Joint Fire Science Program
Fire Science Brief
RESEARCH SUPPORTING SOUND DECISIONS

A spring prescribed fire clears the way for oak regeneration.

Sharpening the Tools for Prescribed Burns In Eastern Mixed-oak Forests

Summary

A research project on forest lands in the mid-Atlantic region was performed with the dual goals of testing which of the 13 Anderson fuel models most accurately depicts common understory fuel characteristics in these forests, and what proportion of advance regeneration of desired species will sprout after burning. The work covered a range of public forest lands, and varying types of fuels and different burn intensities.

Researchers found that, overall, one or more of the Anderson fuel models accurately portray most of the fuel conditions found on the experimental areas. However, no fuel model appears to represent evergreen heath shrubs such as mountain laurel. They believe this is true for the entire central Appalachian mixed-oak region. Evaluation of sprouting potential indicates variability in sprouting with the size and location of the root collar, and the duration and intensity of the fire.

Key Findings

- One or or more of the Anderson Fuel Models accurately portray most of the fuel conditions found in eastern mixed-oak forests.
- In areas of evergreen heath shrubs—mountain laurel and rhododendron—no fuel model is accurate and fire behavior can be extreme if they ignite. Consequently, fire behavior is difficult to forecast or to control.
- Seasonal variation occurs in fire behavior, especially in deciduous shrubs. Spring fires in these areas are much more intense than any other time of year, probably because of resin droplets on leaves and bark during this season.
- Prescribed burning is effective in promoting mixed oak regeneration. Oaks and hickories will usually sprout after a fire regardless of its duration and intensity. Often such a fire is effective in eliminating other hardwoods.
- The optimum time for burning was determined to be late spring.

After the chestnuts

Many forest areas from eastern Ohio through Pennsylvania, West Virginia, New Jersey and up through southern New York and parts of New England are classified as "mixed-oak" types. Although at one time these forests had a significant proportion of chestnuts, the large chestnuts are gone since the passage of chestnut blight in the last century.

In most places the forests are dominated by a mixture of five oak species (black, chestnut, northern red, scarlet, and white). Other oaks may be present, but are usually less numerous. Forests include many other deciduous species including maple, birch, ash, hickory, basswood and others. But oak gives these forests their name and their character.

Understory variety

Understory species may include striped maple, dogwood, hophornbeam, sassafras, ironwood, and even young chestnuts regenerating from sprouts. Below this is often a shrub layer of deciduous heath plants such as blueberry, deerberry, huckleberry, and/or heath evergreens such as mountain laurel and rhododendron. The amount of fuel on the floor varies widely depending on recent logging or burning activity, the shrub and understory species, and the stage of growth of the forest.

A fall prescribed fire in blueberry undergrowth.

Forest managers are interested in maintaining or improving the value of the forest by stimulating growth of new oaks from sprouts, as well as decreasing fuel levels in some areas, and reducing levels of understory shade that currently inhibits oak regeneration. The goal of this research was to provide the necessary planning tools to help make prescribed burning a reliable tool for these purposes.

Do the Anderson Fuel Models work?

The 13 widely used Anderson fuel models—and the derivative BEHAVE-generated fire behavior prediction software—have been in wide use in the western United States for several decades. The models characterize the fire-carrying potential of forest floor and understory layers in grassland, shrubland, forest lands and logging slash areas.

Grass and grass-dominated

1—Short grass (1 foot)
2—Timber (grass and understory)
3—Tall grass (2.5 feet)

Chaparral and shrub fields

4—Chaparral (6 feet)
5—Brush (2 feet)
6—Dormant brush, hardwood slash
7—Southern rough

Timber litter

8—Closed timber litter
9—Hardwood litter
10—Timber (litter and understory)

Slash

11—Light logging slash
12—Medium logging slash
13—Heavy logging slash

When applied by professional forestry managers experienced in prescribed burning, the models have been shown to be effective tools for estimating fire behavior.

Still a new idea

However, the use of prescribed burning in eastern mixed-oak forest land is still in its infancy. Because fuel build-up is less commonly a problem here than in the drier West, managers have been slower to look into the prescribed burn approach.

