Joint Fire Science Program

Fire Science Brief

RESEARCH SUPPORTING SOUND DECISIONS

To test whether prescribed fire increases light levels reaching the forest floor, researchers use hemispherical photographs of the canopy. Credit: University of Kentucky.

Fire Returns to Southern Appalachian Forests

Summary

In the Daniel Boone National Forest (DBNF) in eastern Kentucky, controlled experiments are shedding light on the role of fire in meeting an urgent need: encouraging regeneration of oak in the forest. Though mature oak dominates the canopy in much of the forest, competition from species that tolerate shade has jeopardized the ability of oak to successfully regenerate.

Since 1995, researchers have been collaborating with Forest Service managers, with funding from the Joint Fire Science Program (JFSP), to document the multiple effects of prescribed fire on canopy opening, seedling recruitment, damage to mature trees, fuel loading, and effects on native invasive species in the midstory and understory that compete with oak seedlings for survival.

These efforts not only add to the knowledge base; the collaborative nature of the research also opens pathways of communication between researchers and resource managers. In addition, the research teams are engaged in efforts to improve understanding by the general public, who enjoy recreation in the national forest or live in nearby communities, of the important role of fire on the landscape.

Key Findings

- Intensive logging at the turn of the last century and a strict fire exclusion policy beginning in the 1930s has resulted in a predominantly even-aged, oak-dominated landscape in much of the southern Appalachians.
- Prescribed fire has been used experimentally by the Forest Service and others since the 1980s to encourage regeneration of viable sapling oaks and reduce competition from competing, shade-tolerant species such as red maple and shade-intolerant species such as yellow poplar.
- Research has not shown that fire alone in the manner that it has been applied has so far substantially benefited oak regeneration.
- Other considerations such as improved habitat for wildlife may nevertheless justify the use of fire alone in some instances.
- Complementary techniques such as mechanical thinning, herbicide treatment, and selected harvesting may improve the outlook for regeneration of oak across a variety of landscapes.

A fire regime for today's forests

In the late 1980s, the Forest Service began to introduce fire as a management tool in southern Appalachian forests. This is in partial requirement of its mandate to maintain the community composition and diversity of the lands it manages.

Little information was available, however, as to optimal treatment regimes or specific effects of fire on the much-altered modern forest landscape. Now, after more than 20 years of experimental prescribed fire and more than a decade of research, a clearer picture of the complex effects of prescribed fire is emerging.

Prescribed fires in the central Appalachian hardwood forest are typically low to moderate intensity ground fires that primarily consume leaf litter and small diameter woody fuels. Credit: Patrick Brose, USDA Forest Service.

For the long-term health of mature, oak-dominated forests, this information is critical. Mary Arthur, a Professor in the Department of Forestry at the University of Kentucky, Lexington, and other researchers are working in DBNF as part of a larger effort spearheaded by the Upland Hardwood Ecology and Management unit of the Forest Service to explore the role that prescribed fire may play in restoring Southern Appalachian upland hardwood forests. "It is important to recognize that since the last ice age and the retreat of the glaciers, humans have been an interactive part of our environment," says project leader David Loftis, headquartered at Bent Creek Experimental Station in Pisgah National Forest, "and fire has been an important component in our manipulation of the landscape. We need to adapt our management policy to uses compatible for today's purposes, whether economic, aesthetic, recreational, or to support wildlife."

The aging oak forest

In the early 20th century, massive culling by the timber industry, the blight that decimated the American chestnut, and a strict policy of fire exclusion converged to produce an even-aged stand of mature oak. "In essence, we have created an aging generation or couple of generations of oak-dominated forests," Loftis says. Below the canopy, oak seedlings and saplings are failing to develop into competitive regeneration sources as shade-tolerant species such as white pine and red maple thrive.

Research is shedding light on the specific effects of fire at different frequencies and intensities on stand structure, the light environment, seedling survival, canopy cover, and potential adverse effects on oak seedlings and mature trees. As the data accumulate, a clearer picture of management strategies to encourage oak regeneration is emerging, though 8 to 10 years of study have yielded conflicting and sometimes confusing results. "Our results using fire alone to encourage oak regeneration indicate that prescribed fire is not a silver bullet," says Arthur.

Prescribed fire reduces the number of stems less than 8 inches in diameter but stimulates the sprouting response of damaged trees. Credit: University of Kentucky.

Upland oaks such as scarlet oak, chestnut oak, white oak, black oak, and southern red oak have a strategy of persisting through disturbance. "Upland oak species have a strategy to regenerate from advance regeneration—the

establishment and development of seedlings and saplings from acorns—and from stump sprouts, following release," Loftis says. "The oaks in the next stand are proportional to the regeneration sources present in the previous stand." Success, their ability to become dominant or co-dominant trees in the overstory, is related to the size of these sprouts and saplings at the time of release.

