**1.7 How do we restore fire to ecosystems where it has been excluded for many years?**

Fire has a long history in the southern Appalachian landscape. Soil charcoal, tree-ring scars, and fire-adapted vegetation all provide evidence for the role of fire as a natural process over the past several thousand years (Aldrich and others 2010, Fesenmyer and Christensen 2010, Flatley and others 2013, Zobel 1969). Beginning in the early 20th century, however, land managers in the southern Appalachians began to prevent or suppress forest fires, effectively excluding fire from the landscape for nearly 80 years (Aldrich and others 2010, Flatley and others 2013). Long-term exclusion of fire has led to major changes in forest structure, function, and composition, particularly among forest types dominated by yellow pines and oaks. For example, excluding fire has increased the density of fire-sensitive trees and shrubs, which, in turn, has prevented pine and oak regeneration, shaded out grasses and forbs, and reduced the diversity of vegetation across the southern Appalachians (Harrod and others 2000, Harrod and others 1998, Turrill and others 1995).

Since the mid 1990’s, land managers throughout the Appalachians have sought to use natural and prescribed fires to reverse the effects of fire exclusion. Fire exclusion, however, has contributed to a buildup of wildland fuels that make wildfires more difficult to control, and that pose a threat to forest health: when these forests eventually burn, they often burn with undesirable intensity and/or severity. (Knoepp and others 2005, Reilly and others 2012, Vose 2000, 2003). As a result, land managers restoring fire in the southern Appalachians face two, inter-related questions: first, how to effectively reduce hazardous fuels, and second, how to restore fire-dependent communities, especially pine and/or oak forest, while minimizing undesirable effects.

* ***Hazardous Fuels*.** Wildland fuels in Appalachian forests fall into two general categories -- live and dead. Live fuels consist primarily of evergreen shrubs, particularly mountain laurel, that can pose serious problems for fire control, but do not typically contribute significantly to available fuels during landscape-level burns. Dead fuels, on the other hand, are flammable vegetation at or near the forest surface, such as leaf litter, duff, and woody debris. Organic duff is the most common form of dead fuel (50-70% of the total). Other dead fuels include litter (10-20%) and logs >3” (also called 1000-hour fuels, 10-20%). These fuel classes are not consumed at the same rate by dormant-season burning (Jenkins and others 2011, Waldrop and others 2010, Vose and others 1999). Dormant-seasons burns, which occur in late winter and early spring, consume relatively high amounts of litter, but most of the heavier, longer-burning fuels are not consumed.

In contrast, Jenkins and others (2011) found late summer and fall burns consumed a much higher percentage of duff and 1000-hour fuels. These growing season burns generally coincided with the annual peak of the drought index for the region (as measured by the **Keetch-Byram Drought Index;** Keetch and Byram 1968). While higher levels of heavy fuel consumption were associated with successful pine regeneration, they were also strongly correlated with higher levels of mortality in the pine and oak overstory, which led to large increases in fuel loading, as dead trees fell to the ground. In addition, growing season burns and wildfires frequently increase the rate at which non-native plants invade the community (see Kuppinger 2008).

* *Pine and Oak Restoration*. Specific objectives for restoring pine and oak communities usually center on reducing the abundance of fire-sensitive trees and shrubs, increasing pine and oak regeneration, and increasing the abundance of grasses and forbs. Several burning techniques have been used to achieve these objectives, with mixed results.

Single, and even multiple, low-intensity burns (backing/flanking fires with flame length < 3’) during the dormant season have not achieved objectives for pine and oak restoration (Jenkins and others 2011, Chiang and others 2005, Elliott and Vose 2005). In general, pine and/or oak regeneration did not increase following low-intensity burns, and, although all of the studies documented initial reductions in fire-sensitive trees and shrubs, these and other studies also documented prolific and repeated basal resprouting for many of these species.

