteers.

For more information:

TACF: www.acf.org/history.php



The natural range of the American chestnut (Castanea dentata) *extended from Mississippi to southern Ontario and as far northeast as Maine. (Map courtesy of The American Chestnut Foundation)*



Mighty Giants

With the publication of its first book, *Mighty Giants: An American Chestnut Anthology*, **The American Chestnut Foundation** has brought to life, in words and pictures, the story of the American chestnut tree over the last century. From Native Americans and early explorers, to colonists, naturalists, loggers, and industrialists—from presidents, poets, and artists, including Jefferson, Lincoln, Carter, Thoreau, Frost, and Wyeth—the story of the once mighty native chestnut tree is a lesson for our times. It is ultimately a story of how people, working together, can harness the power of community, scientific knowledge, and our growing awareness of the workings of nature to make a difference.

For ordering information:

www.acf.org/

THE AMERICAN CHESTNUT: A LEGACY TO COME

by Meghan Jordan

"In the youth of a man not yet old, native Chestnut was still to be seen in glorious array—the great forest below waving with creamy white Chestnut blossoms in the crowns of the ancient trees, so that it looked like a sea with white combers plowing across its surface." *—Naturalist Donald Culross Peattie*

You can still see American chestnut trees in the forests of the Southern Appalachians, but most are small, mere echoes of the giants that once fed wildlife and livestock and provided that famous spreading shade for farmhouses and city streets alike. In the first half of the 20th century, nearly 4 billion of these iconic trees were felled by a lethal fungus known as chestnut blight, and southern forests and their inhabitants were transformed by what has been called one of the greatest ecological disasters of all time.

The American chestnut tree grew tall and straight—80 feet or more high and several feet in diameter—and was often free of branches for the first 50 feet or so. Because of its strong wood, the chestnut was known in the Southern Appalachians as a "cradle-to-grave" tree; its strong, rot-resistant wood served a multitude of purposes including home building, fencing—and of course, cradles and coffins.

The late 19th and early 20th centuries brought a wave of visitors to the mountains of western North Carolina. Drawn by the fresh mountain air, some of these visitors decided to settle down and build summer homes, while others opened lodges and resorts. With the plentiful supply of American chestnut in local forests, builders used the wood and bark from these giants to create a rustic, all-American style that became known as the "vacation architecture" of western North Carolina.

Then the chestnut blight arrived in the Southern Appalachians, and the consequences were devastating. Mountain families were left without a major source of food and cash income; many had grown used to harvesting the nuts to sell during the holidays in cities as far away as New York. Families would fatten their hogs on sweet-tasting American chestnuts, living on the meat during the long mountain winters. Once the tree was gone, either felled by blight or cut down by landowners to salvage what they could for lumber, an entire generation of Americans would never know the beauty and grandeur of this giant.

As the blight spread throughout the natural range of the American chestnut, many species of wildlife declined or disappeared altogether from eastern forests. Before the blight, the American chestnut was the most important wildlife food source throughout it range, especially in the mountains of western North Carolina. The single most abundant tree, its plentiful, reliable nut crop provided

(continued)

***Gathering Chestnuts*, painting by Ernest Smith (1907–75), a Tonawanda Seneca artist and craftsman.** *(From the collections of the Rochester Museum & Science Center, Rochester, NY)*

Cherokee Uses of Chestnut

Tea of year-old leaves for heart trouble; leaves from young sprouts cure old sores; cold bark tea with buckeye to stop bleeding after birth; apply warmed galls to make infant's navel recede; boil leaves with mullein and brown sugar for cough syrup; dip leaves in hot water and put on sores; tea for typhoid; for stomach; bark makes brown dye; firewood (pops badly); lumber (wormy or good); rails for fences; acid wood; coffee substitute (parched).

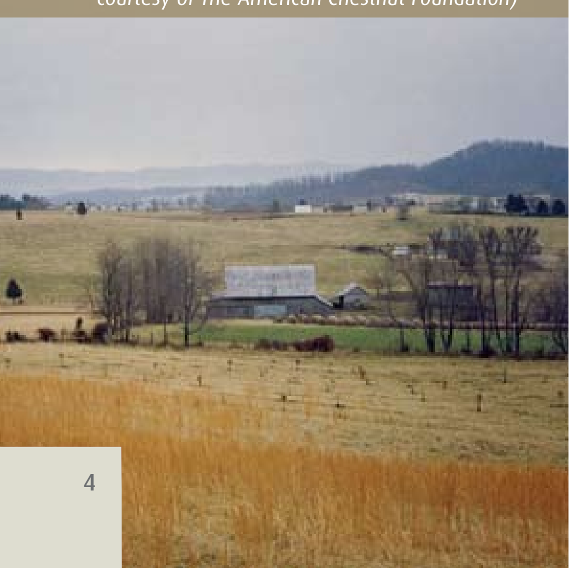
From: *Hamel, P.B.; Chiltoskey, M.U. 1975. Cherokee plants and their uses, a 400 year history. Sylva, NC: Herald Publishing Co. 65 p.*

The Meadowview Research Farms

In 1989 **The American Chestnut Foundation** (TACF) established the Wagner Research Farm in Meadowview, VA, to start the backcrossing program developed by TACF founding scientists **Charles Burnham**, **David French**, and **Philip Rutter**. Plant pathologist **Fred Hebard** was persuaded to move to Meadowview to manage the research farm, where he immediately began testing the backcross method. By 1993, Hebard had produced thousands of healthy trees, including several highly blight-resistant seedlings, from two intercrossed generations. Hebard has been able to reduce the time it takes chestnut to flower from between 6 and 10 years to between 2 and 4 years, which has stepped up the pace of breeding for blight resistance.

By 1995, the research farm was filled to capacity, with over 5,800 chestnut trees at various stages of backcrossing. A generous donation allowed TACF to purchase a tract of land nearby, now known as the Glenn C. Price Research Farm. TACF purchased a third farm in 2002 and a fourth in 2006. Today, there are four research farms at Meadowview, with over 34,000 trees at various stages of breeding on more than 150 acres.

***Meadowview Research Farms.** (Photo courtesy of The American Chestnut Foundation)*



winter sustenance for deer, rabbits, bear, raccoons, wild boar, squirrels, mice, wood rats, wild turkeys, grouse, crows, and jays.

Today, you can walk through almost any forest in the Southern Appalachians and see the remains of the American chestnut—fallen logs and giant stumps, sometimes several feet in diameter, with young sprouts growing up out of the root collars. Some of these sprouts will grow tall, perhaps very tall, but they will almost always succumb to chestnut blight before they even flower.

In 1983, a group of scientists who had long believed that there was a strong chance of reviving the American chestnut formed **The American Chestnut Foundation** (TACF) with the sole purpose of restoring the tree to its native forests. Inspired by the work of noted geneticist and corn breeder **Charles Burnham**, the group embraced the idea of using a traditional backcross plant-breeding method based on Burnham's work with corn. Scientists, including geneticists and plant pathologists, crossed the American chestnut with its blight-resistant cousin, the Chinese chestnut. By crossing the two species, scientists were able to confer a degree of blight resistance on the American chestnut. The ultimate goal: a 15/16 pure American tree that's resistant to chestnut blight.

From that initial group of scientists, TACF has expanded its national breeding program to include four research farms located in Meadowview, VA; more than 34,000 trees in various stages of the breeding process; and a network that includes 17 State chapters and nearly 6,000 individual members. Today, TACF is closer than ever to producing that blight-resistant tree, though the progenies of its breeding program are still in the testing phase, their value still to be determined on many forest sites over the next decade. By harvesting only the most highly blight-resistant nuts, TACF will be able to ensure that later generations of trees will survive infection and grow to full height.

The first blight-resistant seeds to be tested were harvested in 2005. As seed production is gradually increased over the next few years, these blight-resistant seeds will be distributed to cooperators to test in sites across the natural range of the American chestnut tree. At some point, TACF hopes to harvest enough blight-resistant seeds to make them available to TACF members and eventually to the general public.

At the same time, TACF is continuing its breeding program to make further gains in disease resistance, growth rate, and tree form. A new testing phase that begins in 2009 will include plantings on national forest land under a Memorandum of Understanding signed in 2004 with the Forest Service. After 25 years, TACF's plant pathologist **Fred Hebard** describes this phase in TACF's national breeding program as "the end of the beginning." While there is still much work to be done, he feels confident that the next phase of TACF's program will bring even more success in producing a blight-resistant American chestnut.

Meghan Jordan is director of communications for the Southern Appalachian Regional Office of The American Chestnut Foundation located in Asheville, NC.

The Way Forward is Back

The American Chestnut Foundation (TACF) breeders began planting the final generation of blight-resistant chestnut hybrids on their research farms in Virginia in 2005. Backcrossing Chinese and American chestnut trees towards this point has been a long and painstaking process built on the efforts of people who just wouldn't give up on the idea of restoring American chestnut to eastern forests.

Arthur Graves, professor at the Yale School of Forestry at the turn of the 20th century, tried for years to find native resistance in the American chestnut trees that remained after the blight first swept through. In 1930, he decided that the path to resistance lay in breeding, in crossing American chestnut with resistant Japanese and Chinese stock. He started by pollinating mature Japanese chestnuts with pollen from American chestnuts; he crossed the resulting hybrids with Chinese chestnut trees and with one another. As breeding continued, crossing hybrids with Asian stock started to yield inconsistent and discouraging results. An apparently healthy tree might grow for decades, but top out at 40 feet because of a high percentage of Asian genes. Many others never made it through the resistance trials.

Around 1980, **Charles Burnham**, a geneticist and plant pathologist who had worked with food crops most of his career, turned his attention to the American chestnut. Burnham's expertise was in backcrossing, a plant breeding method designed to transfer a particular trait among species that are able to interbreed. With others interested in producing a blight-resistant tree with the timber qualities of American chestnut, Burnham set out the backcross method that TACF has used to move towards producing blight-resistant, almost pure American chestnut seedlings.

How It's Done

The backcross starts off by pollinating the female flowers of a blight-resistant Chinese chestnut with pollen from an American chestnut, producing a first-generation hybrid with half of its genes from each parent and resistance somewhere between that of the parents. This Chinese-American hybrid is pollinated with pollen from an American chestnut—a cross "back," or backcross, to

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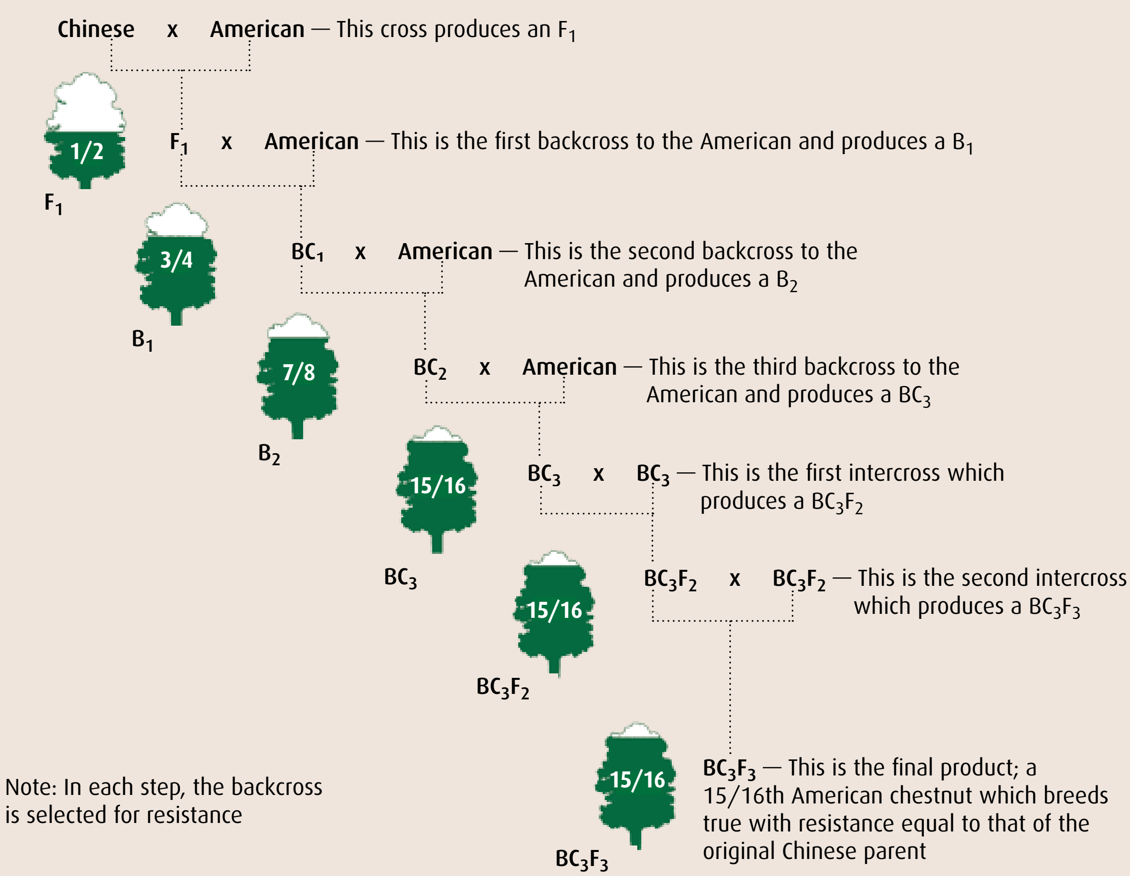

the American that increases the percentage of American chestnut genes in the second generation—again, with blight resistance somewhere between that of the two parents.

After the seedlings from the first backcross have grown enough to reveal their form—usually 5 years or until they're around 1.5 inches in diameter—they're inoculated with the blight to test for resistance. Only the most resistant seedlings with straight (rather than spreading) forms are selected to be crossed back again to American chestnut for the second generation of hybrids.

The process of testing hybrids and backcrossing them with pure American chestnut is continued for three more generations, using the pollen from a variety of American chestnut trees to prevent inbreeding and maintain genetic variation. Trees grown from the third backcross are then pollinated with one another (intercrossed) to produce the fifth generation; a small percentage of these have the blight resistance of the first generation Chinese chestnut and the desired characteristics of the American chestnut. These fifth-generation trees are then intercrossed to produce the grail—a blight-resistant, almost pure American chestnut tree.

At Meadowview, TACF has reached the sixth generation of the breeding program; the first seedlings to be tested in the field were produced in 2005, and TACF projects that the seedlings will be widely available by 2015 to 2020. —*ZH*

Adapted from: *Lord, W. 2007. Burnham relights the torch. In: Bolgiano, Chris, ed. Mighty giants: an American chestnut anthology. Bennington, VT: The American Chestnut Foundation: 204–205.*

Solutions From the Double Helix

by Zoë Hoyle

Tom Kubisiak spends a lot of his time in a world that's invisible to most of us—the double-stranded, DNA world of genes and chromosomes. A geneticist based at the **SRS Southern Institute of Forest Genetics** in Saucier, MS, Kubisiak is a master at using small snippets of DNA called genetic markers to tease out variations among individuals—whether they're trees or the pathogens that infect them. He has worked with **The American Chestnut Foundation** (TACF) on just about every aspect of their restoration program, from charting the genetic diversity of the American chestnut trees still living to helping map the genome of the chestnut blight fungus. Most of his research for TACF has had immediate practical application—a rarity in the world of genetic research.

Is it Really American Chestnut?

There are still millions of American chestnut trees in eastern forests, though most are actually sprouts from roots of trees killed long ago by chestnut blight. In full sunlight, these sprouts can grow up to 30 feet tall, sometimes flowering and even producing nuts before the blight kills them again. To maintain genetic diversity in their breeding nurseries, TACF volunteers regularly search forests for flowering native chestnuts they can use as "mother trees."

It's important that the "mother trees" used to produce blight-resistant hybrids are pure American chestnut. Out in the forest, it can be hard to separate pure American chestnut from hybrids just by looking. European and Asian chestnut trees have been planted extensively in the East since European settlement, crossing with native trees to produce hybrids that look very similar to American chestnut.

Problems can also arise in the research fields themselves, where breeders produce hybrids by controlled pollination, bagging inoculated flowers to protect them from other pollen sources. Even though the flowers are protected, it's still possible for pollen from a rogue source to fall onto an uncovered female flower. For the long process of backcrossing to recapture the desirable characteristics of an almost pure blight-resistant American chestnut, it's particularly important that mistakes don't get bred in and repeated in future crosses.

In some cases, the only way to tell for sure if a tree is pure American chestnut is by testing its DNA—in much the same way as the DNA of human children can be tested to establish paternity. Kubisiak and fellow researchers started working on the problem in the late 1990s, screening DNA from pure American chestnut, the foreign chestnut species, and various hybrids. For markers, they examined stretches of neutral DNA, fragments of genetic code that differ among individuals but haven't been tied to a specific trait.

"We don't know anything else about the markers, whether, for instance, they're a gene or not," says

Tom Kubisiak with the gene sequencer he uses to map the genomes of chestnut blight and other organisms. (Photo by John Butnor, U.S. Forest Service)

Kubisiak. "You can think of them as little monitors along a strand of DNA that allow you to look at variation in individuals. If you're comparing two trees, you look at how many of these markers they share to see how alike they are."

