Reintroducing Fire to the Oak Forests of Pennsylvania: Response of Striped Maple[1]

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Abstract

We studied the role of fire exclusion in the formation of striped maple (*Acer pensylvanicum*) understories in mixed oak (*Quercus* spp.) forests of Pennsylvania and the response of this species to the reintroduction of fire. Prescribed fires were applied to parts of three mixed oak stands and data from the burned and unburned portions were compared. Increment cores and basal cross sections were collected from the unburned portions to document the dates when the different species had regenerated. In all three stands, the striped maple understories originated in the 1950s and 1960s when fire was no longer a disturbance. The prescribed fires initially reduced density of striped maple by 25 to 50 percent with delayed mortality increasing this rate to more than 80 percent. These data suggest that prescribed fire could be a viable means of controlling striped maple in mixed oak forests.

Introduction

There is growing appreciation and understanding of the important role periodic, low-intensity, surface fires played in the historic dominance of mixed oak forests throughout eastern North America, including the mid-Atlantic region (Abrams 1992, Brose et al. 2001, Yaussy 2000). This fire regime was largely the result of American Indian burning practices and, in conjunction with other environmental factors, helped perpetuate mixed oak forests on a wide variety of soils, especially mesic upland sites. The advent of effective fire control policies and practices ended the periodic surface fire regime of the mid-Atlantic region, like they did in the Southeast and the Interior West. However, unlike those other regions, the exclusion of fire did not translate into an increased loading of hazardous fuels that contributed to catastrophic, stand-replacing wildfires. Rather, the cessation of periodic surface fires in the mid-Atlantic region led to a new forest succession pathway, one in which fire-sensitive, tolerant shrubs and trees invade and eventually impede successful oak regeneration in mixed oak forests.

One beneficiary of the cessation of periodic surface fires is striped maple (*Acer pensylvanicum*). Striped maple is a small- to medium-sized, shade tolerant tree found from Nova Scotia west to the Great Lakes region and south along the Appalachian Mountains to North Carolina (Gabriel and Walters 1990). Within that range, it generally occurs in northern hardwood forests and is most common on cool, moist

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slopes. However, it is being found more frequently and abundantly in mixed oak forests, an environment from which it was historically absent or sparse.

Striped maple lives only about 40 years, but can subsist as a small seedling for 40 years before that (Hibbs 1979). It is a prolific seeder and, in conjunction with its seedling banking strategy, can develop high density populations in forests. When such populations develop, striped maple becomes a serious silvicultural problem as it casts a dense shade on the forest floor that impedes oak seedling survival and growth. In Pennsylvania, striped maple is considered the most troublesome woody understory species that competes against oak regeneration (pers. comm. Gary Rutherford, Silviculture Section Chief, Pennsylvania Department of Natural Resources, Bureau of Forestry).

Glyphosate-based herbicides often are used to control striped maple when its density becomes an obstacle to forest regeneration (Horsley and Bjorkbom 1983, Marquis et al. 1992). However, there are times and places when herbicide use is not possible, so there is growing interest in using prescribed fire as an alternative control method. Striped maple exhibits several attributes that suggest it might be quite sensitive to fire. Striped maple bark is quite thin regardless of stem diameter; its root collar (the location of dormant buds) is relatively high in the litter layer; and its root system is small and shallow. Striped maple leaves also emerge earlier in the spring than many other species. As a result, root carbohydrate reserves are depleted earlier thus rendering striped maple susceptible to surface fires for a longer period.

Surprisingly, literature on the effects of fire on striped maple is sparse. Swan (1970) compared burned and unburned northern hardwood stands in southern New York. He found unburned stands to have five times more striped maple than those that had been burned. Unfortunately, fire behavior was unknown and pre-fire striped maple density between stands was not documented. Conversely, Collins and Carson (2003) reported that nearly all striped maple sprouted vigorously following prescribed fires in West Virginia. Again, fire behavior was poorly described.