High intensity burns (headfires with flame length > 8’) have also been used during the dormant/early season to address pine and oak restoration objectives. A common response to high-intensity, early-season burns, which has not been widely reported, is for these fires to kill large numbers of overstory trees, creating large, stand-level gaps that subsequently become dominated by hardwood resprouts. This can happen with fires at any time of the year, although pines can regenerate after late season fires where a seed source exists (Jenkins and others 2011). High-intensity burns have been shown to be successful in regenerating Table-Mountain pine (Waldrop and Brose 1999), and may contribute to oak regeneration in formerly pine-dominated sites (Elliott and others 2009). In general, however, these types of fires are not effective in regenerating oak stands, and are not recommended for restoration projects, due to concerns about fire control, burn effectiveness, and the loss of seed trees (Jenkins and others 2011, Elliott 2009, Brose and others 2005, Waldrop and Brose 1999).

In summary, we have found the combination of vegetation change and fuel accumulation, attributed to fire exclusion, coupled with the topographic complexity of the landscape and the operational constraints in applying fire, poses a conundrum for land managers in the southern Appalachians:

* Burning too hot (high-intensity or dry-season burning) may reduce high levels of fuels and establish pine regeneration, but will typically produce undesirable levels of overstory mortality, which, in turn, will increase forest fuel loading, decrease the oldest structural components in the stand, exacerbate the loss of seed trees, increase the growth of undesirable hardwood resprouts through overstory release, and facilitate the invasion of non-native plant species.
* Burning too cool (low-intensity or dormant-season burning) may avoid some of the negative effects of high-intensity burning, but could produce less-than-desired fire spread, fuel reduction, and reductions in fire-sensitive trees and shrubs. As a result, restoration objectives such as pine regeneration may not be met in a timely fashion, especially while seed trees continue to diminish across the landscape.

A Fire Restoration Strategy

What, then, is the best course of action for reintroducing fire into long-unburned sites to restore oak and pine communities in the southern Appalachians? Because the consequences of burning too hot are far more difficult to overcome than the consequences of burning too cool, we believe the most cautious approach is to begin with cool, dormant-season burns, and to gradually increase burn severity by varying burn season and fire intensity. Our experience in the Great Smoky Mountains has led us to a multiple-burn strategy with the following features:

* Frequent burning (2-7 year intervals) over a 20 year period.
* Gradual reduction of heavier fuels such as duff and coarse woody debris.
* First- and second-entry burns that are primarily low intensity (flame length < 3’) and occur in the dormant or very early growing season. The goal for first- and second-entry burns is to avoid creating stand-level (>2 acre) canopy gaps that increase fuel loads and release fire-sensitive resprouts. This is most important during first-entry.
* Subsequent burns that increasingly use variable intensity and seasonality to reduce fuels, and achieve desired community structure and composition.
* Some form of monitoring that can be the basis for adaptive management. Monitoring can include simple visual assessments, burn severity maps, or various types of plots.

Restoring fire to long-unburned sites is a long-term process that requires the insight of fire researchers, as well as the experience and skill of fire managers. The strategy outlined above is, at best, an informal consensus, and may not be applicable to the broad range of regional fire management objectives or conditions that occur at a specific site. Additionally, this management approach does not consider the use of mechanical treatments, which may contribute to the rapid creation of desired forest structure, but which are typically limited to small-scale projects. Rather, this strategy constitutes a general set of guidelines that should allow managers to achieve long-term vegetation and fuels objectives across broad landscapes while avoiding negative outcomes. The most important principles embedded in this strategy are the reliance on moderation, patience, and adaptive management in the application of varied combinations of fire intensity and seasonality to meet regional goals for fuels management and pine/oak restoration.

**– Rob Klein, Great Smoky Mountains National Park, Gatlinburg, TN**

Works Cited

Aldrich, S.R., C.W. Lafon, H.D. Grissino-Mayer, G.G. DeWeese, and J.A. Hoss. 2010. Three centuries of fire in montane pine-oak stands on a temperate forest landscape. Applied Vegetation Science 13: 36-46.