Kubisiak showed that markers can be used to distinguish between the different chestnut species and to quickly determine if a given tree is likely to be a pure American chestnut. "Fortunately, chestnut species are turning out to be different enough that each species harbors its own unique variation that can be used for identification purposes," says Kubisiak. "The challenge we face now is to characterize this variation and determine which set of markers will be most useful for excluding hybrids. To be operationally feasible, the assay needs to be simple and inexpensive."

So far, TACF has only used markers to look at seedlings from early generation backcrosses. But several of these progeny turned out to be products of contaminating pollen, so even these results have helped guide TACF in its breeding program. As more markers become available and easier and less expensive to use, they may be routinely used to determine such things as the percent of American chestnut in hybrids.

Diversity Issues

The markers Kubisiak is examining are also being used to ensure that the hybrids TACF develops are genetically diverse.

TACF's ultimate goal is to restore a blight-resistant form of American chestnut throughout a native range that extends from Maine southwest

(continued)

Why American Chestnut?

Why go to so much trouble to restore American chestnut when other blight-resistant chestnut species from Asia will grow in the former range of the American giant?

Uniquely adapted to Eastern North America, the American chestnut tree lived longer and grew taller than the Asian species. Flowering late, the tree was unaffected by the late frosts that are typical of the Appalachian Mountains. American chestnut trees produce more hard mast than other chestnut species; their nuts have been shown to have higher nutritional value and were once the major food source for wildlife and for livestock in rural communities. Before the chestnut blight, American chestnut lumber was a major rural industry; lightweight, straight-grained, and easily worked, the wood was ideal for fence posts, railroad ties, barn beams, and home construction—as well as for fine furniture and musical instruments.

Chestnut burrs. *(Photo courtesy of The American Chestnut Foundation)*

to Mississippi, which means creating seedlings adapted to different climate and soil conditions. When they started their breeding program, TACF researchers already suspected that the seedlings they produced on research farms in Meadowview, VA, might not survive in northern Maine or southern Mississippi. They turned to the geneticists to find out how much genetic variation still existed in native American chestnut trees, and whether this information might be used to help TACF decide how many different breeding locations they needed to capture most of the genetic variation still present in the species.

In 2003, Kubisiak and SRS research geneticist **James Roberds** did a baseline study that analyzed DNA markers from 993 surviving American chestnut trees from 22 sites across the natural range. "We found that American chestnut acted like one big population," says Kubisiak. "We showed that roughly 95 percent of the natural genetic variation in the species occurred in any one local population."

That sounds like good news, but Kubisiak cautions that because researchers work with neutral DNA fragments, they're not able to determine if the individual trees sampled have developed genetic adaptations to local environments. "Again, our study was based on neutral gene fragments, rather than on genes for traits such as bud break or cold hardiness that might show adaptations for specific locations," says Kubisiak.

Microscopic view of the fruiting bodies of chestnut blight fungus. *(Photo by Ministry of Agriculture and Regional Develpment Archive, Hungary)*

Kubisiak and Roberds suggested that breeding efforts collect material from a fairly large number of individuals (50 to 100 or more) from each of several geographic areas to capture variation associated with adaptive traits. They also suggested that at least three areas—northern, central, and southern parts of the range—be considered as locations for breeding efforts. There are now 17 State chapters, each with breeding programs that use surviving American chestnuts in their States, to ensure that there are materials adapted for much of the natural range.

Breeding Resistance

Kubisiak's genetic markers really paid off for the hybrid breeding work when, in the late 1990s, he identified genetic markers linked with regions of the Chinese chestnut genome associated with resistance to chestnut blight. A DNA-based toolkit to test hybrid seedlings for resistance—as well as for how much unwanted Chinese chestnut still remains—is allowing researchers to know where they are in the quest to produce an almost pure American chestnut with full blight resistance.

To breed for blight resistance, TACF started off by simply crossing resistant Asian trees with American trees and testing for resistance by inoculating the resulting seedlings with chestnut blight. Resistant seedlings are then "backcrossed" with pure American chestnut three more times and then intercrossed with one another (see page 5). As backcrossing proceeded, TACF needed to know how many resistance genes from Chinese chestnut had to be present for crosses to produce elite trees with full blight resistance.

“Fortunately, there don’t seem to be that many genomic regions conditioning resistance,” says Kubisiak. “We were able to identify two regions that repeatedly show significant associations, which was very good news for TACF breeders. If more genes were involved, they might have to screen thousands to tens-of-thousands of plants to find elite seedlings for each cross.”

Meanwhile, out on the TACF research farms, the latest backcross seedlings are growing towards the revival of a great American tree. TACF projects that they’ll have tens-of-thousands ready for planting by 2015.

For more information:

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or tkubisiak@fs.fed.us

Recommended reading:

Kubisiak, T.L. 1999. **Using DNA markers to distinguish among chestnut species and hybrids.** The Journal of The American Chestnut Foundation: 13(1): 38–42.

Kubisiak, T.L.; Roberds, J.H. 2003. **Genetic variation in natural populations of American chestnut.** The Journal of The American Chestnut Foundation: 26(2): 42–48.

Kubisiak, T.L.; Roberds, J.H. 2006. **Genetic structure of American chestnut populations based on neutral DNA markers.** In: Restoration of American chestnut to forest lands: Proceedings of a conference and workshop. Natural Resour. Rep. NPS/NCR/CUE/NRR–2006/001. [Washington, DC]: U.S. Department of the Interior, National Park Service, National Capital Region, Center for Urban Ecology: 109–122.

Chestnut sprouts with blight. *(Photo courtesy of The American Chestnut Foundation)*

Chestnut Blight

Chestnut blight is caused by *Cryphonectria parasitica*, a member of the largest group of fungi, the ascomycetes. *C. parasitica* enters through cracks in chestnut bark and through wounds, causing dead areas on bark called cankers. Once introduced, the fungus grows rapidly, producing a network of filaments called mycelial fans that quickly girdle the tree and grow down into the wood, where they destroy the vascular systems that carry sap. The leaves on the stem then die, showing the symptoms that give rise to the name “chestnut blight.”

When the cankers grow into the wood, the fungus forms bright orange, rounded structures on the surface of the bark. These stromata produce two types of spores—ascospores and conidia. Ascospores appear whenever conditions are right, and are forcibly expelled from the stromata to be carried away on the wind. The second spore types, conidia, ooze out after rain and can be carried by waterdrops or on the feet of insects, birds, squirrels, and other creatures.

Adapted from: *Hebard, F.V.; Double, M.L.; MacDonald, W.L. 2007. A pathogen without rival. In: Bolgiano, Chris, ed. Mighty giants: an American chestnut anthology. Bennington, VT: The American Chestnut Foundation: 172–174.*

The Promise of a Virus Blighted

Tom Kubisiak's real passion is unlocking the genetic secrets of tree diseases, which, like those in humans, are rarely simple, often involving interactions among multiple life forms. Take, for example, the interactions among American chestnut trees, the chestnut blight that's killed most of them in the Eastern United States, and a group of viruses that infect the fungus.

Chestnut blight is caused by a fungus that probably entered the United States on nursery stock in the late 1800s. First noticed when the American chestnut trees in the Bronx Zoological Park started dying, the fungus was identified as *Cryphonectria parasitica* in 1905. A weak parasite in its native China, the fungus spread ferociously in America—up to 50 miles a year—killing an estimated 4 billion trees in just half a century.

In the 1930s, *C. parasitica* showed up in Europe. It looked as if European chestnut trees would also be killed off, but in the 1950s researchers started finding chestnut trees that seemed to be recovering from the blight. The fungus isolated from these trees had a unique white color, which was in stark contrast to the bright orange isolates, or samples, recovered from nonhealing trees. Eventually plant pathologists discovered that the blight itself was infected with a unique virus that altered the pigment produced by the fungus and reduced virulence to the host tree, an effect which they called "hypovirulence."

Numerous "hypoviruses" that infect the blight fungus have been discovered since, and several strains have been used to control chestnut blight fungus in Europe. Managers inoculate chestnut blight cankers with the virus and let it spread through the fungus. Unfortunately, though it once held great promise, using hypoviruses to weaken the effects of blight has not panned out for American chestnuts in forest settings, where the fungus continues to kill new chestnut sprouts unabated.

Kubisiak, geneticist with the **SRS Southern Institute of Forest Genetics**, and **Michael Milgroom** at Cornell University are studying the genome of *C. parasitica* to learn more about the mechanisms that affect the spread of hypoviruses. They're looking for clues in the system fungi evolved for self-recognition called "vegetative compatibility," which allows fungi to fuse together to share resources—and to spread hypoviruses.

One clue to the continued virulence of chestnut blight fungus in America may lie in the genetic diversity of American strains. In Europe, one strain of chestnut blight fungus usually dominates in a given area, freely passing along the hypovirus from canker to canker, tree to tree. In American forests, the presence of genetically different but sexually compatible chestnut blight strains ensures that genetic variation in the fungus is high, reducing the chances that any two isolates will be vegetatively compatible—which means they won't merge and share the virus.

"We wanted to find markers in the blight genome linked to vegetative compatibility so we could clone these genes and begin to study the dynamics of this system in natural populations," says Kubisiak. "So far, we know of at least seven genes involved in the process, and there is evidence that more are likely to exist, so it won't be a matter of just changing one gene to turn on or off compatibility. The fungus is quite sexual and keeps producing even more variability that can, in turn, increase incompatibility among strains, making it very difficult to make one alteration that would allow the virus to spread."

Though the promise of hypovirulence as a biocontrol for chestnut blight in America has waned, Kubisiak is still excited about studying the genes that govern compatibility in chestnut blight. "The ultimate goal is to understand these genes from a fundamental viewpoint—what they do, what their evolutionary purpose is," says Kubisiak. "Why are they there, and what is the underlying biochemical mechanism? Maybe,

In Europe, hypoviruses can be used to control chest
Casalecchio di. Reno, Bugwood.org)

at some point, we'll discover key regulators that could be used as on-off switches to override the entire compatibility system and hence break the barrier that is hampering the spread of the hypoviruses."—*ZH*

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Tom Kubisiak at 228–832–2747, x213 or tkubisiak@fs.fed.us

Recommended reading:

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nut blight. *(Photo by Piero Amorati, ICCroce -*

A Chromosomal Conundrum

The goal of **The American Chestnut Foundation's** (TACF) breeding programs is to transfer Chinese chestnut blight resistance to American chestnut while transferring as little Chinese chestnut genetic material as possible. Producing these blight-resistant hybrids is not as simple as it might seem. As early as 1999, TACF scientist **Paul Sisco**, SRS research geneticist **Tom Kubisiak**, and others were reporting on DNA marker studies that indicated irregularities in the genetic maps of Chinese/American chestnut hybrids—defects that could throw a spanner into breeding efforts. In a 2006 review of TACF's science program, **Ron Phillips** (University of Minnesota) also noted the irregularities and urged TACF to investigate whether there were differences in chromosomal structure between the two species.

To take a closer look at the chromosomes themselves, TACF turned to SRS research geneticist **Nurul Faridi**, lead scientist with the **SRS Forest Tree Molecular Cytogenetics Laboratory** located in College Station, TX. While most genetic scientists work with techniques that result in two-dimensional printouts or maps, cytogeneticists use high-powered microscopes and fluorescent probes to look directly at chromosomes and genes.

"Dr. Faridi is one of a very few scientists worldwide who can do this work," noted **Dana Nelson**, project leader for the **Southern Institute of Forest Genetics** that manages the cytogenetics lab. "Faridi can literally watch through a microscope as a chestnut pollen cell goes through meiosis, the elegant process by which the paired chromosomes from two parents recombine into a single set of chromosomes ready to fertilize an egg cell."

Mismatched Pairs

Chinese and American chestnut trees both have 12 pairs of chromosomes, but Faridi found that their chromosomes differ structurally from one another, which can create problems when the two trees are crossed. Faridi started looking at pairing between Chinese and American chestnut chromosomes during meiosis in first-generation hybrids, which were half Chinese and half American chestnut. What he's seen in hybrid chestnut mother pollen cells isn't exactly good news.

"One problem is that one of the chromosome pairs from the two species doesn't really match up," says Sisco. "So when it comes time for the Chinese and American chestnut chromosomes to exchange genes during recombination, they don't line up precisely. They pair only on the ends, leaving a bulge in the middle. In genetics, we call this an inversion."

Another problem involves 2 other pairs of the 12 chromosomes. Eons ago chromosomes from one pair broke and recombined with another pair to cause what is called a translocation. In the Chinese/American chestnut hybrid,

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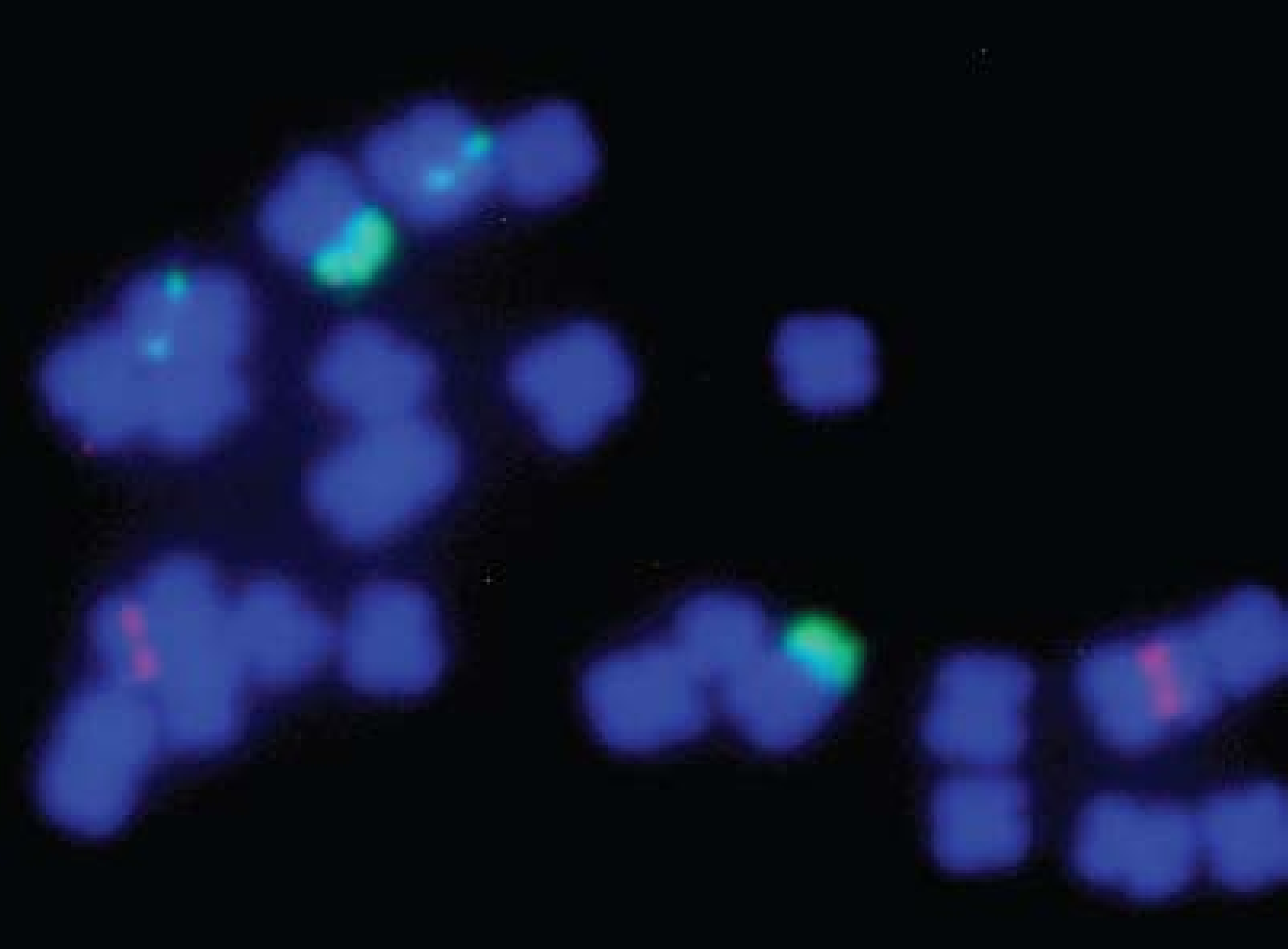

A Chromosomal Conundrum

four chromosomes come together into a cross shape instead of the normal linear shape. Translocation, like inversion, hinders the exchange of genes between the two species and causes some pollen to abort.

And what if the genes for resistance are on those areas that don't match up? "There's some evidence that this might be the case for at least two of the three genes involved in resistance that have been identified so far," says Sisco. "The chromosomal differences between Chinese and American chestnut can either work for or against us in transferring Chinese resistance to American. The hope is that the genes for resistance are out on the ends of the chromosomes, where the strands meet and interlock so they can be easily transferred from Chinese to American chestnut without bringing along a large block of Chinese genes."