Competition for survival

Upland oak species are intermediate in shade tolerance and fire-resistant with a large root system relative to other species. Since the decimation of the chestnut, it is the primary source of hard mast for wildlife. Excessive shade in the understory and midstory from competing species such as red maple is one of the key reasons oak fails to successfully regenerate. "Red maple is proliferating on the upland sites," says Arthur. "Historical pollen records show that, since the 1930s, red maple has proliferated."

Research conducted in the Red River Gorge Geological Area of the DBNF on the Cumberland Plateau in eastern Kentucky following prescribed burns by the Forest Service aims to correlate gap fraction, defined as the percentage of sky area not blocked by vegetation, with the density of stems in the understory.

Though fire increases gap fraction in the short-term, red maple sprouts vigorously after fire, negating the effects within 1 to 4 years. Even on the most frequently burned sites, late winter, moderate-intensity fire was not sufficient to favor oak recruitment in the long term. Arthur suggests that mechanical treatments to eliminate sprouts or burning later in the season when stumps are actively sprouting could improve recruitment of oak seedlings.

Another important competitor with oak on eastern Kentucky ridgetops is eastern white pine. Young white pine has a thin bark, is moderately shade tolerant, and is fire sensitive. As pine matures, the bark thickens and fire tolerance increases. The presence of mature trees on mixed oak-pine ridgetop ecosystems has therefore been used as an indicator of the time since the last fire.

A study conducted on the Red River Gorge Geological Area in March of 1995 and 1996 detailed the effects of single prescribed burns on treatment sites where mixed oaks and a few large white pines dominated the overstory, with red maple and white pine dominating the midstory. The Forest Service objective was to kill most of the white pines under 10 feet (3 meters) tall in the hopes of creating conditions favorable to oak recruitment.

Prescribed fire led to mortality of white pines up to 20 years old, and though pine mortality was documented for 3 years after the single fire, where good seed fall was measured, prescribed fire actually encouraged establishment of white pine seedlings. These results suggest that repeated periodic fire applied before white pines reach maturity will be necessary to achieve the long-term goal of reducing competition of eastern white pine with oak. "To control white pine, a fire interval of about 15 years would be required," Arthur says. "Ongoing research will help determine the role of prescribed fire on these ridgetop communities."

"Ongoing research will help determine the role of prescribed fire on these ridgetop communities."

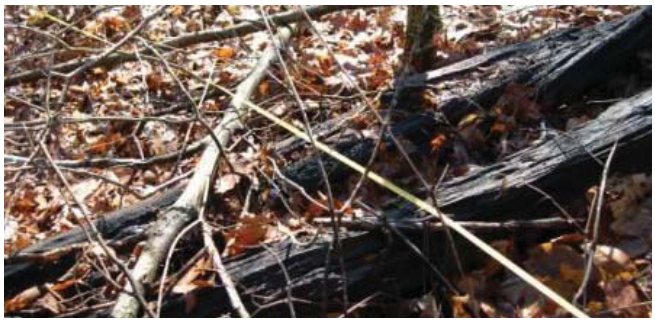
Other studies have also determined that later season, more intense fire may be necessary to reduce competition from species such as red maple and achieve regeneration of oak-dominated forests. In research conducted toward her Master's thesis at the Department of Forestry at the University of Kentucky, Stephanie R. Green found that the current management regime of late winter or early spring, low intensity fire kills more maple seedlings than oak seedlings. However, it will be necessary to maintain increased canopy openness in order to promote the growth of oak seedlings. Later season fire, when the maple sprouts are physiologically active, may be required to give oak seedlings a competitive edge.

Prescribed fire may be an effective tool for reducing the litter layer, allowing new oak seedlings to establish when mast events follow prescribed burning. Credit: University of Kentucky.

Tree health and fuel loads

Oak is not only essential to wildlife, it is also a valuable timber tree. In response to concerns expressed by Forest Service personnel about the effects of prescribed fire on overall forest health, fuel loading, and wildfire risk, a study was conducted in the Morehead Ranger District of the DBNF in an area where neither wildfire nor prescribed fire had been documented for more than 30 years. Three treatments—control, frequent fire, and infrequent fire—were applied on three study areas. The plots in each of the study areas range from sub-mesic (seasonally moist) to intermediate and sub-xeric (drier) positions. This experiment, conducted in March and April 2003, will serve as a baseline for longer term studies in the area.