The objectives of this study were twofold. First, we wanted to document the establishment timelines of the striped maple populations in mixed oak forests, especially in regard to the establishment of the overstory oaks. Second, we wanted to determine whether striped maple densities increased or decreased following prescribed burning. Understanding both of these aspects of striped maple ecology will help foresters deal more effectively with the species when it poses a regeneration obstacle.

Methods

Study Sites

This study was conducted between 2002 and 2005 on three Pennsylvania State Forests: Bald Eagle, Clear Creek, and Moshannon. The Bald Eagle State Forest is located in the Ridge and Valley region of central Pennsylvania. The study site was a 10-acre stand situated at the bottom of an 18 percent, north-facing slope. Elevation was approximately 1400 feet. Soil was a stony loam (Typic Fragidult) formed from sandstone alluvium (Braker 1981). Consequently, it was moderately acidic, fertile, and well drained. Severe gypsy moth (*Lymantria dispar*) defoliation occurred there in the late 1980s and early 1990s, resulting in substantial overstory mortality. Salvage logging occurred in late 1993. The remaining overstory trees resembled a shelterwood stand and had a relative density (a measure of stocking) of 54 percent as per SILVAH stocking criteria (Marquis et al. 1992). Common overstory species included black oak (*Quercus velutina*), chestnut oak (*Q. montana*), northern red oak (*Q. rubra*), white oak (*Q. alba*), and red maple (*A. rubrum*). A dense sapling layer, more than 20 ft^2 of basal area, formed in response to this reduction in canopy cover and included striped maple, sweet birch (*Betula lenta*), red maple, and witch-hazel (*Hamamelis virginiana*). The forest floor contained abundant blueberry (*Vaccinum angustifolium*), huckleberry (*Gaylussacia baccata*), mountain laurel (*Kalmia latifolia*), and seedlings of several hardwood species, especially chestnut and northern red oak.

The Clear Creek State Forest is located on the Allegheny Plateau region of northwestern Pennsylvania. The study site was a 12-acre stand found at midslope of a five percent, east-facing hill. Elevation was approximately 1800 feet. Soil was a loam (Typic Dystrochept) formed in place by the weathering of sandstone and shale parent material (Zarichansky 1964). Consequently, it was moderately acidic, fertile, and well drained. The stand experienced light gypsy moth defoliation in the 1980s, with little attendant overstory mortality (relative density was 100-percent). Dominant canopy species included northern red oak, sugar maple (*A. saccharum*), black cherry (*Prunus serotina*), and yellow-poplar (*Liriodendron tulipifera*). The sapling layer was quite dense, more than 20 ft^2 of basal area, and consisted almost entirely of striped maple with a few American beech (*Fagus grandifolia*). The hardwood regeneration layer was virtually nonexistent, but the forest floor was covered with hundreds of thousands of northern red oak acorns because of a bumper mast crop in fall 2001. A few scattered pockets of hay-scented fern (*Dennstaedtia punctilobula*) comprised the herbaceous plant community.

The Moshannon State Forest also is located in northwestern Pennsylvania in the Allegheny Mountians region. The study site was a 12-acre stand situated on an upperslope bench with a northwest aspect and slope of two percent. Elevation was approximately 2100 feet. The stand experienced light to moderate gypsy moth defoliation and mortality in the 1980s but relative denisty was nearly 100 percent. Soil was a loam (Typic Fragiudult) formed in place by the weathering of sandstone and shale parent material (Hallowich 1988). Consequently, it was moderately acidic, fertile, and moderately drained. Dominant canopy species included northern red oak, sugar maple, black cherry, and yellow-poplar. The sapling layer was quite dense, more than 25 ft^2 of basal area, and consisted almost entirely of striped maple with a few American beech. The hardwood regeneration layer was virtually nonexistent but the forest floor was covered with hundreds of thousands of northern red oak acorns because of a bumper mast crop in fall 2001. A few scattered pockets of hay-scented fern comprised the herbaceous plant community.