Forest managers need more information on how to characterize fuels for prescribed burns because fuel models have not been as thoroughly tested in this area of the country. According to Patrick Brose, a research forester at the USDA Forest Service's Northeastern Research Station in Irvine, Pennsylvania, this uncertainty about fuel characterization has delayed implementation of prescribed burning in eastern mixed-oak forests.

Different conditions in the East

Brose observes, "The use of prescribed burning is much more widespread in the West and the Southeast. Until quite recently here, foresters have not felt comfortable with the technique, because of different forest types and the need to have tight control of the burn, especially around developed areas."

Brose has had extensive experience performing prescribed burns in the West and the Southeast, and has more recently been involved in Pennsylvania in projects to make prescribed burning easier and more reliable. He was the principal investigator, along with Thomas Schuler and Jeffrey Ward, in a recent project documenting the fuel characteristics for prescribed burns in a range of eastern mixed-oak forest areas. According to Brose, the purpose was to evaluate fire behavior versus the traditional Anderson fuel models in order to fine-tune the use of the models for these forest types.

The next forest

A second goal of the project was to document sprouting of oak and competing species after the prescribed burns. The purpose was to measure the effectiveness of burning in stimulating oak regeneration. In many eastern mixed-oak forests, oak succession is blocked by dense understory growth. The researchers wanted to evaluate the effect of prescribed burning as a tool to improve oak succession. One key to this is to assure the survival of sprouting oaks after the burn.

Prescribed burns, as in this oak shelterwood area, are effective in improving oak succession.

Hard to get project started

According to Brose, planning for the project began in late 2001, and the goal was to perform and document prescribed burns at 29 sites in Pennsylvania and New Jersey. The original plan was for the fires to be conducted from early 2002 through late 2004. However, a number of circumstances including wetter than normal weather, personnel retirements, and a damaging arson fire at the Fire Sciences Laboratory in Irvine, Pennsylvania caused many of the burns to be delayed.

Nonetheless, 20 of the 29 planned burns were completed and sufficient data tabulated to draw useful conclusions. It is anticipated that the remaining fires will eventually be done, and the data added to project results. Additional data will be coming from prescribed burns in mixed-oak forests in Connecticut and West Virginia.

Comparing forecasts and results

For all of the prescribed fire projects, the fuel characteristics used to generate initial fire behavior forecasts were created using BEHAVE software, following the Anderson models. Maximum fire temperatures were recorded for each burn during the research process. Understory fuel types encountered in this study are listed here, along with the recorded maximum temperature, sample size, flame characteristics, and the fuel model that seemed to most appropriately characterize the actual fire behavior:

Fuel Type	Max Temp	Sample Size	Flame Length (feet)	Rate of Spread (feet/min)	Fuel Model
Northern Hardwood Litter	104°C	11	<1	1–2	8
Oak Leaf Litter	192°C	33	1–3	2–5	9
Deciduous Shrub, Fall	285°C	11	1–3	2–5	9
Deciduous Shrub, Spring	285°C	9	2–4	3–6	6
Evergreen Heath Shrub	506°C	8	6–12	5–10	?
Logging Slash	782°C	15	10–15	4–8	12

Discoveries from models

The ranges of behavior in the mixed-oak forests studied were significant. Brose notes, for example, that the fires in mixed northern hardwood leaf litter were documented to be significantly lower in temperature, shorter in flame length, and to spread at a much slower rate than fires in oak litter. For this reason, it appears that Anderson Fuel Model 8 is appropriate for northern hardwood litter and Fuel Model 9 is better for oak litter. The researchers feel this is because oak leaves weigh more and burn at a hotter temperature than leaves of most other hardwoods. Also, oak leaves form a porous fuel bed and are slow to decompose, even after being buried in snow for several months.

Fires in oak leaf litter burn hotter and faster than those in other northern hardwood leaf litter types.

It's different in spring

Fire results also showed great variability between spring and fall with fires in deciduous heath shrubs. These shrubs were typically blueberry, deerberry, huckleberry and similar types. In the fall, after these shrubs are dormant, fires were just slightly more intense than would be predicted by Fuel Model 9. Researchers felt this intensity was perhaps due to the low stature of the shrubs holding fallen leaves off the ground, creating a more aerated litter.