By measuring fuel load before and 10 months after prescribed fire, graduate student Elizabeth Loucks at the University of Kentucky found that the litter layer—the main fuel source in low to moderate intensity fire—and small woody debris were significantly reduced over the short term, but leaf fall quickly replaced burned litter, negating the effects of fire on fuel loading in the long term. Loucks also found that there was little reduction in large woody debris, an important component of the forest for nesting birds and small mammals that feed on the insects present in rotting logs.



Leaf litter and small diameter woody fuels are the primary fuel for prescribed fires in this region. Credit: University of Kentucky.

Except in cases such as the widespread pine mortality caused by the pine beetle in this region, woody fuels are not the fuel for wildfires; litter is, so there is little we can really do to reduce the risk of wildfires. "Many of our systems can burn over and over again, once the litter layer is replenished," Arthur says.

Loucks also assessed fire intensity and bark scorch height on tree boles—the main stem of the tree that is of commercial value—in nearly 20 species on the experimental plots. Bark scorch height is a way to estimate damage from fire since scars allow fungal pathogens and insects to enter the bole of the tree, potentially increasing mortality and reducing the economic value.

Although most prescribed fires in this region are of moderate intensity, trees less than 8 inches in diameter are often killed by fire, and even larger trees may be damaged. Credit: University of Kentucky.

This study is also one of few attempts to correlate damage and mortality with bark characteristics. Yellow pine and black oak, with thick, insulating bark had the highest scorch height, although a confounding factor may be that it is more difficult to measure damage on smooth barked species such as red and sugar maple. In addition, bark scorch height was greater on the more xeric sites.

Shelterwood-burn method

The reintroduction of fire alone in oak-dominated forests has not proven definitively helpful in suppressing competing species. Patrick Brose, a research forester with the Forest Service Northern Research Station in Irvine, Pennsylvania, is exploring an alternative method to promote oak regeneration in the Piedmont region of Virginia and Pennsylvania: combining fire with selective harvesting of trees. The shelterwood-burn method is proving to be ecologically promising for the oak and the wildlife that depend on its mast for survival. "There is no replacement species for the oak in terms of wildife," he says.

This technique involves harvesting mature trees in two phases. First, poor quality and undesirable trees are removed, providing immediate income. After several years, a spring fire of moderate to high intensity is applied. A second harvest of more valuable mature trees several years after the burn provides additional income.

(Top) The first step is a heavy partial cut that creates about 50 percent open canopy. (Middle) After prescribed fire and initial harvest, wait several years for the oak regeneration to develop large root systems and competing species to surpass the oak in height growth. (Bottom) Because of different sprouting probabilities among species, the composition of the regeneration shifts strongly towards oak. Credit all: Patrick Brose, USDA Forest Service.

"With the shelterwood-burn technique, the fire needs to be in the spring when things are greening up," says Brose. One late spring burn has a comparable effect on competitors as three winter burns, since in spring the oak is still dormant, while other species such as birch, maple, and cherry leaf out sooner. The oak also survives fire better because its root collar is buried beneath the forest floor.

The shelterwood-burn method is being applied in the Great Lakes region and in the interior south and could be a promising method in southern Appalachian hardwood forests as well.

Communicating results

The collaborative nature of these research efforts in the southern Appalachians in general and the DBNF in particular is helping break down barriers between the research community and on-the-ground resource managers. These stakeholders agree on one key point: peer-reviewed literature is not necessarily the best way to reach forest managers. By timing research efforts to coincide with Forest Service prescribed burns, scientists like Mary Arthur, colleagues, and graduate students are reaching out to managers. In addition, by regularly attending DBNF Management Team Meetings, she creates an open channel through which managers can communicate to researchers their knowledge gaps and information needs.

Feedback from Forest Service personnel revealed the public often has negative attitudes toward prescribed fire.

Feedback from Forest Service personnel revealed the public often has negative attitudes toward prescribed fire. In response, the Department of Forestry at the University of Kentucky, the JFSP, and the Forest Service have produced an attractive, full-color brochure available in hard copy and online titled, "Prescribed Fire: An Ancient Practice for Today's Forests."

Additional outreach and communication activities include the U.S. Fire Learning Network, a joint project of The Nature Conservancy's Global Fire Initiative, the Forest Service, and the U.S. Department of the Interior. The Appalachian Mountains unit is one of six regional networks across the United States aiming to overcome barriers to returning fire to the landscape to achieve fuel reductions and promote restoration projects. To foster a better understanding of their work, Forest Service personnel at DBNF host one of the network's 15 demonstration sites in the Appalachians.

Considering that fire has been used over thousands of years to manipulate the landscape, it is not surprising that two to three decades of experimental fire and research have not yielded definitive results in terms of encouraging regeneration of oak species in the southern Appalachians. "We are fairly early in this research and the results are often inconclusive," Loftis says. Nevertheless, scientists have laid an essential foundation for understanding how best to ensure the long-term survival of the species in the forest mix.