If a resistance gene is on one of the sections that doesn't interlock, a large segment of the Chinese genetic code might get carried over along with the gene when the chromosomes combine, which would make it more difficult to breed an almost pure, but resistant American chestnut. Faridi's next project, partly funded by a TACF grant, is to see whether known resistance genes are on the chromosomes that have abnormal pairing, and, if they are, whether the genes are in the middle of the chromosomes, where pairing is hindered, or at the ends, where pairing is more normal. —*ZH*

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(Above) Fluorescent in situ hybridization (FISH) image of chestnut chromosome taken by Nurul Faridi, U.S. Forest Service.

Charles Burnham, upper left, was a postdoctoral student in his mid-twenties studying corn cytogenetics when this photo was taken at Cornell University in 1929. Marcus Rhoades, standing next to Burnham, and George Beadle (with dog), were graduate students of Dr. R.A.Emerson (in cap), head of the Cornell Department of Plant Breeding and Genetics. At right is Barbara McClintock, who taught Burnham, Rhoades, and Beadle how to work with chromosomes. McClintock and Beadle both won a Nobel prize in Medicine. (Photo courtesy of Richard Zeyen, University of Minnesota)

Chestnut Cytogenetics:
Faridi, Burnham, and McClintock

by Paul Sisco

Cytogenetics, the study of the behavior of chromosomes and their effect on heredity, has a long and distinguished history that includes several winners of the Nobel Prize.

Charles Burnham, one of the founding scientists of **The American Chestnut Foundation** (TACF) would be very interested in the cytogenetic studies of chestnut that **Nurul Faridi** has taken on at the **SRS Southern Institute of Forest Genetics**. Burnham, a distinguished cytogeneticist and generous teacher, trained at Cornell University during the “golden age of maize cytogenetics” in the late 1920s and early 1930s, when research on corn revealed the link between chromosome behavior seen under the microscope and genetic changes seen in corn plants in the field.

A group of students and postdoctoral research associates which included Burnham, **George Beadle**, **Marcus Rhoades**, and **Harriet Creighton** worked with **R.A. Emerson** in genetics and **Barbara McClintock** in botany on the pioneering research that led to the discovery of the chromosomal basis of heredity. Beadle and McClintock went on to become Nobel Laureates.

Before coming to Cornell in 1929, Burnham completed his Ph.D. with **Alexander Brink** at the University of Wisconsin. Brink and Burnham discovered semisterile maize lines with unusual inheritance patterns. They suspected that the pollen sterility was caused by chromosomal differences, but they had no way of looking at the chromosomes to make sure. At Cornell, McClintock taught Burnham how to stain and visualize chromosomes under a light microscope, and with her help, Burnham was able to prove the hypothesis that he and his professor Brink had made about the maize line.

After his stint at Cornell, Burnham went on to a long and distinguished career at the University of Minnesota, where he helped train generations of maize cytogeneticists, including **Ron Phillips**, who headed up two scientific reviews of TACF in 1999 and 2006—and who came up with the hypothesis about chestnut chromosome recombination that SRS geneticist Faridi is now investigating.

Just as McClintock helped Burnham and Brink prove their hypothesis, Faridi has come up with good evidence to prove the hypothesis posed by Phillips. Almost 80 years after what was seen as its “golden age,” cytogenetics has once again shown itself to be an extremely useful tool—this time in the effort to restore American chestnut trees to the forests of Eastern North America.

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Paul Sisco is regional science coordinator for the Southern Appalachian Regional Office of The American Chestnut Foundation located in Asheville, NC.

Where Great Forests Once Stood

Chestnut Blight and the Loss of Foundation Species

by Gary Kuhlmann

Old photographs tell part of the story. A few on file in the offices of the **SRS Coweeta Hydrologic Laboratory** near Otto, NC, offer a dramatic portrayal of where great forests once stood. In warm summer months, when American chestnut trees cloaked themselves with white blossoms, the Southern Appalachian Mountains used to look like they were blanketed with snow. But that was a long time ago. The rest of the story is about a botanical plague, the lethal fungus known as chestnut blight that moved across the Eastern United States from 1920 to 1950 and wiped out chestnut trees more efficiently than the fiercest wildfire.

Scientists at Coweeta are interested in the details of that story. **Katherine Elliott**, an ecologist at Coweeta for the past 17 years, has spent a lot of time in Coweeta's 5,400-acre experimental forest, where she and her colleagues have been digging into the details. Their work adds to knowledge about the loss of the American chestnut, but its real importance may lie in what's happening now to foundation species across the globe.

A foundation species is a primary life form, one that's abundant and influential in its ecosystem—coral in a coral reef, kelp in kelp forests, chestnut in chestnut forests. Studying the loss of a foundation species such as American chestnut is especially difficult when very little is left of the trees that once made up a quarter of forest hardwoods over 200 million acres from Maine to Florida. Today all that remains are decaying stumps and sprouting saplings—and Elliott and other scientists are seeing fewer of these small saplings in the woods.

"A large tulip tree or eastern hemlock may give you a sense of what an old hardwood forest looked like once upon a time," Elliott says. "But nothing left today looks like the old photographs of American chestnut forests."

Fortunately, Elliott and her colleagues at Coweeta have more to work with than old photographs. The Forest Service started taking inventories of tree species across 987 plots at Coweeta back in the 1930s; Elliott and other Coweeta researchers used this data as the basis for reconstructing what a Southern Appalachian chestnut forest was like before the blight struck.

The data fills in a poorly documented history of how the blight transformed southeastern forests. For most historical invasions like the chestnut blight, scientists don't have much to go by—neither good baseline data on the distribution and abundance of the affected species nor information on basic ecosystem processes. Until now, what scientists have known about the loss of the American chestnut has come mostly from records of a few preblight plots in Connecticut, short-range studies (none longer than 20 years) of blighted regions in the mid-Atlantic and Northeast, and investigations limited to using existing chestnut stumps as a reference.

"Our study area, a basin of more than 4,000 acres, is larger and more environmentally varied than those examined previously, and the period covered by our observations—about 60 years—is longer than those in other studies," says Elliott, who conducted the study with fellow Coweeta scientist **Wayne Swank**.

Elliott and Swank's findings illustrate the unique role the American chestnut played in the Southern Appalachians. Mountain streams probably benefited most from chestnut forests, because decomposition of chestnut wood is much slower than other hardwoods, even slower than oak and hemlock. Chestnut logs remained in the streams longer, providing structure and habitat for fish. The species' abundant, yearly production of nuts provided a reliable supply of food for wildlife. Additionally, because chestnut trees grow fast, chestnut forests quickly stored, or sequestered, carbon and nutrients.

Where oak grew up in place of chestnut, rapidly decaying chestnut leaves with high-nutritional quality for aquatic insects and other macroinvertebrates were replaced by more slowly decaying oak leaves with lower nutritional quality. As a consequence, leaf processing and consumption rates would have declined, decreasing growth rates and adult body mass in macroinvertebrate shredder communities.

This Time, Eastern Hemlock

Chemicals in the leaves of the American chestnut may have suppressed the growth of other riparian trees and shrubs, including eastern hemlock and rhododendron, according to research by another Coweeta scientist, **Barry Clinton**.

"Ironically, the loss of one foundation species—American chestnut—may have facilitated the establishment of another—eastern hemlock—which in turn is now threatened," Elliott says. But history does have a way of repeating itself. The hemlock woolly adelgid, an exotic insect smaller than a poppy seed, threatens to bring another round of changes to Southern Appalachian forests. Despite an aggressive campaign to control the adelgids, the region's hemlocks may be dead within the next decade, opening up the forest canopy and removing shade from cool mountain streams.

Elliott and others at Coweeta are looking closely at the effects of hemlock death on the riparian zones, including changes to soil moisture, stream temperature, and water quality. "When forests lose whole species of trees, the impact is profound," Elliott says. "Foundation species are, by definition, irreplaceable. For example, without hemlocks, hemlock forests cease to exist. No other native conifer can do exactly what the hemlock does for the forest, particularly along riparian corridors."

Circling Back to Chestnut

Elliott's colleagues at Coweeta—Clinton, **James Vose**, and **Jennifer Knoepp**—are very interested in studying the possibility of planting American chestnut seedlings in areas opened up by dying hemlocks. The seedlings would have to be the blight-resistant hybrids TACF scientists are developing—big, fast growing, and adaptable like the original American chestnuts but with the blight resistance of Chinese chestnuts.

The question is whether even the hybridized chestnuts would ever grow tall enough to get past the dense thickets of rhododendron that have taken over many cove forests of the Southern Appalachians.

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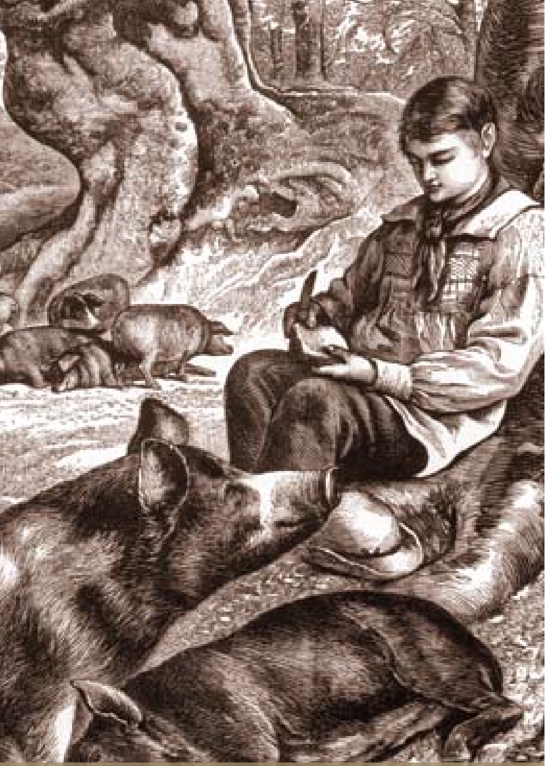
Coweeta Basin in western North Carolina. (Photo by Rodney Kindlund, U.S. Forest Service)



Chestnuts were a favorite food source for hogs in the early 1900s. (Illustration courtesy of The American Chestnut Foundation)

A Prolific and Nutritious Nut

The prolific chestnut reportedly produced many millions of bushels of nuts in hundreds of thousands of square miles across the Eastern United States. A mature American chestnut tree could reliably produce as many as 6,000 nuts each year. In contrast, white oaks produce approximately 1,000 nuts per tree and red oaks produce about 2,000 nuts per tree—and neither family of oaks produces acorns reliably. Chestnuts are a high-energy food, containing roughly 11 percent protein compared to acorns, which average 6 percent. Chestnuts also contain around 16 percent fat and a whopping 40 percent carbohydrates.

(Right) Katherine Elliott. (Photo by Randy Fowler, U.S. Forest Service)

Where Great Forests Once Stood

Coweeta studies implicate the demise of the chestnut in the spread of rhododendron. Because it tolerates shade and reproduces vegetatively, rhododendron has extended its influence far beyond streamsides and into upland forests, where its thick growth blocks the sunlight needed by many tree seedlings to establish and grow.

Worldwide Loss Prevention

"Hemlock and chestnut are only two examples of the many foundation species worldwide that provide fundamental structure and function to ecosystems," Elliott says. "We have long-term data from inventoried tree plots. We have species-level measures of water use, and we have stand-level measurements of microclimates related to light, temperature, and soil moisture. Together these give us important findings about the dynamics of foundation species. If we develop relationships—or models—using forest composition, tree growth and water use, and microclimate, then we can identify possible future trends in forests. This kind of information has application worldwide."

Studying the effects of this rapid and possibly dramatic ecological change could even lead to better predictions about the effects of disturbances—from not only insects and pathogens but also land use change, human population growth, and hurricanes, to name a few—at regional, national, and global levels.

"How do we respond to the loss of a tree species? How soon do we become aware that there is a problem—a serious threat? Look how quickly we lost the chestnut," Elliott says. "Because foundation species are common and abundant, and they have a wide distribution, our responses to a potential threat often come late and are not enough. The introduction of a nonnative species such as the hemlock woolly adelgid can reduce or eliminate a species in a short time."

For more information:

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Gary Kuhlmann is a freelance science writer based in Elgin, SC.

Coweeta Hydrologic Laboratory

Established in 1933 as the **Coweeta Experimental Forest**, the laboratory today represents the longest continuous environmental study on any landscape in North America, as well as one of the oldest gauged watershed sites in the world. Located in the Nantahala Mountain Range in western North Carolina, the 5,400-acre laboratory is made up of two adjacent, bowl-shaped basins containing several well-defined watersheds and more than 45 miles of stream. It is covered with a deciduous forest typical of the Southeastern United States, with a mix of oak, hickory, and rhododendron, as well as scattered groups of pitch pine and eastern hemlock, and an understory of dogwood, maple, and birch.

(Right) Weir at Coweeta Hydrologic Laboratory. *(Photo by Rodney Kindlund, U.S. Forest Service)*

The First Enemy of American Chestnut

In the early to mid-1800s, the American chestnut got its first shock from *Phytophthora cinnamomi*, an exotic root-borne fungus. Called ink disease because it turns roots black, *P. cinnamomi* reduced the range of the American chestnut by eliminating it from lower elevations. The disease causes root rot and persists in wet clay or compacted soils. Globally, *P. cinnamomi* causes economic and ecologic damage to forest, ornamental, and crop trees, including avocado and walnut.

According to SRS research forester **Stacy Clark**, one question being posed in nursery production of chestnut seedlings relates to the best fertilization and irrigation protocols to limit the growth of fungal pathogens such as ink disease. Field studies have shown that American chestnut seedlings planted in soils contaminated with *P. cinnamomi* have little to no chance of survival.

Can Chestnuts Survive on Their Own?

by Claire Payne

In spring 2009, the Forest Service (FS) will begin planting a mixture of pure American chestnut, three generations of hybrids, and Chinese chestnut seedlings on national forests in Tennessee, North Carolina, and Virginia. According to **Stacy Clark**, SRS lead scientist for implementing the first test plantings, the hybrids will include 100 final-generation seedlings and 300 to 400 seedlings from earlier generations.

Clark, research forester with the **SRS Upland Hardwoods** unit, works closely with **Scott Schlarbaum**, professor and director of the Tree Improvement Program at the University of Tennessee, to run the science component of the chestnut outplanting project. They also work with **Don Tomczak**, regional silviculturalist for the **FS Southern Region**, to locate ideal sites for the first outplanting. They have already secured the nuts from ***Fred Hebard*** of **The American Chestnut Foundation** (TACF), who designed the nursery experiments, and will lay out the test plantings in the field in 2009.

The FS began working with TACF in 2004 when former Chief **Dale Bosworth** signed a memorandum of understanding to cooperate on restoring American chestnut on national forest land. If nuts germinate and grow as expected, over 100 of the hybrid seedlings will

(Photo by Brad Smith, courtesy of The American Chestnut Foundation)

be planted on the **Cherokee National Forest** in Tennessee, the **George Washington-Jefferson National Forest** in Virginia, and the **National Forests in North Carolina**. **John Blanton**, forest silviculturalist for the National Forests in North Carolina, is working with Clark, Tomczak, regional geneticist **Barbara Crane**, pathologist **Bill Jones** from the **Forest Health Protection** (FHP) unit, and district silviculturalists to determine which districts in North Carolina are best suited for the chestnut seedlings.

In 2010, the FS and TACF intend to extend the experiment to the **Daniel Boone National Forest** in Kentucky and the **Monongahela National Forest** in West Virginia. It will take at least 3 to 4 years for the hybrid seedlings to demonstrate how blight resistant they are.

The seedlings destined for national forest lands grow from nuts from trees grown at the TACF farm in Meadowview, VA. The nuts are the result of years of crossbreeding the American chestnut with the Chinese chestnut in an attempt to make them resistant to the *Cryphonectria parasitica* fungus that causes the chestnut blight. FS scientists and cooperators, FS Southern Region silviculturalists and geneticists, and FHP scientists have been working with TACF to develop a hybrid that is 94 percent pure American chestnut. Seedlings from the nuts are grown for a year in a commercial nursery before they're outplanted. Clark and Schlarbaum have also implemented a first study of its kind to find out which nursery breeding materials work best, and will be able to determine differences in blight resistance and outplanting performance among pure American seedlings and hybrid seedlings.

What Chestnuts Need

Clark and Schlarbaum have found that chestnut seedlings planted in soils that are not free of *Phytophthora cinnamomi*, the exotic root-borne ink disease that reduced the chestnut's range in the 1800s, will have little to no chance of survival. That disease persists in wet clay or compacted soils in the Southeastern United States, particularly in lower elevations of the tree's original range.

The national forest sites chosen to grow the chestnut seedlings already include small chestnut trees—sprouts from still living roots that grow to a certain height then succumb to chestnut blight, usually before they can flower. The presence of sprouts indicates the soil is likely free of *P. cinnamomi*, which completely kills chestnuts. The national forest sites are chosen to insure that site and climatic conditions are similar to those of the seed source of Meadowview, VA, but the outplanted seedlings will have to be able to make it on their own.