In the spring, however, the deciduous shrubs burn with a longer flame, and fire spreads more rapidly. Researchers note that many of these shrubs have resin droplets on their foliage and branch tips. This characteristic causes behavior that would be more typical of Fuel Model 6.

Slash burns hotter than predicted

For areas of mixed hardwood slash, Fuel Model 6 is recommended for use in BEHAVE. It appears that this is not correct for eastern mixed-oak forests. Preliminary results in the study indicate that hardwood slash areas burn considerably hotter than would be indicated by BEHAVE Fuel Model 6 predictions. It appears that one of the slash models, perhaps Fuel Model 12, would be more appropriate.

However, in most of the fires under these conditions, there was considerable variability in the data. Additionally, the sample size was small, so caution must be applied in this finding. A mitigating factor appeared to be the presence of large numbers of black birch (*Betula nigra*) regeneration and saplings among the slash. This species produces several aromatic compounds that become highly flammable when heated.

Evergreens can be explosive

Fires in areas with evergreen heath shrubs—typically mountain laurel and rhododendron—do not appear to be well represented by any of the 13 fuel models. Where these species were dominant in the understory, ignition is unpredictable. Where they do not catch fire, a surface fire behaves like a leaf litter fire.

But if they do ignite, the fire can move incredibly fast and produce tremendous flame lengths. This explosive characteristic also makes these fires difficult to study, as cooperating agencies are often reluctant to use prescribed burning in areas containing significant thickets of evergreen heath shrubs. According to Brose, this is an area that requires more study. He says, "For now, we are unable to classify these fires under the Anderson system, so we cannot make recommendations for prescribed burning where these understory conditions are present."

Sprouting potential

Sprouting ability of hardwoods following a prescribed burn was found to be a function of five key values:

1. Root collar diameter of the plant stem,
2. Root collar location in the forest floor,
3. Season of the fire,
4. Number of seconds the fire exceeds 60°C, and
5. Maximum fire temperature.

Fires in evergreen heath shrubs, as here in mountain laurel, can move very fast and have long flame lengths.

Using data gathered with this fire research, it was found that the first two factors are largely species specific at the time of the fires. It has been documented that some species, such as the oaks, emphasize root development when they are young. Others, for example black birch, emphasize stem height growth in lieu of root development. This research linked survival to physical fire data to create post-burn sprouting probability curves for the most common species and groups of hardwoods.

The sprouting probability curves show that different species can be separated into four groups:

1. All hardwood species with a root collar diameter of less than 0.25 inches. Virtually none of these survive prescribed fire, especially if the fire is in mid to late spring.
2. Weak sprouters, such as black birch and yellow poplar. The majority of these fail to sprout after a fire, regardless of root collar diameter.
3. Strong sprouters, such as the oaks and hickories. Most of these species will sprout after a fire, regardless of duration or temperature of the fire.
4. Intermediate sprouters, such as red maple and striped maple, whose ability to sprout are strongly influenced by season and intensity of the fire. If the fire is not intense or occurs during the dormant season, the likelihood of sprouting is high. However sprouting probability drops if the fire is in the spring and its intensity is high.

This aspect of the research suggested that prescribed burning can effectively increase regeneration of oaks while suppressing many competing hardwood species. According to Brose, they found the optimum time for burning was in mid to late spring. He says, "From the perspective of maximizing oak regeneration, the later in the season the better. But if the goal is simply to open up the understory, timing of the burn in the spring doesn't make a great deal of difference."

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Striped maple research

A closely related research project was performed by Brose along with Gary Miller and Kurt Gottschalk. This project studied the effect of prescribed burns on understories dominated by striped maple (*Acer pensylvanicum*). In the history of the northeastern mixed-oak forests, the striped maple appears to be a relative newcomer, becoming widespread only in the last 50 years. This coincides with the elimination of widespread forest burning which had been done by Native Americans and European settlers until the first decades of the 20th Century.