Brose, P.H., T.M. Schuler, and J.S. Ward. 2005. Responses of oak and other hardwood regeneration to prescribed fire: what we know as of 2005. Proceedings: Fire in Eastern Oak Forests: Delivering Science to Land Managers. GTR-NRS-P-1: 123-135

Chiang, J.M., M.A. Arthur, and B.A. Blankenship. 2005. The effect of prescribed fire on gap fraction in an oak forest understory on the Cumberland Plateau. Journal of the Torrey Botanical Society 132(3): 432-441

Elliott, K.J. and J.M. Vose. 2005. Effects of understory prescribed burning on shortleaf pine (*Pinus echinata*)/mixed-hardwood forests. Journal of the Torrey Botanical Society 132: 236-251.

Elliott, K.J. and J.M. Vose, and R.L. Hendrick. 2009. Long-term effects of high intensity prescribed fire on vegetation dynamics in the wine spring creek watershed, western North Carolina, USA. Fire Ecology Vol 5(2): 66-85.

Fesenmyer, K.A. and N.L. Christensen. 2010. Reconstructing Holocene fire history in a southern Appalachian forest using soil charcoal. Ecology 91 (3): 662-670.

Flatley, W.T., C.W. Lafon, H.D. Grissino-Mayer, and L.B. LaForest. 2013. Fire history and its relation to Climate and land use in three southern Appalachian landscapes in the eastern U.S. Ecology. Preprint.

Harrod, J., P. S. White, and M. E. Harmon. 1998. Changes in xeric forests in western Great Smoky Mountains National Park, 1936-1995. Castanea 63: 346-360.

Harrod J.C., M.E. Harmon, and P.S. White. 2000. Post-fire succession and 20th century reduction in fire frequency on xeric southern Appalachian sites. Journal of Vegetation Science 11: 465-472.

Jenkins, M.A., R.N.Klein, V.L. McDaniel. 2011. Yellow pine regeneration as a function of fire severity and post-burn stand structure in the southern Appalachian mountains. Forest Ecology and Management. 262: 681-691.

Keetch, J. J., and G. M. Byram, 1968: A drought index for forest fire control. USDA Forest Service Research Paper SE-38, Southeastern Forest Experiment Station, Asheville, NC, 33 pp.

Kuppinger, D. 2008. Post-fi re vegetation dynamics and the invasion of *Paulownia tomentosa* in the

 southern Appalachians. Doctoral Dissertation, University of North Carolina at Chapel Hill.

Reilly, M.J., T.A. Waldrop, and J.J. O’Brien. 2012. Fuels management in the southern Appalachian

mountains, hot continental division. USDA Forest Service. Ch. 6 in: GTR-SRS-161.

Turrill, N.L., E.R. Buckner, and T.A. Waldrop. 1995. *Pinus pungens* Lam. (Table mountain pine): a

threatened species without fire? Proceedings: Fire Effects on Rare and Endangered Species and Habitats Conference, Nov. 13-16, 1995.

Vose, J.M. 2000. Perspectives on using prescribed fire to achieve desired ecosystem conditions. Pp. 12-

17 in W. Keith Moser and Cynthia F. Moser (eds.). Fire and Forest Ecology: innovative silviculture and vegetation management. Tall Timbers Fire Ecology Conference Proceedings. No. 21 Tall Timbers Research Station, Tallahassee, FL.

Vose, J.M., W.T. Swank, B.D. Clinton, J.D. Knoepp, L.W. Swift. 1999. Using stand replacement fires to

restore southern Appalachian pine-hardwood ecosystems: effects on mass, carbon, and nutrient pools. Forest Ecology and Management 114: 215-226

Waldrop, T.A. and P.H. Brose. 1999. A comparison of fire intensity levels for stand replacement of table mountain pine (*Pinus pungens* Lamb.). Forest Ecology and Management 113: 155-166.

Waldrop, T.A., R.A. Phillips and D.A. Simon. 2010. Fuels and predicted fire behavior in the southern Appalachian Mountains after fire and fire surrogate treatments. Forest Science 56: 32-45.

Zobel, D.B. 1969. Factors affecting the distribution of *Pinus pungens*, an Appalachian endemic. Ecological Monographs 39: 303–333.