"We're not going to pamper them," says Tomczak. "TACF wants us to see how they do against natural competition. According to people who have tried to grow them, they should grow pretty quickly, and there's a good chance they'll do well. We'll plant them under two-aged shelterwood systems, with ample but not full sunlight." Tomczak, retiring after a 30-year FS career, will leave the project in the hands of co-coordinator Crane.

Give Pure A Chance

Clark, along with scientists **Henry McNab** and **David Loftis** from the SRS Upland Hardwoods unit, has set up preliminary research plots with pure chestnut seedlings on four sites: timber company land in Jackson County, AL; the Cherokee National Forest in Tennessee; the **Bent Creek Experimental Forest** in North Carolina; and at the **Bankhead National Forest** in Alabama. Clark is in charge of analyzing the experiments, and she hopes results will help forest managers understand what's needed to grow, establish, and outplant chestnut seedlings—as well as provide chestnut breeders with a better understanding of genetic influence on early establishment of forest plantings.

"A lot of attention has been given to producing a blight-resistant tree, but foresters need to know the best methods needed for seedling establishment and growth if there is to be any chance of success for chestnut restoration," says Clark. "We need to find out how competitive these seedlings are going to be in the face of fierce competition and insect and animal pests."

The scientists used both clearcut and shelterwood sites to test response to light and competition. Early results indicate a high level of mortality. The scientists report that successful establishment of pure American chestnut seedlings in forest stands will depend on conditions not easily controlled, including animal damage, the presence of ink disease, and other exotic pests such as gypsy moth, the Oriental chestnut gall wasp, and numerous varieties of ambrosia beetles.

It's been tough going for the young seedlings, with as many as 86 percent dying due to attacks from hungry rabbits and exotic pests; the good news is the survivors grow very fast, keeping up with yellow-poplar and red maple in some test plots.

The project is in its early stages, and survivors will reveal what it takes for

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chestnuts to reclaim their place. The cost of losing the American chestnut has been too high and the benefits of restoring the species too many to get discouraged. For many people, this effort is a long-term trial with numerous participants and vested cooperators. For some, the restoration of the American chestnut is a life's work.

For more information:

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Barbara Crane at 404–347–4039 or barbaracrane@fs.fed.us

Recommended reading:

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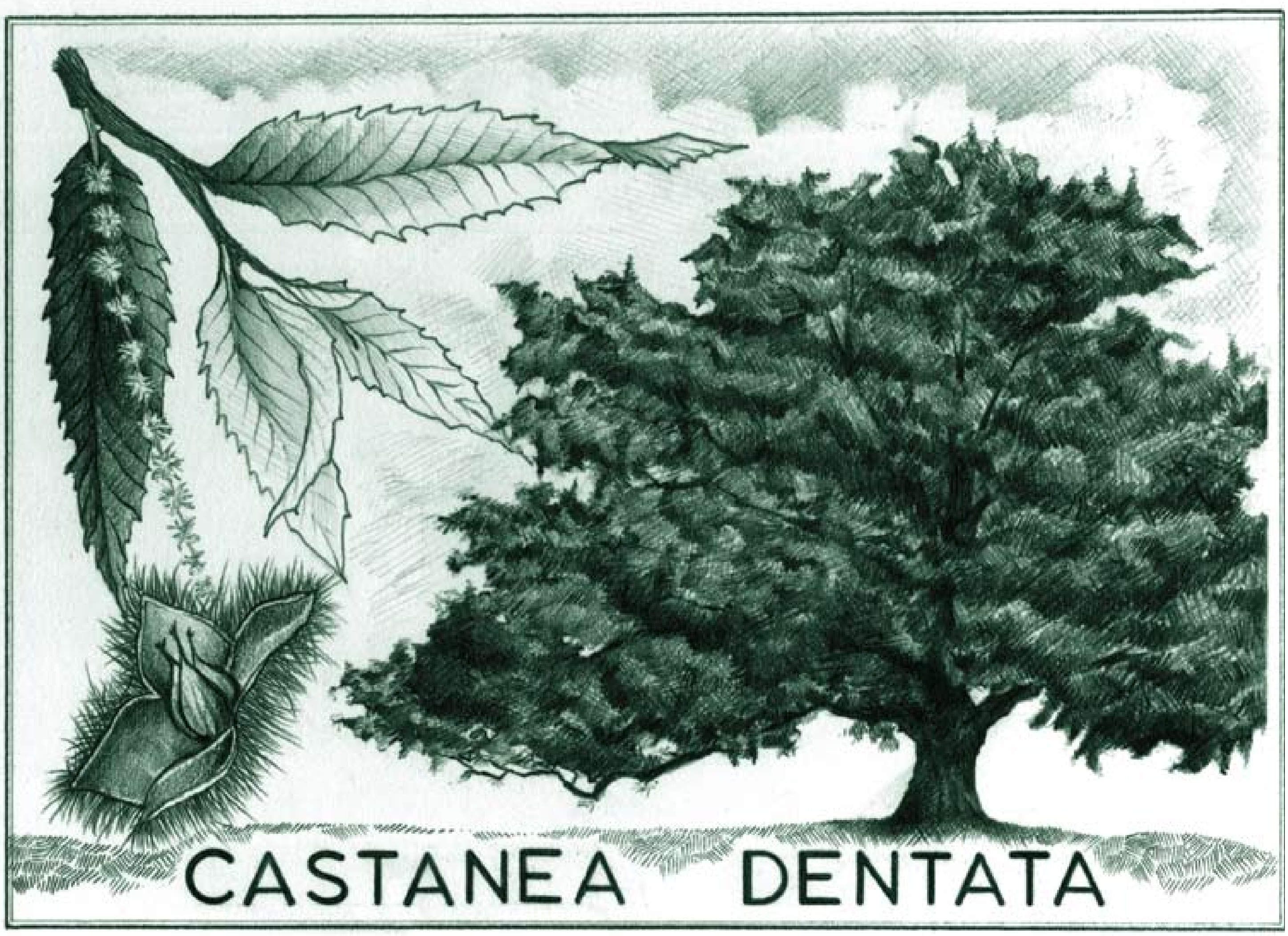
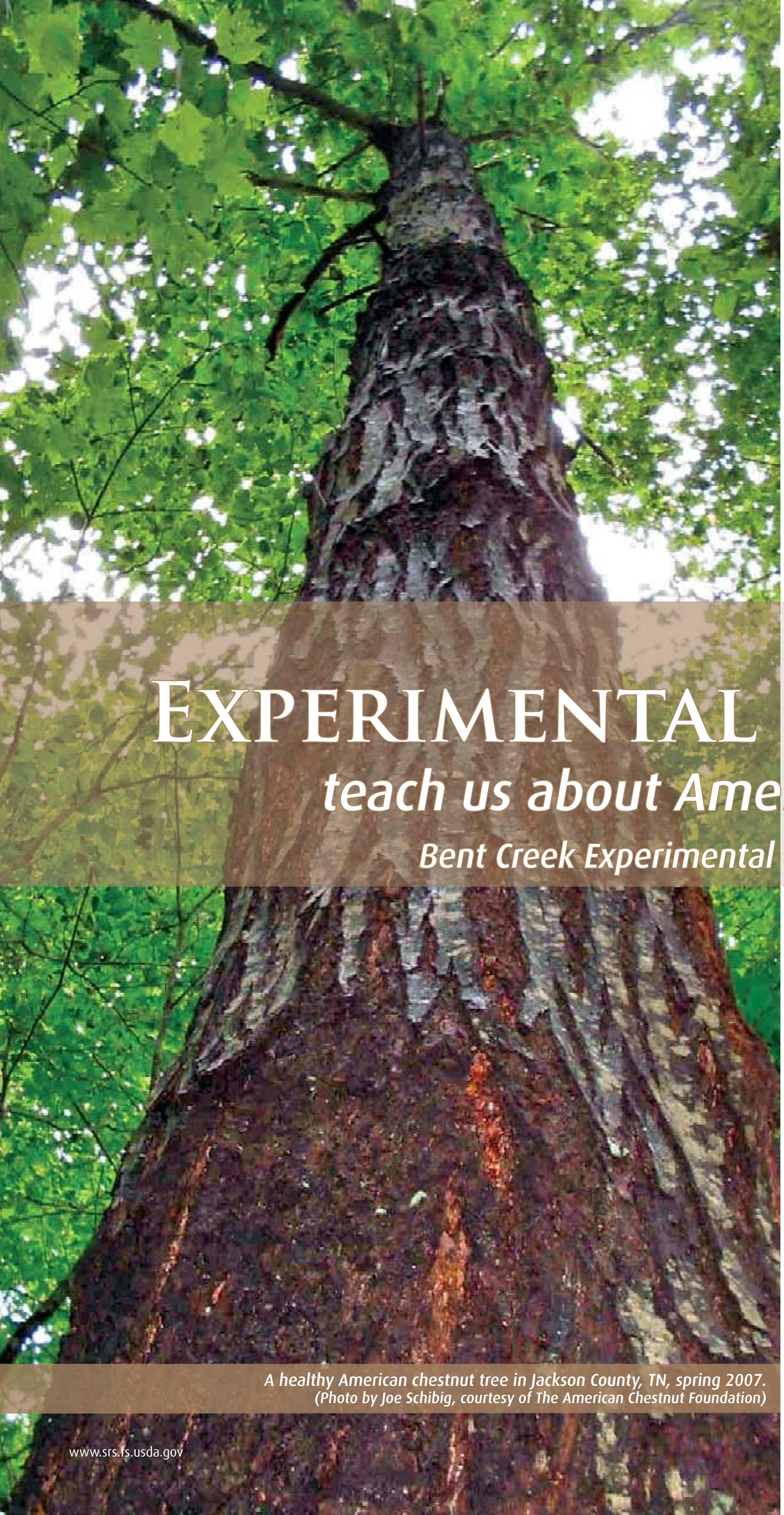


(Illustration courtesy of The American Chestnut Foundation)

What can EXPERIMENTAL FORESTS teach us about American chestnut?

Bent Creek Experimental Forest near Asheville, NC



A healthy American chestnut tree in Jackson County, TN, spring 2007.
(Photo by Joe Schibig, courtesy of The American Chestnut Foundation)

The earliest research foresters were not a sentimental lot. They had a big job to do in the 1920s—restoring the Southern Appalachian forests left by logging, subsistence farming, and approaching chestnut blight—and they had a very small appropriation from Congress to bring to the task. Working out of three rented rooms at the *Asheville Citizen-Times* newspaper office and supported by a single secretary, the first Forest Service research director in the South and his three technical assistants began an ambitious program at the **Bent Creek Experimental Forest** that stretched well beyond its boundaries. They lived in tents, prepared their own food on campfires, and divided their time between installing plots, making shingles from dead and dying trees, helping with surveys, and writing research papers.

It is no surprise that these early pioneers viewed the approaching chestnut blight not as the tragedy that many see it as today, but as just one more obstacle between them and their goal of establishing a new forest that would be a continuous source of goods and services to the American public.

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Trees had to be cut. Uses needed to be found for the chestnut trees that were dying. Decisions had to be made about which species would take the place of American chestnut in the forest and in a myriad of products—not only tannin for a thriving leather-tanning industry, but also nuts for animal and human sustenance and wood for log cabins, furniture, caskets, and fences.

The land had to be prepared for the new "crop" of trees. Later, when stump sprouts began to appear where chestnut trees had been felled, steps had to be taken to ensure that these doomed offspring would not crowd out other more viable species before dying themselves.

In the midst of this activity, the researchers found time to record valuable information about the forest that was dying at Bent Creek. In 1926 and 1927, two timber sales removed most of the American chestnut trees there. But first, foresters mapped the distribution of the species, measured 7,190 individual trees, and tagged their stumps. Although their goal was to understand the new forest that would replace the old, the foresters ended up taking one of the few detailed records of where and how the American chestnut, which once made up 25 percent of the Southern Appalachian landscape, grew in different terrains and elevations.

"With presumably no hope for survival from the chestnut blight, chestnut now serves no useful purpose and the apparent diminution [of seedlings growing to sapling size] is to the advantage of [other species]."

*—**E.H. Frothingham**, research forester and first director of the **Appalachian Forest Experiment Station** (later to become part of the **Southern Research Station**), writing about the species that would replace American chestnut in the forests of the Southern Appalachians.*

New Research Builds on Old

The irony is that the demise of American chestnut coincided with the beginnings of forest research; today's researchers know little about the ecology of the species—or how it will compete if successfully reintroduced into the forest landscapes of the 21st century.

These questions interested **Henry McNab**, a research forester at Bent Creek who shares the same practical bent and ingenuity that characterized his early predecessors. In 1998, McNab began a pilot study, planting pure American chestnut seedlings to test their survival and growth in relation to canopy density using three adjacent

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(Above) Research forester Henry McNab at the site of a chestnut study that he established in the late 1900s. *(U.S. Forest Service photo)*

(Left) An early researcher measures American chestnuts destined to be felled ahead of Cryphonectria parasitica*, a blight that destroyed the species throughout the Eastern United States.* *(U.S. Forest Service photo)*

sites: one under a dense canopy, a second cleared of all trees, and a third with partial canopy. McNab also tested three treatments: fertilization only, installation of plastic tree shelters only, and combined fertilization and shelter installation. After 5 years, McNab found that survival was higher in the plots under the full canopy than in those with partial or no canopy. When compared with seedlings that were left untreated in a control plot, survival was higher with the tree shelter treatment and lower with the fertilizer treatment.

McNab cautions that this pilot study was too small to draw any firm conclusions, but the results do suggest that small chestnut seedlings can hold their own in forests with little or no investment of time, equipment, and followup attention. "One thing that people forget is the reason that American chestnut was such a dominant species in the Southern Appalachians," says McNab. "Thanks

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to its extensive root system, its ability to sprout when conditions are right, and its rapid growth, the American chestnut was once able to outcompete its rivals for sunlight and nourishment. This was true both on dry slopes where oaks now prevail and in the rich, moist cove sites that are currently dominated by yellow-poplars."

Plans are underway to continue chestnut research at Bent Creek—a restoration study adjacent to a popular bicycling and hiking trail, and a study on using herbicides to control competition in a hybrid chestnut plantation—but McNab's involvement will be to advise and share perspectives with the next generation of research foresters. **Stacy Clark** will add the Bent Creek studies to those she has already underway in Alabama and on the **Cherokee National Forest** in Tennessee.

A Final Word

The Bent Creek Experimental Forest is a microcosm of the Southern Appalachian region, from its early days of abusive logging and farming to the replacement forests that grew in abundance to the effects of urbanization that we see today. As such, it is a living record of history as well as a source of data, both published and as yet untapped.

Although the researchers of the 1920s did not know how the information they were collecting would be used, their training and integrity compelled them to collect it anyway. This ethic continues among the researchers at Bent Creek today.

But the landscapes of the Southern Appalachians are becoming more fragmented and the suburbs of Asheville are rapidly expanding towards Bent Creek, ratcheting up demands for hiking, horseback riding, mountain biking, and other urban pressures—often at the cost of installing new studies and maintaining old ones. McNab thinks that it's important to temper those pressures with yet unknown threats and opportunities for discovery by continuing to collect long-term data. "If we can find uses today for chestnut information that was collected a hundred years ago, who knows what will be needed in another half century? It's important to keep our options open."

For more information:

Henry McNab: 828–667–5261 x119 or hmcnab@fs.fed.us

Stacy Clark: 256–585–0652 or stacyclark@fs.fed.us

Recommended reading:

Beattie, R.K.; Diller, J.D. 1954. **Fifty years of chestnut blight in America.** Journal of Forestry. May: 323–329.

Loftis, D. 2005. **Planting trials with American chestnut in Southern Appalachian forests.** In: Steiner, K.C.; Carlson, J.E., eds. Proceedings of the conference on restoration of American chestnut to forest lands. Natural Resour. Rep. NPS/NCR/CUE/NRR—2006/001. Washington, DC: U.S. Department of the Interior, National Park Service, National Capital Region, Center for Urban Ecology: 167–172.

McNab, W.H.; Patch, S.; Nutter, A.A. 2003. **Early results from a pilot test of planting small American chestnut seedlings under a forest canopy.** Journal of the American Chestnut Foundation. 16 (2): 32–41.

Loggers with an oxen-drawn sled containing a chestnut log. (Photo courtesy of Great Smoky Mountains National Park Library)

science You Can Use!

How Can You Help?

by Livia Marqués

Although it may seem counterproductive to plant a tree knowing it will become infected and die, there are several reasons you might want to plant the pure American chestnut seedlings available now. The most significant reason is to preserve the diversity of native American chestnut genetic material. New plantings can help guarantee that the genetic background of living chestnuts will be conserved for a couple more generations.

The trees you plant could also be used for future breeding to support conservation efforts. With proper care, pure American chestnut seedlings can grow to 30 feet in height and be very productive before succumbing to blight. If you plant several trees, you can harvest crops of chestnuts which can further preserve the stock, give others an opportunity to plant and grow chestnuts, and provide a food source for wildlife.