Because its aggressive growth tends to prevent oak regeneration, control of the striped maple is a goal of many forest managers in this region. Some projects have used glyphosphate herbicides. Brose and colleagues were interested in documenting the potential of prescribed burning as an alternative method for striped maple control. Until recently, little research had been carried out on this topic. Because of the paper-thin bark of the young striped maple, it was felt to be a good candidate for control by burning.

The research was conducted between 2002 and 2005 on three Pennsylvania State Forest sites. Fuel conditions at the three sites were variable, with some having a rich stock of fuel that would support a vigorous fire and others being quite thin and barely supporting fire progress. The goal of all three fires was to remove the sapling layer that was competing with the oak regeneration. The Pennsylvania Bureau of Forestry conducted the three prescribed burns in April and May of 2002 and in May of 2004. Portions of all three sites were left unburned as control sites.

After the first post-burn growing season in the unburned treatment, virtually all the striped maples were alive. The burn areas consistently had many more dead and sprouting striped maples and fewer living ones than the unburned areas. After the third post-burn season, the number of dead striped maples in the burn areas increased from the one-year number. It is believed that this increase was a result of the delayed demise of previous living and sprouting stems that had been measured at the one-year interval.

How can we use this?

Both of these research projects reinforce the viability of prescribed burning as a tool for eastern mixed-oak forest managers to promote oak regeneration from sprouts, and to thin out understory and reduce fuel loads. Since the research was completed, the three investigators have led numerous tours of the more accessible burn sites, have published documentation of the burn results, and have worked with forest managers, helping to classify proposed burn areas by fuel model, and helping them to prepare for safe and effective burns.

One important result, according to Brose, is that the research has revealed a wide range of variation in the appropriate model for burns in this forest type. "We recommend that planners take the most conservative approach, and if there is any question as to the appropriate model, use the one that has the hottest fire, the longest flame, and the fastest rate of spread." He notes that situations that involve significant amounts of evergreen heath growth require special caution. "We don't yet fully understand how to model these fires, so we suggest prescribed burning in these areas be done only with the most extensive precautions."

Another important piece of management information coming out of this research is the documentation of oak being among the most durable species in terms of sprouting after a burn. Brose points out, "a late spring burn will be the most effective if the goal is simply oak regeneration." He points out the related research on striped maple as additional documentation of the value of this tool for oak release.

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Management Implications

- Prescribed burning is an effective tool to promote oak regeneration from sprouts. The fire must be hot enough to suppress other, more sensitive hardwood sprouts.
- Susceptibility of hardwood sprouts to mortality by understory burning varies considerably among species.
- The optimum time for prescribed burning for oak regeneration is late spring. However if burning is planned simply for fuel stock reduction, it can be done any time of year.
- Conventional Anderson fuel models do not cover all possible conditions in eastern mixed-oak forests. It is necessary to consider the full variety of species and conditions that are encountered, and adjust accordingly.
- Special precautions are necessary if there are widespread areas of hardwood slash or numerous evergreen heath species, as these can create fire conditions that are difficult to manage.

Further Information: Publications and Web Resources

Brose, P.H., T.M. Schuler, and J.S. Ward. Final Report, Joint Fire Science Program Project 01B-3-3-15. Integrating prescribed fire into management of mixed-oak forests of the Mid-Atlantic region: Developing basic fire behavior and fuels information for the SILVAH system.

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Brose, P.H.; G.W. Miller, and K.W. Gottschalk. Re-introducing fire to the oak forests of Pennsylvania: Response of striped maple. Proceedings of the 2005 National Silviculture Workshop. USGA Forest Service General Technical Report 203. 2007.

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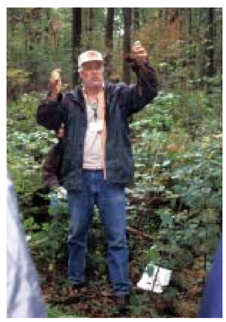
Ward, J.S. and P.H. Brose. Mortality, survival and growth of individual stems after prescribed burning in recent hardwood clearcuts. Proceedings of the 14th Central Hardwoods Forest Conference. USDA Forest Service General Technical Report NE-316. 2004.

Scientist Profile



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