Further Information: Publications and Web Resources

Brose, Patrick H., David H. van Lear, Patrick D. Keyser. 1999. A Shelterwood-burn Technique for Regenerating Productive Upland Oak Sites in the Piedmont Region. *South. Journal of Applied Forestry*. Appl. 16(3):158-163. http://www.treesearch.fs.fed.us/pubs/2146

Delcourt, Paul A., Hazel R. Delcourt, Cecil R. Ison, William E. Shar, and A. Gwynn Henderson. 1999. Forests, Forest Fires, & Their Makers: The Story of Cliff Palace Pond, Jackson County, Kentucky. Kentucky Archaeological Survey (jointly administered by the Kentucky Heritage Council and the University of Kentucky, Department of Anthropology). Education Series Number 4. Lexington, Kentucky. http://www.fs.fed.us/r8/boone/districts/london/cliff_palace.shtml

Fire in Eastern Oak Forests: Delivering Science to Land Managers. Proceedings of a Conference, November 15-17, 2005, Fawcett Center, The Ohio State University, Columbus, Ohio. United States Department of Agriculture Forest Service Northern Research Station General Technical Report NRS-P-1. http://www.nrs.fs.fed.us/pubs/gtr/nrs_gtrP1.pdf

Loftis, David L. Upland Oak Regeneration and Management. 2004. In Spetich, Martin A., ed. 2004. Upland oak ecology symposium: history, current conditions, and sustainability. Gen. Tech. Rep. SRS-73. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 311 p. http://www.treesearch.fs.fed.us/pubs/6532

Prescribed Fire: An Ancient Practice for Today's Forests. Daniel Boone National Forest, USDA Forest Service. 2007. http://www.fs.fed.us/r8/boone/documents/fire/pfirelett.pdf

Management Implications

- Research conducted in the DBNF will be generally useful across many land ownerships, including the National Park Service, that need information about using fire as a tool to maintain certain forest types.
- Logistical problems with prescribed fires may tie the hands of resource managers, for example when state forestry or air quality policies ban fire at the optimum time for management to enhance oak regeneration.
- Burning later in spring when plants start to flush may have a better chance of differentially affecting species and encouraging oak regeneration.
- Strategies that are successful in dry or intermediate (sub-xeric) upland forests may not have similar success in high quality wet forests.
- Fire alone at currently adopted intervals may not be sufficient to encourage oak regeneration. Repeated fire and/or more intense fire that coincides with the time that maples are budding out, along with mechanical or herbicide treatment or harvesting of commercially viable trees, may be necessary.

Scientist Profiles

Mary A. Arthur is a Professor of Forest Ecology in the Department of Forestry at the University of Kentucky, Lexington. A primary focus of her research is the role of prescribed fire in upland oak ecosystems in the central Appalachians.

Mary Arthur can be reached at:
Department of Forestry
University of Kentucky
Lexington, KY 40546-0073
Phone: 859-257-2852
Email: marthur@uky.edu

Patrick Brose is a Research Forester with the USDA Forest Service Northern Research Station in Irvine, Pennsylvania. His current research emphasis is on the ecology and silviculture of oak and fire behavior in mixed-oak forests.

Patrick Brose can be reached at:
USDA Forest Service
Northeastern Research Station
Irvine , PA 16329-0267
Phone: 814-563-1040
Email: pbrose@fs.fed.us

David L. Loftis is Project Leader of the Upland Hardwood Ecology and Management research unit of the USDA Forest Service Southern Station. He is a leading expert on oak regeneration and prediction and control of species composition of regeneration.

David Loftis can be reached at:
USDA Forest Service
Bent Creek Experimental Forest
Asheville, N.C.
Phone: 828-667-5261
Email: dloftis@fs.fed.us

Results presented in JFSP Final Reports may not have been peer-reviewed and should be interpreted as tentative until published in a peer-reviewed source.

The information in this Brief is written from JFSP Project Number 01-3-3-14, which is available at www.firescience.gov.

An Interagency Research, Development, and Applications Partnership

USGS
science for a changing world

JFSP *Fire Science Brief*
is published monthly.
Our goal is to help managers find and use the best available fire science information.

Learn more about the Joint Fire Science Program at
www.firescience.gov

John Cissel
Program Manager
208-387-5349
National Interagency Fire Center
3833 S. Development Ave.
Boise, ID 83705-5354

Tim Swedberg
Communication Director
Timothy_Swedberg@nifc.blm.gov
208-387-5865

Writer
Elise LeQuire
cygnete@mindspring.com

Design and Layout
RED, Inc. Communications
red@redinc.com
208-528-0051