Chestnuts grow well in slightly acidic soils—the same sort of conditions preferred by azaleas and blueberries. The nuts should be directly seeded in the spring, as soon as you can work the soil. Don't plant the nuts deeper than about 1 inch in the ground and protect nuts and seedlings from rodents and deer.

Locating surviving American chestnut trees is another critical component of efforts to conserve the species. These native trees are the foundation for building a breeding stock to develop blight-resistant trees. The goal is to marry the best characteristics of the American and Asiatic chestnut species through backcrossing. It's important to have genetic diversity in the American chestnut trees used in backcrossing, which takes at least 6 generations.

Although once a massive tree reaching over 80 feet tall, American chestnuts are now found mostly as stump sprouts, less than 20 feet tall. The native chestnut is most often confused with Chinese chestnut, chinkapin, and native hybrids.

For more information:

Planting—chestnut.cas.psu.edu/Procedures/growing/planting.htm

Purchasing—Pure American chestnut seeds and seedlings are available from **The American Chestnut Foundation** (TACF) as a member benefit. TACF also provides a list of other suppliers on its Web site at www.acf.org/seeds_seedlings.php.

Identifying—*(see the guide on the next page)* The American Chestnut Foundation: www.acf.org/find_a_tree.php.

American chestnut seedling. (Photo courtesy of The American Chestnut Foundation)

Take a Chestnut Journey Along the Appalachian Trail

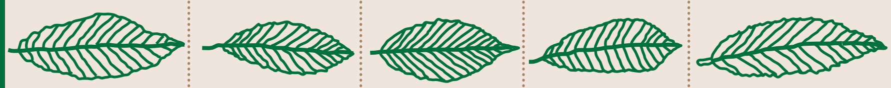
As part of its 25th anniversary celebration, **The American Chestnut Foundation** (TACF) has invited the group's members, volunteers, and scientists to collect data on the remaining American chestnut trees along the Appalachian Trail (AT) this summer. The data will not only help TACF scientists estimate how many American chestnut trees remain along the AT, but also enable them to locate and document trees that produce flowers towards incorporating more genetic diversity into their breeding programs.

The idea of hiking the AT to study the American chestnut population began in 1999 when **Eric Wiese**, a graduate student of Hill Craddock at the University of Tennessee, counted the number of American chestnuts along the trail as part of his degree program. Wiese documented 40,701 American chestnut trees as visible from the AT, with the highest population density in the Nantahala Mountains of southwestern North Carolina, and the most evidence of blooming and nut production in Pennsylvania.

Those interested can print off the tree identification sheet on the right or from the TACF Web site. Hikers are encouraged to log the miles they walk as a way to focus attention on the importance of restoring the American chestnut to its native forests as well as on the ongoing work of TACF, its State chapters, and its volunteer community. The 2008 "chestnut journey" ends in Chattanooga, TN, at TACF's 25th annual meeting October 24–26.

TACF Trail Walk:
www.acf.org/apptrail/index.php

Chestnut Identification[1]



	Allegheny Chinquapin	Chestnut Oak	Beech	Chinese Chestnut	American Chestnut
Leaf taper to stem	Straight	Slightly curved	Curved	Curved	Straight
Taper to tip	Straight	Slightly curved	Straight	Curved	Straight
Teeth	1–3 mm, small, no hook	Scalloped	Small teeth, hook	Large or small, no hook	6 mm, big, sharp, and often curved (hooked)
Leaf underside	Sun leaves noticeably hairy	Sun leaves somewhat hairy	Sun leaves somewhat hairy	Sun leaves obviously hairy	Sun leaves not hairy, long, sparse hairs only on midrib
Twig	Hairy tips, purple or brownish-grey	Stout, brown in color	Slender, light brown in color	Hairy tips, tan to pea green, large, elliptical yellow lenticils	Slender, smooth, hairless, reddish brown, small white lenticils
Bud	Up to 3 mm, downy, dark red, pointed rather than wide, sticks out from stem	Brown, multiple buds, conical and pointed	Up to 3/4 inch long, light brown, overlapping scales	Hairy, tan, dull brown to black, rounded and flat against stem	Up to 6 mm, smooth, reddish brown to yellow, pointed or longer than wide, sticks out from stem
Nut	One nut, 1/2 inch tip pointed with a round cross-section	Acorn, one nut, approximately 1 inch long	Two nuts, 1/2 to 3/4 inch long, irregularly triangular, shiny brown	2–3 nuts, 3/4 to 2 inches, rounded, hairy tip, blurred sunburst pattern, often light brown	2–3 nuts, 1/2 to 1 inch, pointed tip, 1/3 to 2/3 downy, sunburst at base
Taste	Sweet	Somewhat bitter	Sweet	Sweet	Sweet
Resistance to blight	None	High	High	High (varies with variety)	Low to none

[1] *Information provided by The American Chestnut Foundation, Southern Appalachian Regional Office, Asheville, NC.*

TACF Celebrates 25 Years!

1983–2008

25th Annual Meeting

Please join us in Chattanooga, TN, October 24–26, 2008, at the Sheraton Read House. We begin with a chestnut feast at our annual reception, followed by a visual journey through a virtual forest. On Saturday, we will be touring historic Ashland Farms—The Patten Family Home, followed immediately by an elegant sit-down lunch and live entertainment by a very special guest. Sunday will be a day of reflection where we look back on the last 25 years—what was, what is, and what will be. This will be a day not soon forgotten. Don't miss this once in a lifetime event!

For more information:
www.acf.org/anniversary25th.php

around the STATION...

Experimental Forests

1	Bent Creek	NC
2	Blue Valley	NC
3	Coweeta	NC
4	John C. Calhoun	SC
5	Santee	SC
6	Scull Shoals	GA
7	Hitchiti	GA
8	Olustee	FL
9	Chipola	FL
10	Escambia	AL
11	Tallahatchee	MS
12	Delta	MS
13	Harrison	MS
14	Palustris	LA
15	Stephen F. Austin	TX
16	Crossett	AR
17	Alum Creek	AR
18	Sylamore	AR
19	Henry F. Koen	AR

New Director for the Southern Research Station

by Perdita Spriggs

Dr. Jim Reaves assumed the helm of the Southern Research Station (SRS), headquartered in Asheville, NC, in January 2008, as only the second director since the Southeastern Forest Experiment Station in Asheville and the Southern Forest Experiment Station in New Orleans merged in 1995. His leadership comes at a time when forest science research is uniquely poised to have a voice in the decisions that can affect the changing landscapes of the South.

"I am excited to come back to the South and work with the Station's esteemed scientists, whose research is recognized internationally," says Reaves, who served as a SRS project leader, research scientist, and assistant station director from 1991 to 1998, as well as a team leader during the consolidation of the two experiment stations. "My hope is to foster an atmosphere that encourages our employees to conduct innovative and usable research that informs natural resources policy and land management decisions. I want the Station to be a premier natural resources organization which leads cutting-edge research and encourages and values a dynamic and diverse workforce."

With a 26-year career with the Forest Service, Reaves understands the Agency well, and he knows his science. Most recently, as Associate Deputy Chief for Research and Development in Washington, DC, he provided national leadership for research programs and enhanced the Agency's external partnerships. Reaves has also held key Forest Service positions and conducted research on both the east and west coasts. He has represented the United States as a delegate to the United Nations Forum on Forestry in Switzerland, led scientists on a USDA delegation to China, and served as a keynote speaker at a forest restoration conference in Seoul, Korea. A plant pathologist by training, Reaves' research has been published in national and international science journals.

The wealth of experience Reaves brings to the directorship gives him exceptional insight into leading a science organization that can lend sound science to emerging forest issues. "We will continue to place emphasis on forecasting natural resource issues for land managers and

(continued)

policymakers, ensuring our science is consistently relevant to current issues and diverse audiences," says Reaves, who will focus on people, partnerships, and communications during his tenure. He is committed to helping employees "be empowered, grow, and contribute" to the Agency; developing and enhancing effective partnerships to interconnect social and economic natural resources issues; and exploring new and improved communication technologies to share cutting-edge science with internal and external audiences.

"So much has changed regarding natural resources issues in the South since I last worked at the Station," says Reaves, who grew up on a tobacco farm in rural South Carolina. "This is an exciting time for natural resources research as we address rapidly changing land uses and serious impacts from drought, wildland fire, and other natural disturbances. I also strongly believe that SRS is positioned to deliver our science in a timely, effective manner that can be comprehended by a variety of audiences. When people think about natural resources in the South, I want them to think of the Southern Research Station."

Reaves earned a bachelor's degree in biology from Voorhees College in Denmark, SC, and a master's and doctorate, both in biology/plant pathology, from Atlanta University in Georgia. He is a member of the Society of American Foresters, American Phytopathological Society, Smithsonian Institute, Kennedy Center, and Omega Psi Phi Fraternity. Reaves and wife, Adrienne Scott-Reaves, are avid dog lovers and enjoy the outdoors with their bichon friese and Japanese akita.

Perdita Spriggs is communications director for the SRS Eastern Forest Environmental Threat Assessment Center, Asheville, NC.

SRS Scientists Win *Wings Across The Americas* Awards

On March 27, SRS scientists **Susan Loeb** and **Paul Hamel** received honors at the Wings Across the Americas awards ceremony held at the 73rd North American Wildlife and Natural Resources Conference in Phoenix, AZ. Awards go to Forest Service (FS) employees and their partners, including conservation organizations, universities, volunteers, foundations, and private-sector firms.

Wings Across the Americas is an FS program that represents an integrated and collaborative approach to bird conservation across Agency program areas. The annual awards ceremony celebrates exceptional work that conserves birds, bats, and butterflies and their habitats across America, recognizing the important roles that these sometimes overlooked species play in the environment and in relation to human concerns.

SRS research ecologist Loeb shared the Bat Conservation Award for cooperative research on the ecology and conservation of forest bats with the National Forests, Region 8; the Sumter, Chattahoochee, Daniel Boone, and Nantahala National Forests; the Congaree and Great Smoky Mountain National Parks; the U.S. Fish and Wildlife Service; Clemson University; and MeadWestvaco. Individuals recognized include **Eric Britzke**, a private consultant, and **John Blake**, FS assistant manager for research at the Savannah River Site near Aiken, SC.

Loeb leads a comprehensive research program on the ecology and conservation of southern forest bats developed in direct response to needs expressed by customers and cooperators. The program is part of the **SRS Upland Hardwoods** unit, but continues to serve the research needs of managers in a variety of ecosystems throughout the Southeast.

Paul Hamel, SRS wildlife biologist, received the International Cooperation Award for the Cerulean Warbler Nonbreeding Habitat Assessment conducted by El Grupo Cerúleo, a subcommittee of The Cerulean Warbler Technical Group, of which Hamel is a founding member. Project locations in the Northern Andes of South America include Venezuela, Colombia, Ecuador, Peru, and Bolivia.

Hamel is an expert on the cerulean warbler, a bird that is becoming a less common sight in the Eastern United States; habitat loss and fragmentation is thought to be behind a steady decline in recent decades. Hamel's studies on the national and international assessments of bird conservation needs and opportunities—along with research, monitoring, and evaluation for bird habitat protection—were key to his receiving this award. The award will be shared among FS employees and 40 other partners involved in the project. —*WF*

Susan Loeb. *(U.S. Forest Service photo)*

Paul Hamel. *(U.S. Forest Service photo)*

(Photo by Julia Murphy, U.S. Forest Service)

Greenberg Named New Project Leader for Upland Hardwoods Research Unit

Cathryn (Katie) H. Greenberg is the new project leader with the **SRS Upland Hardwood Ecology and Management** unit, which includes research scientists and staff in five Southern States and is headquartered at the Bent Creek Experimental Forest in Asheville, NC. She succeeds David Loftis, who continues to work at Bent Creek as a full-time research forester.

Greenberg holds a Ph.D. from the University of Florida in wildlife ecology, an M.S. in wildlife ecology from the University of Tennessee, and a B.A. in philosophy from the George Washington University. Before coming to Bent Creek in 1995 she studied fire ecology and forest management impacts in Coastal Plain ecosystems in Gainesville, FL.

Since moving to Asheville, Greenberg's research focus has shifted to forest communities of the Southern Appalachians. One major effort is to study the effects of forest management practices, such as timber harvesting, fuel reduction practices, and prescribed fire, and natural disturbances, such as wind damage, on plant and animal communities. Another is to show how different forest types and silvicultural disturbances affect the production of forest food resources, such as native fleshy fruit and hard mast.

Since she began her new role as project leader, Greenberg and the Upland Hardwood Ecology and Management research team have been working with State and private partners on a new multidisciplinary study that focuses on methods for regenerating upland oak hardwood forests across a moisture gradient and at a regional scale. Drawing on the geographic locations and expertise within the research unit and their partners, the study will address how prescribed fire and other treatments that alter light levels and competition affect a wide range of ecological responses, ranging from the regeneration of hardwood tree species to herbaceous plants to bats, birds, mice, and salamanders.

Greenberg lives in Arden, NC, with her husband and five children, ages 7 to 13.

Compass Wins National Award

The National Association of Government Communicators (NAGC) recently awarded *Compass* a second place Blue Pencil award in the category of external magazines. NAGC is a national not-for-profit professional network of Federal, State and local government employees who disseminate information within and outside government. Their annual Blue Pencil awards honor the best in print-related government communications products in 36 different categories. NAGC announced the award on April 29, 2008.

Compass, published by the SRS science delivery group, is designed to inform a wide range of audiences about SRS research on focused topics. Now in its fourth year, the magazine has covered subjects ranging from the possibilities and challenges of biomass-based energy to the interaction of forests with global climate change. The region served, the Southeast, is one in which the pressures of development, lost timber economy, and climate change increasingly affect forest ecologies. *Compass* brings into focus the issues the region faces while highlighting the work of SRS researchers and collaborators to come up with solutions.

Issue 9 of *Compass*, which focused on upland hardwood forests in the South, was submitted for the award. SRS staff writers contributing to the issue included Zoë Hoyle, Livia Marqués, Claire Payne, Perdita Spriggs, and Carol Whitlock. Art director Rodney Kindlund designed the magazine and took many of the photos for the issue.

Southern Research Station headquarters in spring 2007. (Photo by Rodney Kindland, U.S. Forest Service)

NEW PRODUCTS

natural resources inventory and monitoring

1 Bechtold, William A.; Patterson, Paul L., eds. 2005. **The enhanced forest inventory and analysis program—national sampling design and estimation procedures.** Gen. Tech. Rep. SRS-80. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 85 p.

The Forest Inventory and Analysis (FIA) Program of the U.S. Department of Agriculture, Forest Service is in the process of moving from a system of quasi-independent, regional, periodic inventories to an enhanced program featuring greater national consistency, annual measurement of a proportion of plots in each State, new reporting requirements, and integration with the ground-sampling component of the Forest Health Monitoring Program. This documentation presents an overview of the conceptual changes, explains the three phases of FIA's sampling design, describes the sampling frame and plot configuration, presents the estimators that form the basis of FIA's National Information Management System (NIMS), and shows how annual data are combined for analysis. It also references a number of Web-based supplementary documents that provide greater detail about some of the more obscure aspects of the sampling and estimation system, as well as examples of calculations for most of the common estimators produced by FIA.

2 Bentley, James W.; Lowe, Larry. 2007. **Kentucky's timber industry—an assessment of timber product output and use, 2005.** Resour. Bull. SRS-124. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 32 p.

In 2005, roundwood output from Kentucky's forests totaled 191 million cubic feet, 3 percent more than in 2003. Mill byproducts generated from primary manufacturers increased 2 percent to 91 million cubic feet. Ninety-six percent of plant residues were used, primarily for fuel, miscellaneous, and fiber products. Saw logs were the leading roundwood product at 143 million cubic feet; pulpwood ranked a distant second at 25 million cubic feet; composite panels were third at 14 million cubic feet. The number of primary processing plants declined from 297 in 2003 to 292 in 2005. Total receipts increased 2 percent to 214 million cubic feet.

3 Bentley, James W.; Schnabel, Doug. 2007. **Tennessee's timber industry—an assessment of timber product output and use, 2005.** Resour. Bull. SRS-126. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 31 p.

In 2005, roundwood output from Tennessee's forests was 325 million cubic feet. Mill byproducts generated from primary manufacturers totaled 119 million cubic feet. Seventy-three percent of the plant residues were used primarily for fuel and fiber products. Saw logs were the leading roundwood product at 189 million cubic feet; pulpwood ranked second at 121 million cubic feet; other industrial products were third at 13 million cubic feet. There were 354 primary processing plants operating in Tennessee in 2005. Total receipts amounted to 322 million cubic feet.

4 Brandeis, Thomas J.; Helmer, Eileen H.; Oswalt, Sonja N. 2007. **The status of Puerto Rico's forests, 2003.** Resour. Bull. SRS-119. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 72 p.

The third forest inventory of Puerto Rico shows the islands' continued recovery from past widespread deforestation. Forest cover has reached 57 percent for mainland Puerto Rico, 85 percent for Vieques, and 88 percent for Culebra, although these forests are still mostly made up of young stands of smaller trees. The most important tree species were the African tuliptree (*Spathodea campanulata*), American muskwood (*Guarea guidonia*), cabbagebark tree (*Andira inermis*), and pumpwood (*Cecropia schreberiana*). Few trees were unhealthy or stressed, and widespread pest and disease problems were not observed. Down woody materials and forest fire fuel were estimated for the first time.

5 Brandeis, Thomas J.; Oswalt, Sonja N. 2007. **The status of U.S. Virgin Islands' forests, 2004.** Resour. Bull. SRS-122. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 61 p.

The first forest inventory of the U.S. Virgin Islands found that forest covered 61 percent of the islands. St. John had the highest percentage forest cover (92 percent), followed by St. Thomas (74 percent), and St. Croix (50 percent). Forest cover decreased 7 percent from 1994 to 2004, a loss of 1671 ha of forest. These forests are mostly young, undeveloped stands, reflecting past and present land use and disturbances. Black mampoo (*Guapira fragrans*) was the most important tree, followed by gumbo limbo (*Bursera simaruba*), and genip (*Melicoccus bijugatus*), while tan tan (*Leucaena leucocephala*) was the most important smaller-sized tree.

6 Johnson, Tony G.; Becker, Charles W. 2007. **Virginia's timber industry—an assessment of timber product and use, 2005.** Resour. Bull. SRS-125. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 34 p.

In 2005, roundwood output from Virginia's forests increased 3 percent to 503 million cubic feet. Mill byproducts generated from primary manufacturers totaled 179 million cubic feet, 5 percent more than in 2003. Seventy-three percent of the plant residues were used primarily for fuel and fiber products. Saw logs were the leading roundwood product at 228 million cubic feet; pulpwood ranked second at 200 million cubic feet; composite panels were third at 57 million cubic feet. The number of primary processing plants declined from 234 in 2003 to 196 in 2005. Total receipts increased 5 percent to 515 million cubic feet.

7 Johnson, Tony G.; Mann, Michael C. 2007. **North Carolina's timber industry—an assessment of timber product and use, 2005.** Resour. Bull. SRS-127. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 33 p.

In 2005, industrial roundwood output from North Carolina's forests totaled 784 million cubic feet, 1 percent more than in 2003. Mill byproducts generated from primary manufacturers declined 3 percent to 306 million cubic feet. Almost all plant residues were used primarily for fuel and fiber products. Saw logs were the leading roundwood product at 400 million cubic feet; pulpwood ranked second at 274 million cubic feet; veneer logs were third at 60 million cubic feet. The number of primary processing plants declined from 235 in 2003 to 180 in 2005. Total receipts increased 9 million cubic feet to 751 million cubic feet.

8 Johnson, Tony G.; McClure, Nathan; Wells, John L. 2007. **Georgia's timber industry—an assessment of timber product and use, 2005.** Resour. Bull. SRS-123. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 36 p.

In 2005, industrial roundwood output from Georgia's forests totaled 1.17 billion cubic feet, 1 percent more than in 2003. Mill byproducts generated from primary manufacturers increased 4 percent to 433 million cubic feet. Almost all plant residues were used primarily for fuel and fiber products. Pulpwood was the leading roundwood product at 543 million cubic feet; saw logs ranked second at 458 million cubic feet; veneer logs were third at 74 million cubic feet. The number of primary processing plants was down from 187 in 2003 to 181 in 2005. Total receipts increased 3 percent, from 1.17 billion cubic feet in 2003 to 1.21 billion cubic feet in 2005.

9 Johnson, Tony G.; Smith, Nathan. 2007. **South Carolina's timber industry—an assessment of timber product and use, 2005.** Resour. Bull. SRS-121. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 28 p.

In 2005, industrial roundwood output from South Carolina's forests totaled 645 million cubic feet, 13 percent more than in 2003. Mill byproducts generated from primary manufacturers increased 10 percent to 186 million cubic feet. Almost all plant residues were used primarily for fuel and fiber products. Pulpwood was the leading roundwood product at 318 million cubic feet; saw logs ranked second at 258 million cubic feet; veneer logs were third at 42 million cubic feet. The number of primary processing plants remained at 75 in 2005. Total receipts increased 8 percent to 582 million cubic feet.

10 Oswalt, Sonja N.; Brandeis, Thomas J.; Woodall, Christopher W. 2008. **Contribution of dead wood to biomass and carbon stocks in the Caribbean: St. John, U.S. Virgin Islands.** Biotropica. 40(1): 20-27.

There is little information about dead wood in tropical ecosystems. Our goal was to fill knowledge gaps in current Caribbean carbon and biomass literature. We described the relative contribution of down woody materials to carbon stocks on the island of St. John, compared the contributions across subtropical dry and moist forests of varying structure and composition, and compared down woody materials' carbon stocks on St. John to those observed in other tropical forests. Our study indicates that down woody materials are important contributors to the total biomass and, therefore, carbon budgets in subtropical systems. Contributions of down woody materials on St. John appear to be comparable to values given for similar dry forest systems.

11 Oswalt, Sonja N.; Oswalt, Christopher M. 2008. **Relationships between common forest metrics and realized impacts of Hurricane Katrina on forest resources in Mississippi.** Forest Ecology and Management. 255: 1692-1700.

This paper compares and contrasts hurricane-related damage recorded across the Mississippi landscape in the 2 years following Hurricane Katrina, with initial damage assessments based on modeled parameters by the U.S. Forest Service. Logistic and multiple regressions are used to evaluate the influence of stand characteristics on tree damage probability. This paper addresses four primary questions: whether inventory data substantiated damage zone estimates made using remotely sensed and climate data following Hurricane Katrina; whether softwoods or hardwoods were more susceptible to hurricane damage and whether that susceptibility changed as distance from landfall increased; the primary stand-level factors influencing vulnerability to damage; and whether tree-level damage related to tree species, and whether damage types (bole, branch, lean, or windthrow) differed by species. We accepted the hypothesis that damage differed among the developed zones, and confirmed the acceptability of the figures initially generated. However, we were not able to accept the hypothesis that softwoods experienced more damage than hardwoods. Our data showed a marked increase in damage to hardwood species, except in the first zone of impact. Additionally, the likelihood of hardwood damage increased with increasing distance from the zone of impact. However, species group was confounded with the other predictor variables in many cases, making it difficult to separate the effects of each variable.

forest ecosystem restoration and management

12 Haywood, James D. 2007. **Influence of herbicides and felling, fertilization, and prescribed fire on longleaf pine establishment and growth through six growing seasons.** New Forests. 33: 257-279.

In central Louisiana, nitrogen and phosphorus fertilizer, multiple prescribed fires, and intensive vegetation control were applied to container-grown longleaf pine plantings in two studies. In study 1 (grass dominated), fertilization resulted in lower longleaf pine survival. Six-year-old longleaf pine trees were taller after intensive vegetation control (3.4 m) than after prescribed burning (1.8 m). In study 2 (brush dominated), survival was unaffected by treatment. The longleaf pine trees were 4.7 m tall after intensive vegetation control and were 3.9 m tall on prescribe burned plots. Native fertility was not limiting to longleaf pine growth in either study.


Male flowers of the American chestnut. (Photo courtesy of The American Chestnut Foundation)

13 McCarthy, Heather R.; Oren, Ram; Finzi, Adrien C. [and others]. 2007. **Temporal dynamics and spatial variability in the enhancement of canopy leaf area under elevated atmospheric CO_2.** Global Change Biology. 13: 2479-2497. [Editor's note: Southern Station scientist Kurt H. Johnsen co-authored this publication.]

Leaf area and phenology impact forest productivity, and species variation in these traits impact species dynamics and composition. Although elevated CO_2 has been shown to cause increases in forest productivity, there has been little research and no evidence on impacts on leaf area and/or phenology. At the Duke FACE site in Durham, NC, we show that elevated CO2 had no impact on pine needle phenology, although it did delay abscission of hardwood leaves. On average, following canopy closure, elevated CO_2 increased pine and hardwood leaf area by 14 and 16 percent, respectively, relative to ambient-grown stands. Across all plots, enhancement only occurred on sites with moderate soil fertility. These results partly explain our past work showing increases in forest growth due to elevated CO_2 is dependent on soil nutrition.

14 Perry, Roger W.; Thill, Ronald E. 2007. **Summer roosting by adult male seminole bats in the Ouachita Mountains, Arkansas.** American Midland Naturalist. 158:361-368

Roost sites are an essential habitat component for the survival of bats. The range of the seminole bat (*Lasiurus seminolus*) is restricted to the Southeastern United States, where it often roosts in the needles of southern pines (*Pinus* spp.) during summer days. We used radiotransmitters to locate 51 roosts used by 17 male seminole bats during summer in Arkansas. All but two roosts were located in the foliage of large (greater than 21 cm in diameter) pines (*Pinus* spp.). Compared to random, seminole bats were more likely to roost in forests with abundant large pines, few small pines, few large hardwood trees, and abundant recently cut stumps. Most roosts were located in forests that were partially harvested or thinned recently, but where large pines were retained. Open park-like forests that contain large, mature pines, such as pine woodlands or savannas, appear to be important roosting habitat for male seminole bats during summer on the western edge of their range.

15 Perry, Roger W.; Thill, Ronald E.; Carter, S. Andrew. 2007. **Sex-specific roost selection by adult red bats in a diverse forested landscape.** Forest Ecology and Management. 253: 48-55.

Because of their great abundance and insectivorous diet, eastern red bats (*Lasiurus borealis*) likely play important roles in forested ecosystems by consuming forest pests and reducing disease-carrying insects. However, red bat ecology has received little attention until recently, and few studies have compared roost selection between sexes. Using radiotelemetry, we located 142 tree roosts of red bats in forests of Arkansas. Both sexes roosted mostly in the leaves of large deciduous trees, but males occasionally roosted in small trees (under 5 cm in diameter), whereas females did not. Females roosted at greater heights than males, possibly to protect their young from predators. Both sexes preferred to roost in white oaks (*Quercus alba*) and hickories (*Carya* spp.) but avoided pines (*Pinus* spp.). Most roosts for both sexes were in forests dominated by mature (≥50 years old) trees, but many of those stands had recently been partially harvested. Retaining some overstory hardwoods and retaining unharvested buffers along stream drains in harvested forests would benefit both sexes of red bats in managed landscapes during summer.

16 Stanturf, John A.; Goodrick, Scott L.; Outcalt, Kenneth W. 2007. **Disturbance and coastal forests: A strategic approach to forest management in hurricane impact zones.** Forest Ecology and Management: 250: 119-135.

The Indian Ocean tsunami focused world attention on societal responses to environmental hazards and the potential of natural systems to moderate disturbance effects. Coastal areas are critical to the welfare of up to 50 percent of the world's population. Coastal systems in the Southern United States are adapted to specific disturbance regimes of tropical cyclones (hurricanes) and fire. In August and September 2005, Hurricanes Katrina and Rita caused what has been termed the most costly natural disaster in U.S. history, including an estimated $2 billion to $3 billion in damage from wind alone. A total of 2.23 million ha of timberland in the coastal States of Texas, Louisiana, Mississippi, and Alabama was damaged. Although financial loss estimates are incomplete, there is little doubt that these hurricanes caused extensive damage, and their effects on the landscape will linger for years to come. Crafting a strategy for incorporating large, infrequent disturbances into a managed landscape such as the forested coastal plain of the Southern U.S. must balance the desirable with the possible. We advance an adaptive strategy that distinguishes event risk (hurricane occurrence) from vulnerability of coastal forests and outcome risk (hurricane severity). Our strategy focuses on managing the disturbance event, the system after disturbance, and the recovery process, followed by modifying initial conditions to reduce vulnerability. We apply these concepts to a case study of the effects of recent Hurricanes Katrina and Rita on forests of the coastal plain of the northern Gulf of Mexico.

forest values, uses, and policies

17 Call, Jessica; Hayes, Jennifer. 2007. **A description and comparison of selected forest carbon registries: a guide for States considering the development of a forest carbon registry.** Gen. Tech. Rep. SRS-107. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 36 p.

There is increasing interest in tools for measuring and reducing emissions of carbon dioxide, a major greenhouse gas. Two tools that have been receiving a lot of attention include carbon markets and carbon registries. Carbon registries are established to record and track net carbon emission levels over time. These registries provide quantifiable and verifiable carbon for trade within a market. This report discusses the benefits and major elements of registries and then describes a selection of existing registries and protocols with forest carbon components. The report focuses on forests because of their carbon storage potential. The purpose of this report is to provide a starting point for any State government or other party considering the development of a carbon registry with a forestry component.

American chestnut leaves. (Photo courtesy of The American Chestnut Foundation)

18 Cho, Seong-Hoon; Bowker, J.M.; Park, William M. 2006. **Measuring the contribution of water and green space amenities to housing values: an application and comparison of spatially weighted hedonic models.** Journal of Agricultural and Resource Economics. 31(3): 485-507.

This study estimates the influence of proximity to water bodies and park amenities on residential housing values in Knox County, TN, using the hedonic price approach. Values for proximity to water bodies and parks are first estimated globally with a standard ordinary least squares model. A locally weighted regression model is then employed to investigate spatial nonstationarity and generate local estimates for individual sources of each amenity. Spatial nonstationarity implies that regression coefficients in a model looking at spatial relationships (proximity of park in explaining price of house, etc.) can be different over the range of the model's data or applicability. The local model reveals some important local differences in the effects of proximity to water bodies and parks on housing price.

19 Cho, Seong-Hoon; Newman, David H.; Wear, David N. 2005. **Community choices and housing demands: a spatial analysis of the Southern Appalachian Highlands.** Housing Studies. 20(4): 549-569.

This paper examines housing demand using an integrated approach that combines residential decisions about choices of community in the Southern Appalachian region with the application of a Geographic Information System (GIS). The empirical model infers a distinctive heterogeneity in the characteristics of community choices. The results also indicate that socio-economic motives strongly affect urban housing demands, while environmental amenities affect rural housing demands.

20 Cordell, H. Ken; Bowker, J.M. 2007. **The global economic contribution of protected natural lands and wilderness through tourism.** The Wild Planet Project. Boulder, CO: The WILD Foundation. 28-30.

These are the first-round results aimed at exploring at a global scale the complex relationships between protected natural lands, tourism, and economic growth. For this project we tightly defined concepts of tourism and nature-based tourism relevant to assessing global impacts. We identified and obtained contemporary best data enumerating tourists, travels, and spending. Finally, we pulled key concepts and data together for defining, quantifying, and spatially marking economic activities associated with tourists traveling to visit and see protected natural lands.

21 Mitchell, Dana. 2006. **Perspectives on woody biomass fuel value and specifications in Alabama.** ASABE Paper No. 068050. St. Joseph, MI: ASABE: 1-7.

Pulp and paper mills in Alabama buy woody biomass, but the specifications required by the mills vary and are not widely known. Some characteristics of woody biomass that are often included in mill specifications include size, species, ash content, and moisture content. These characteristics are briefly reviewed in reference to how they impact the energy value, physical handling, or processing of the material. An informal structured telephone interview was used to obtain the mill specifications and testing procedures used in some of the pulp and paper mills in Alabama. Finally, the relationships between woody biomass characteristics and the mill specifications were summarized.

22 Mitchell, Dana; Gallagher, Tom. 2007. **Chipping whole trees for fuel chips: a production study.** Southern Journal of Applied Forestry. 31(4): 176-180.

A time and motion study was conducted to determine the productivity and cost of an in-woods chipping operation when processing whole small-diameter trees for biomass. The study removed biomass from two overstocked stands and compared the cost of this treatment to existing alternatives. The treatment stands consisted of a 30-year-old longleaf pine stand and a 37-year-old loblolly pine stand. In the longleaf pine stand, 71 percent of the trees removed were less than 5 in. dbh. In the loblolly pine stand, approximately 81 percent of the stems removed were less than 5 in. dbh. The harvesting system consisted of conventional ground-based harvesting equipment and a three-knife chipper that processed the biomass into fuel chips. The average production time to fill a chip van was 24.61 minutes. The chip moisture content averaged 94.11

percent (dry basis). Using machine rates and Federal labor wage rates, the in-woods cost of producing fuel chips was $9.18/green ton (gt). The cost of the biomass chipping operation ($15.18/gt), including transportation, compared favorably to existing alternative treatments of cut-and-pile or mulching.

23 Mitchell, Dana; Gallagher, Tom. 2007. **Physiological and psychological impacts of extended work hours in logging operations.** ASABE Paper No. 075011. St. Joseph, MI: ASABE: 1-5.

A study was initiated in 2006 to develop an understanding of considerations of using extended work hours in the logging industry in the Southeastern United States. Through semistructured interviews, it was obvious that loggers were individually creating ways of successfully implementing extended working hours without understanding potential impacts. Some use rotating shifts, while others use permanent shifts. Some work 24 hours/day while most did not. Many employers said they had problems with employee retention while trying to initially implement extended working hours with existing logging crews. This paper provides a brief synthesis of existing literature on physiological and psychological impacts of extended working hours on employees. Because little documentation is available about extended working hours in the logging industry, these interview data are compared and contrasted with published shift work impacts from other industries.

24 Mitchell, Dana; Rummer, Bob. 2007. **Processing woody debris biomass for co-milling with pulverized coal.** ASABE Paper No. 078049. St. Joseph, MI: ASABE: 1-5.

This woody biomass utilization project involves removing small diameter stems and unmerchantable woody material from national forest lands and delivering it to a coal-fired power plant in Alabama for energy conversion. The Alabama Power Company will test the utilization of the woody biomass in one of their energy production facilities to determine the feasibility of this new market. The Talladega National Forest and the Gadsden Steam Plant are serving as the demonstration areas for the project. One of the first steps in this project was to select in-woods processing equipment. The biomass fuel to be created in this project must meet unique criteria that differentiate fuel chips created for the power plant from those of typical fuel chips. The wood fuel was to be created from whole-tree chips and co-milled with coal. Biomass specifications were primarily limited by size so that the chips would pass through the current fuel handling system in the plant. In addition, the fuel chips must have edges that are fairly clean and sharp to prevent plugging fuel pathways in the plant. One of the initial steps was to examine output from a variety of in-woods processing equipment to determine which could meet the specifications with one-pass processing. After further review, it was determined that a cutting action, as opposed to a shearing action, was needed to meet the raw material handling requirements within the plant. Output from a specially equipped horizontal grinder was the final equipment choice.

25 Onokpise, Oghenekome U.; Rockwood, Don L.; Worthen, Dreamal H.; Willis, Ted, eds. 2008. **Celebrating minority professionals in forestry and natural resources conservation: proceedings of the symposium on the tenth anniversary of the 2 + 2 Joint Degree Program in Forestry and Natural Resources Conservation.** Gen. Tech. Rep. SRS-106. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 111 p.

The 22 papers in this symposium highlight the program and its contribution to increasing minority professionals in forestry and natural resources conservation. The 10th anniversary symposium brought together graduates of the program, current students and officials from universities, the Forest Service, other agencies, and private industry. The theme of the symposium was "Education, Training, and Diverse Workforce."

threats to forest health

26 Ambrose, Mark J.; Conkling, Barbara L., eds. 2007. **Forest Health Monitoring 2005 national technical report.** Gen. Tech. Rep. SRS-104. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 76 p.

The Forest Health Monitoring program's annual national technical report presents results of forest health analyses from a national perspective using data from a variety of sources. The report is organized according to the Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests of the Santiago Declaration. The results of several analyses of forest fragmentation are synthesized to evaluate fragmentation in U.S. forests. Drought in 2004 is presented, and drought over the decade 1995-2004 is compared with the historical average. Areas of intense forest fire activity during the 2004 fire season are identified. Ozone bioindicator data are used to create an interpolated ozone map of the United States, and the possible impact on sensitive tree species is examined. Aerial survey data are used to identify hotspots of insect and disease activity based on the relative exposure to defoliation- and mortality-causing agents. Data from the Forest Inventory and Analysis down woody materials indicator are analyzed to produce preliminary per-acre estimates of amounts of woody debris and carbon pools stored in down woody materials. Data from the Forest Inventory and Analysis soil quality indicator are analyzed to provide preliminary information about erosion and soil compaction, soil pH, and effective cation exchange capacity, and to produce preliminary per-hectare estimates of soil carbon.

27 Ambrose, Mark J.; Conkling, Barbara L.; Riitters, Kurt H.; Coulston, John W. 2008. **The Forest Health Monitoring national technical reports: examples of analyses and results from 2001-2004.** [Brochure]. Science Update SRS-18. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. [Not paged].

This brochure presents examples of analyses included in the first four Forest Health Monitoring (FHM) national technical reports. Its purpose is to introduce the reader to the kinds of information available in these and subsequent FHM national technical reports. Indicators presented here include drought, air pollution, forest fragmentation, and tree mortality. These and other indicators were generally analyzed by broad ecological regions characterized by similar climate, vegetation, geology, and soils. Sources are provided for additional information about these analyses, as well as the FHM Program in general.

28 Boggs, Johnny L.; McNulty, Steven G.; Pardo, Linda H. 2007. **Changes in conifer and deciduous forest foliar and forest floor chemistry and basal area tree growth across a nitrogen (N) deposition gradient in the Northeastern U.S.** Environmental Pollution. 149: 303-314.

There was much concern about the impacts of acid rain on New England forests during the 1980s. Acid rain is composed of automobile and industrial emissions of nitrogen and sulfur, and the amount of acid rain increases from east to west across the region. In 1987, SRS research ecologist Steve McNulty lead a research project to sample soil and needle processes and chemistry across 161 high elevation (mainly) spruce sites from Maine to New York. The study concluded that acid rain was negatively impacting for health in the western (i.e., highest acid rain) end of the region. In the early 1990s, the U.S. Congress passed the Clean Air Act that removed much of the sulfur but did little to reduce the nitrogen loading to the forests. In the early 2000s, a subset of the plots from the 1987 sampling was re-sampled to examine how continued nitrogen inputs had changed forest health. The study found that while some of the areas have begun to recover, other areas continue to deteriorate due to continued nitrogen additions. Additional studies are now underway to examine how low nitrogen inputs must be to allow for forest recovery.

29 Coulston, John W.; Ambrose, Mark J.; Riitters, K.H.; Conkling, Barbara L. 2005. **Forest Health Monitoring 2004 national technical report.** Gen. Tech. Rep. SRS-90. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 81 p.

The Forest Health Monitoring (FHM) Program's annual national technical report presents results of forest health analyses from a national perspective using data from a variety of sources. Results presented in the report pertain to the Santiago Declaration's Criterion 1— Conservation of Biological Diversity and Criterion 3—Maintenance of Forest Ecosystem Health and Vitality. We include status and trend information where possible, consistent with previous FHM national technical reports. Additional analytical techniques and results, new to the national report, are presented as examples of ways forest health data can be used. This report has eight sections. The first contains introductory material. The next four contain results from analyses of status and change for selected forest health indicators, e.g., several measures of forest fragmentation, mortality and defoliation-causing insects and diseases, crown condition, and tree mortality, similar to analyses in previous FHM national reports. The next two sections describe analytical techniques and provide information about assessments presented in the national report for the first time, and the final section is a summary.

30 Ebermann, Ernst; Moser, John C. 2008. **Mites (Acari: Scutacaridae) associated with the red imported fire ant, *Solenopsis invicta* Buren (Hymenoptera: Formicidae), from Louisiana and Tennessee, USA.** International Journal of Acarology. 34(1): 55-69.

Four species of *Scutacarus* and one of *Imparipes* (Acari: Scutacaridae) are documented as phoretic from alates and workers of the red imported fire ant (*Solenopsis invicta* Buren) in Louisiana and Tennessee, USA. *Imparipes* (*Imparipes*) *louisianae* n. sp., *Scutacarus nanus* n. sp., and *Scutacarus tertius* n. sp. are described. The biology and phoretic behaviors of all five species are discussed from those collected from the vicinity of Pineville, LA.

31 Fraedrich, S.W.; Harrington, T.C.; Rabaglia, R.J. [and others]. 2008. **A fungal symbiont of the redbay ambrosia beetle causes a lethal wilt in redbay and other Lauraceae in the Southeastern USA.** Plant Disease. 92:215-224. [Editor's note: Southern Research Station scientists M.D. Ulyshen, J.L. Hanula, and D.R. Miller co-authored this publication.]

Extensive mortality of redbay, a tree in the laurel family commonly found in the Coastal Plain forests of the Southeastern United States, has been observed in Georgia and South Carolina since 2003, and Florida since 2005. Mortality is due to vascular wilt caused by a previously unknown fungus related to the Dutch elm disease pathogen. The new fungus is associated with the redbay ambrosia beetle, an exotic insect native to Southeast Asia. Trees affected by the disease often exhibit a rapid wilting of foliage and a dark, black discoloration of sapwood. The fungus is apparently introduced during attacks on stems and branches. This is the first ambrosia beetle symbiont known to cause vascular wilt. Frequent introductions of ambrosia beetles on solid wood packing materials suggests similar pathogens may appear on our shores. Because this disease affects redbay and sassafras as well as other members of the Lauraceae, we propose the common name "laurel wilt." The disease threatens members of the Lauraceae indigenous to the Americas, including avocado in commercial production.

32 Koch, F.H.; Cheshire, H.M.; Devine, H.A. 2006. **Landscape-scale prediction of hemlock woolly adelgid, *Adelges tsugae* (Homoptera: Adelgidae), infestation in the Southern Appalachian Mountains.** Environmental Entomology. 35(5): 1313-1323. [Editor's note: This research was funded by the U.S. Forest Service Forest Health Monitoring Program.]

The spread of hemlock woolly adelgid (HWA) had been described in broad terms, but factors predicting where it would first invade a landscape had not been analyzed previously. We examined first-year infestation locations in the Great Smoky Mountains region to identify possible factors. We derived statistical classification functions distinguishing infested from uninfested sites based on environmental variables, and used the functions to generate risk maps. Our results suggest roads, trails, and riparian corridors provide important connectivity, enabling long-distance dispersal of HWA, probably by humans or birds. The derived functions can also be used to make risk maps for elsewhere in the Southern Appalachians, allowing better targeting of control efforts.

33 McNulty, Steven G.; Cohen, Erika C.; Moore Myers, Jennifer A. [and others]. 2007. **Estimates of critical acid loads and exceedances for forest soils across the conterminous United States.** Environmental Pollution. 149: 281-292. [Editor's note: SRS scientist Harbin Li co-authored this paper.]

For several decades Europe (and most recently Canada) has used the notion of "critical acid load" to measure the state of health of their forests. Acids such as nitrogen and sulfur can negatively impact forest health, and a critical acid load is a measure of a forest's ability to absorb acid without showing negative impacts. If acid loads exceed the forest's ability to absorb acid, then tree mortality may increase. Steve McNulty, SRS research ecologist, led a study to estimate critical acid loads for all forests in the lower 48 United States at a 1 km^2 resolution. Most of the exceedance of the critical acid load occurred in high elevation Northeastern States, but some also occurred in eastern North Carolina. Findings from this study will help forest managers to locate areas of potential exceedance of critical acid loading so that additional study, and, if necessary, corrective management plans can be established.

34 Paoletti, Elena; Bytnerowicz, Andrzej; Andersen, Chris [and others]. 2007. **Impacts of air pollution and climate change on forest ecosystems—emerging research needs.** The Scientific World Journal. 7(S1): 1-8. [Editor's note: Southern Station scientist Steven McNulty co-authored this publication.]

This paper summarizes outcomes from the 2006 meeting "Forests under Anthropogenic Pressure—Effects of Air Pollution, Climate Change, and Urban Development." Tropospheric or ground-level ozone (O_3) is still the phytotoxic air pollutant of major interest. Challenging issues include how to make O_3 standards or critical levels more biologically based and at the same time practical for wide use; quantification of plant detoxification processes in flux modeling; inclusion of multiple environmental stresses in critical load determinations; new concept development for nitrogen saturation; interactions between air pollution, climate, and forest pests; effects of forest fire on air quality; the capacity of forests to sequester carbon under changing climatic conditions and coexposure to elevated levels of air pollutants; and enhanced linkage between molecular biology, biochemistry, physiology, and morphological traits.

35 Pardo, Linda H.; McNulty, Steven G.; Boggs, Johnny L.; Duke, Sara. 2007. **Regional patterns in foliar ^{15}N across a gradient of nitrogen deposition in the Northeastern U.S.** Environmental Pollution. 149: 293-302.

American chestnut burr. (Photo by Paul Wray, Iowa State University, Bugwood.org)

Wormy chestnut paneling. (Photo courtesy of The American Chestnut Foundation)

In the 1980s acid rain was partially responsible for the death of high elevation spruce forests across New England. Research studies determined that sulfur and nitrogen were the primary contributors to the damage. In 1990, the U.S. Congress passed the Clean Air Act, which reduced the amount of acidic precipitation by over 70 percent. Linda Pardo, Northeastern Research Station research ecologist, led a study to examine how the forest has responded to changes in acid rain levels using nitrogen isotopes (δ^{15}) in the leaves of spruce needles. The team compared samples collected in the late 1980s by SRS research ecologist Steve McNulty with those collected from the same sites in the late 1990s by SRS research biologist Johnny Boggs. The study concluded that spruce needle δ^{15} N was strongly correlated with N deposition, and was also positively correlated with net nitrification potential (i.e., an indicator of forest health). This research suggests that very complex ecosystem processes and conditions of forest health can be simplified using measurements of foliar chemistry. This technique may be useful for rapidly assessing forest health in the future.

36 Riitters, Kurt; Estreguil, Christine, eds. 2007. **International research to monitor sustainable forest spatial patterns: proceedings of the 2005 IUFRO World Congress symposium.** e-Gen. Tech. Rep. 106. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. http://www.srs.fs.usda.gov/pubs/28859 [Date accessed: April 21, 2008].

Presentations from the symposium "International Research to Monitor Sustainable Forest Spatial Patterns," which was organized as part of the International Union of Forest Research Organizations (IUFRO) World Congress in August 2005, are summarized in this report. The overall theme of the World Congress was "Forests in the Balance: Linking Tradition and Technology," and the symposium addressed the Congress sub-theme "Demonstrating Sustainable Forest Management."

37 Shelton, Thomas G.; Cartier, Laurent; Wagner, Terence L.; Becker, Christian. 2007. **Influence of a mineral insecticide particle size on bait efficacy against *Reticulitermes flavipes* (Isoptera: Rhinotermitidae).** Sociobiology. 50(2): 521-533.

Termite baits attempt to control large numbers of termites by providing food containing trace amounts of toxicants that eventually kill the insects. Toxicants typically are liquid synthetic compounds. In cooperation with industry, U.S. Forest Service personnel examined the use of a natural insecticide—a mineral called cryolite—mixed with cellulose as termite bait. Cryolite is sold commercially as Kryocide® (by Cerexagri, Inc.) for controlling moths and beetles in vegetable crops. Active concentrations and sizes of cryolite crystals were determined in the laboratory. This is an important first step in identifying a potential new bait active ingredient for controlling termites.

watershed science

38 Adams, Susan B. 2007. **Freshwater sculpins: phylogenetics to ecology.** Transactions of American Fisheries Society. 136: 1736-1741.

Freshwater sculpins are small fishes that live in cool- and coldwater habitats. More than 60 sculpin species occur. Sculpins frequently constitute the largest component of stream fish communities and serve diverse ecosystem functions. Although sculpins are often ignored, many management and conservation goals may be better met by focusing on sculpins than on sport fishes. We review recent literature on freshwater sculpins and introduce a module of papers reporting sculpin research from diverse perspectives. The objectives are to (1) highlight the various scales at which sculpin research is informative, (2) stimulate interest in sculpin research and conservation, and (3) illustrate some conservation needs and management uses of sculpins that are unique from those of sport fishes.

39 Adams, Susan B.; Hamel, Paul B.; Connor, Kristina [and others]. 2007. **Potential roles of fish, birds, and water in swamp privet (*Forestiera acuminata*) seed dispersal.** Southeastern Naturalist. 6(4): 669-682. [Editor's note: Southern Station scientist Emile S. Gardiner co-authored this publication.]

Suspecting diverse seed dispersal avenues for swamp privet (*Forestiera acuminata*), a common wetland plant in the Lower Mississippi Alluvial Valley, we launched an interdisciplinary study of its seed ecology. We identified channel catfish as seed dispersers and cedar waxwings as probable dispersers. Several other bird species consumed, but probably destroyed, the fruits. We inferred that passive seed dispersal by water also occurs. The linkage we identified between aquatic and terrestrial ecosystems presumably benefits both plants and fish. Diverse seed dispersal avenues presumably allows for effective dispersal under a wide range of hydrologic conditions.

40 Amatya, Devendra; Trettin, Carl. 2008. **An eco-hydrological project on Turkey Creek watershed, South Carolina, USA.** In: Meire, P.; Coenen, M.; Lombardo, C. [and others], eds. Integrated water management: practical experiences and case studies. NATO science series IV. The Netherlands: Springer: 80: 115-126.

The low-gradient, forested wetland landscape of the Southeastern U.S. Coastal Plain represents an important ecosystem, yet there is little information available on the region's eco-hydrological and biogeochemical processes. Long-term hydrologic monitoring can not only provide information for understanding basic processes and interactions with climate, land use change, and other disturbances, but also baseline data for evaluating responses and testing eco-hydrologic models. This information is crucial for sustainable management of water resources in the region, with its growing population, rapid development, and timber and agricultural industries. This paper presents a multi-collaborative approach for building a monitoring and modeling framework for conducting long-term eco-hydrological studies on a 5,000 ha watershed in the S.C. Coastal Plain.

41 Bragg, Don C. 2008. **An improved tree height measurement technique tested on mature southern pines.** Southern Journal of Applied Forestry. 32(1): 38-43.

Most methods to measure tree height follow either the geometric approach of similar triangles or the trigonometry-based tangent method. However, few adjust either technique for ground slope, tree lean, crown shape, and crown configuration, making errors commonplace. Given known discrepancies exceeding 30 percent, a reevaluation of height measurement is in order. The sine method is a trigonometric alternative that measures a real point in the crown and thus is not subject to the same assumptions as the similar triangle and tangent approaches. In addition, the sine method is insensitive to distance from tree or observer position and cannot overestimate tree height, advantages demonstrated with mature pines from Arkansas.

42 Bragg, Don C.; Shelton, Michael G.; Guldin, James M. 2008. **Restoring old-growth southern pine ecosystems: strategic lessons from long-term silvicultural research.** In: Deal, R.L., tech. ed. Integrated restoration of forested ecosystems to achieve multiresource benefits: proceedings of the 2007 national silviculture workshop. Gen. Tech. Rep. PNW-GTR-733. Portland, OR: U.S. Dept. of Agriculture, Forest Service, Pacific Northwest Research Station: 211-224.

The successful restoration of old-growth-like loblolly and shortleaf pine-dominated forests requires the integration of ecological information with long-term silvicultural research. Conventional management practices such as timber harvesting or competition control have supplied us with the tools for restoration efforts. For example, the Good and Poor Farm Forestry Forties on the Crossett Experimental Forest (CEF) have been under uneven-aged silvicultural prescriptions for 70 years and have provided insights on pine regeneration, structural and compositional stability, endangered species management, and sustainability. Other studies on the CEFs Reynolds Research Natural Area have provided lessons on the long-term impacts of fire suppression, woody debris and duff accumulation, hardwood competition, and pine regeneration failures.

43 Dosskey, M.G.; Hoagland, K.D.; Brandle, J.R. 2007. **Change in filter strip performance over ten years.** Journal of Soil and Water Conservation. 62(1): 21-32.

Perennial vegetation is often established between agricultural fields and streams to filter sediment and fertilizer out of runoff water before they enter streams. The performance of forested and grassed filter strips were tracked for 10 years following planting on bare ground in

American chestnut stump. (U.S. Forest Service photo) order to see what kind of vegetation works best and how long it takes for the filter strips to become fully functional. Results show that grass and forest vegetation (grass, shrubs, and trees) work equally well and that it takes about three growing seasons before these filters work their best, depending on how quickly a dense groundcover layer develops.

44 Ford, Chelcy R.; Hubbard, Robert M.; Kloeppel, Brian D.; Vose, James M. 2007. **A comparison of sap flux-based evapotranspiration estimates with catchment-scale water balance.** Agricultural and Forest Meteorology. 145: 176-185.

Studies evaluating comparability of sap flux-based estimates of transpiration with alternative methods for estimating transpiration at the landscape scale are rare. Determining and accounting for sources of variation are critical for making landscape inferences about transpiration. We monitored sap flux in 40 trees in a 50-year-old eastern white pine plantation for two years. We scaled estimates of transpiration and interception to the catchment and compared these with water balance estimates. For both years, the two independent estimates were similar, differing by an average of 10 percent. Results indicate that sap flux-based estimates of transpiration may also be useful in mixed-species stands and could provide a tool to evaluate impacts of species losses on catchment water balance.

45 Haag, Wendell R.; Commens-Carson, Amy M. 2008. **Testing the assumption of annual shell ring deposition in freshwater mussels.** Canadian Journal of Fisheries and Aquatic Science. 65: 493-508.

We tested the assumption of annual shell ring deposition by freshwater mussels in three rivers using 17 species. In 2000, we notched shell margins, returned animals to the water, and retrieved them in 2001. In 2003, we measured shells, affixed numbered tags, returned animals, and retrieved them in 2004 and 2005. We validated deposition of a single internal annulus per year in all species and in 94 percent of specimens. Most unvalidated shells were old individuals with tightly crowded rings. Handling produced a conspicuous disturbance ring in all specimens and often resulted in shell damage. Observed growth was similar to but slightly lower than growth predicted by von Bertalanffy length-at-age models developed independently from shell annuli; further, handling specimens in 2 consecutive years reduced growth more than handling only once. These results show that mussels are extremely sensitive to handling. Brief handling does not likely increase short-term mortality, but repeated handling could decrease long-term fitness. Handling effects should be considered in sampling programs or when interpreting results of mark-recapture studies designed to estimate mussel growth. Production of annual shell rings is a pervasive phenomenon across species, space, and time, and validated shell rings can provide accurate estimates of age and growth.

46 Hamel, Paul B. 2007. **Handbook of avian hybrids of the world; Eugene M. McCarthy. [Book review].** Integrative and Comparative Biology. 47(5): 786-787.

The study of hybridization in nature is a difficult task, principally because of the very low probability of finding an animal that represents the offspring of the mating of a male of one species with a female of another species. Certain situations are well-known, some in North America, such as the hybridization between the two subspecies of the yellow-rumped warbler. In the Southern States we have the “myrtle warbler” subspecies in abundance in the winter, while in the Southwest the “Audubon’s warbler” subspecies spends the winter. Where the two subspecies’ ranges meet in the northern Rocky Mountains, hybrids between the two are common. Most hybrid situations are not well-known, however. Thus, a debt of thanks is due to author Eugene McCarthy for the tremendous effort put into the Handbook of Avian Hybrids of the World. He painstakingly compiled and evaluated more than 5000 references documenting hybridization among bird species for this book. It provides a resource for all those interested in bird species, in differences between bird species, and in evolutionary pressures on bird species, not to mention in birdwatching, to add new species to their personal list. Most cases are nowhere near as well-understood as that involving the yellow-rumped warbler.

47 Harder, Scott V.; Amatya, Devendra M.; Callahan, Timothy J. [and others]. 2007. **Hydrology and water budget for a forested Atlantic Coastal Plain watershed, South Carolina.** Journal of American Water Resources Association. 43(3): 563-575. [Editor’s note: Southern Station scientist Carl C. Trettin co-authored this publication.]

Increases in timber demand and urban development in the Atlantic Coastal Plain over the past decade have motivated studies on eco-hydrology and sustainable management of coastal plain watersheds. The purpose of this study was to quantify the water budget of a first-order forested watershed located within the Forest Service Santee Experimental Forest near Charleston, SC. Annual rainfall of 1671 mm in 2003 and 962 mm in 2004 was 300 mm above and 400 mm below normal with runoff coefficients of 0.47 and 0.08, respectively, indicating a wide variability of outflows as affected by antecedent soil conditions. Estimated evapotranspiration (~920 mm) in both years was a major component of water loss. These results may have implications as reference data for forest management practices on the Atlantic Coastal Plain watersheds.

48 Li, Harbin; McNulty, Steven G. 2007. **Uncertainty analysis on simple mass balance model to calculate critical loads for soil acidity.** Environmental Pollution. 149: 315-326.

Simple mass balance equations (SMBE) of critical acid loads (CAL) in forest soil were developed to assess potential risks of air pollutants to ecosystems. However, to apply SMBE reliably at large scales, SMBE must be tested for adequacy and uncertainty. Our goal was to provide a detailed analysis of uncertainty in SMBE so that sound strategies for scaling up CAL estimates to the national scale could be developed. Specifically, we wanted to quantify CAL uncertainty under natural variability in 17 model parameters, and determine their relative contributions in predicting CAL. Improvements in estimates of these factors are crucial to reducing uncertainty and successfully scaling up SMBE for national assessments of CAL.

49 Skojac, Daniel A., Jr.; Ezell, Andrew W.; Meadows, James S.; Hodges, John D. 2007. **First-year growth and quality response of residual hardwood poletimber trees following thinning in an even-aged sawtimber stand.** Res. Note SE-13. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 6 p.

First-year diameter growth and epicormic branching responses of hardwood poletimber trees retained following thinning in a sawtimber stand are reported. Poletimber trees were classified as either superior or inferior poletimber, and then retained on separate plots receiving identical thinning treatments. Comparison of responses by the two classes of poletimber was used to evaluate their future potential for grade sawtimber in the thinned sawtimber stand. Thinning treatments included an unthinned control, two levels of the desirable treatment (retained preferred and desirable sawtimber and either superior or inferior poletimber), and two levels of the acceptable treatment (retained preferred, desirable, and acceptable sawtimber and either superior or inferior poletimber). Preliminary results indicated that future sawtimber production from residual superior poletimber trees may be a realistic option but appears less likely from their inferior poletimber counterparts. The desirable treatment yielded significant first-year diameter growth of superior poletimber trees (0.20 inches), but also stimulated greater production of new epicormic branches on the potentially more valuable superior poletimber trees. The acceptable treatment minimized the production of epicormic branches on superior poletimber.

50 Williams, T.M.; Amatya, D.M.; Hitchcock, D.R. [and others]. 2007. **Chapel Branch Creek TMDL development: integrating TMDL development with implementation.** ASABE Paper No. 072042. St. Joseph, MI: American Society of Agricultural and Biological Engineers: 1-13.

Chapel Branch Creek, which drains a 1600-ha area into Lake Marion, is listed as an impaired water for excess nitrogen (N), phosphorus (P), chlorophyll-a, and pH. Lake Marion is an important recreational area generating economic benefits for both the adjacent Town of Santee and coastal South Carolina. The watershed has land uses with varying potential nonpoint sources of N and P. A project supported by SC Department of Health and Environmental Control is underway to develop and implement a Total Maximum Daily Load (TMDL) for the above pollutants. The major challenge to implementation is developing stakeholder buy-in for load reductions. Successful implementation requires both scientifically valid determination of source loadings and clear demonstration of results to stakeholders. GIS-based watershed characteristics and water quality sampled from various land uses are being used to identify potential source areas. These and on-site measured flow and weather data are being used in a hydrology/water quality model for calculating load allocations and reductions needed to develop a TMDL and BMPs. This information will be used to educate stakeholders about model validity. Early involvement of stakeholders in study design has facilitated development of a strong cooperative attitude.

Meadowview Research Farm. (Photo courtesy of The American Chestnut Foundation)

The family of James and Caroline Shelton pose by a large dead chestnut tree in Tremont Falls, TN, circa 1920. The tree was found to be hollow. (Photo courtesy of the Great Smoky Mountains National Park Library)

Research Work Units

Location & Project Leader	Name & Web Site	Phone
Athens, GA Ken Cordell	Pioneering Forestry Research on Emerging Societal Changes	706-559-4263

Forest Ecosystem Restoration and Management

Location & Project Leader	Name & Web Site	Phone
Asheville, NC Cathryn Greenberg	Upland Hardwood Ecology and Management www.srs.fs.usda.gov/bentcreek	828-667-5261
Auburn, AL Kris Connor	Restoring and Managing Longleaf Pine Ecosystems www.srs.fs.usda.gov/4111	334-826-8700
Monticello, AR James Guldin	Southern Pine Ecology and Management www.srs.fs.usda.gov/4106	870-367-3464
Saucier, MS Dana Nelson	Forest Genetics and Ecosystems Biology www.srs.fs.usda.gov/organization/unit/mississippi.htm#SRS-4153	228-832-2747

Forest Values, Uses, and Policies

Location & Project Leader	Name & Web Site	Phone
Gainesville, FL Vacant	Integrating Human and Natural Systems www.srs.fs.usda.gov/trends	352-376-3213
Auburn, AL Bob Rummer	Forest Operations www.srs.fs.usda.gov/forestops/	334-826-8700
Pineville, LA Les Groom	Utilization of Southern Forest Resources www.srs.fs.usda.gov/4701	318-473-7268
Research Triangle Park, NC David Wear	Forest Economics and Policy www.srs.fs.usda.gov/econ	919-549-4093

Threats to Forest Health

Location & Project Leader	Name & Web Site	Phone
Asheville, NC Danny Lee	Eastern Forest Environmental Threat Assessment Center www.srs.fs.usda.gov/cc/threatassessment.htm	828-257-4854
Athens, GA John Stanturf	Center for Forest Disturbance Science www.srs.fs.usda.gov/disturbance	706-559-4316
Pineville, LA Kier Klepzig	Insects, Diseases, and Invasive Plants of Southern Forests www.srs.fs.usda.gov/4501	318-473-7232

Forest Watershed Science

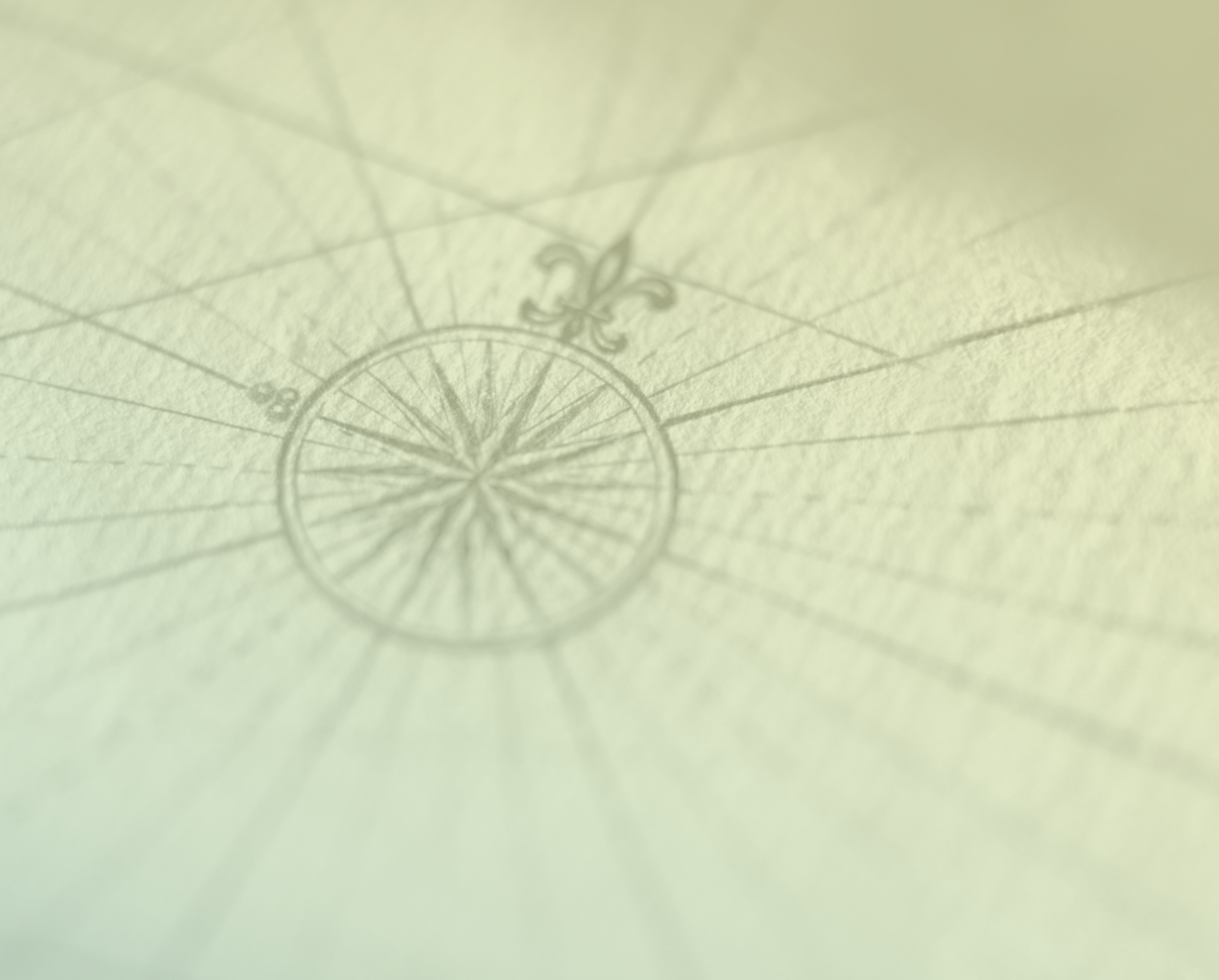
Location & Project Leader	Name & Web Site	Phone
Franklin, NC Jim Vose	Center for Forest Watershed Research www.srs.fs.usda.gov/coweeta	828-524-2128
Lincoln, NE Michele Schoeneberger	National Agroforestry Center - Research www.nac.gov	402-437-5178
Stoneville, MS Ted Leininger	Center for Bottomland Hardwoods Research www.srs.fs.usda.gov/cbhr	662-686-3154

Natural Resources Inventory and Monitoring

Location & Project Leader	Name & Web Site	Phone
Knoxville, TN Bill Burkman	Forest Inventory and Analysis www.srsfia2.fs.fed.us	865-862-2000

"Linking science and human purpose, adaptive management serves as a compass for us to use in searching for a sustainable future."

—Kai N. Lee, *The Compass and the Gyroscope—Integrating Science and Politics for the Environment**



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Hurricane Charley, 2004. (Photo provided by the SeaWiFS Project, NASA/Goddard Space Flight Center, and ORBIMAGE)