The Prescribed Fires

The objective of all three fires was to remove the sapling layer that was competing with the oak regeneration. Personnel of the Pennsylvania Bureau of Forestry conducted the prescribed burns on April 19, 2002 at Clear Creek State Forest, May 23, 2002 at Bald Eagle State Forest, and May 3, 2004 at Moshannon State Forest. Fuel, weather, and fire behavior data are presented in *table 1*. Fires were lit by hand with drip torches in a strip-headfire pattern commencing at the downwind or uphill side of each burn unit. The Clear Creek fire minimally burned as it had only compacted leaf litter as a fuel. Observed flame lengths were only a few inches. Conversely, the Bald Eagle fire produced flame lengths of four to eight feet because that site had an abundance of ericaceous shrubs for fuel. The Moshannon burn displayed widely varying fire behavior. Some areas minimally burned due to a paucity of fuel while other areas produced enough heat to damage and/or kill overstory trees. Leaf expansion of the striped maples was as follows: Clear Creek--swollen buds, Bald Eagle--fully expanded, and Moshannon--half expanded.

Table 1—*Environmental conditions and fire behavior at the time of the prescribed fires*.

Variable	Bald Eagle	Clear Creek	Moshannon
Burn date	23 May 2002	19 April 2002	03 May 2004
Time of burn	13:00 – 15:00	11:00 – 12:00	13:00 –15:00
Burn size (acres)	5	4	6
Aspect	North	East	Northwest
Slope (%)	18	5	2
Slope position	Lower 1/3	Middle 1/3	Upper 1/3
Air temp. (F)	72 – 78	65 – 67	71 – 74
Rel. humidity (%)	23 – 27	35 – 40	42 – 48
Wind direction	West	West	West
Cloud cover (%)	0	0	25
Fuel model (Anderson 1982)	6	8	8
Fuel description	heath shrubs	compact litter	litter, slash
Fuel moisture (%)	10	15	16
Flame length (ft)	4 – 8	<0.5	1 – 4
Rate of spread (ft/min)	3 – 6	1 – 2	1 – 4

Study Design and Sampling Procedures

To determine the establishment timeline of the canopy trees and the sapling layer, increment cores were collected from each site in fall 2004. From the center of 10 systematically selected points in the unburned treatment, all trees intercepted with a 10-factor prism were cored at one foot above the ground on the uphill side. Basal cross sections were cut from an equal number of saplings near, but not in, each control plot. The cores were air dried for several weeks, mounted, and sanded with increasingly finer sandpaper (120, 220, 320, and 400 grit) to expose the annual rings. The cross sections collected from the stands also were dried and sanded. An establishment date for each core and cross section was determined by aging to the innermost ring or pith under a 40-power dissecting microscope. A pith estimator (Villalba and Veblen 1997) was prepared from the cores that intersected the pith and was then used to age the cores that did not intersect the pith. In all, more than 300 cores and 300 cross sections were collected from the three stands.

Because the Bald Eagle and Clear Creek fires occurred with little advance notice to us, collecting pre-burn data was not possible. However, the districts excluded about 50 percent of each stand from the fires as unburned controls and this division was based on visually estimating equivalent densities of striped maple saplings in each half. This provided us with a valid source of data for evaluating the effect of the fires on striped maple survival. Ten to twelve 1/40-acre circular plots were systematically located in each burn and control unit to ensure uniform coverage of the area. In these plots, all saplings (five feet tall to six inches dbh) were identified to species and tallied as alive, i.e., not top-killed by the fires, dead, or sprouting.

Inventories were conducted in fall 2002 and 2004 (one and three growing seasons post-burn) at the Bald Eagle and Clear Creek stands and in spring 2005 (one growing season post-burn) at the Moshannon site.

Statistical Analysis

Because the data set is incomplete at this time, only one year of post-burn inventory for Moshannon, results are preliminary and will be presented as three case studies in this paper. Statistical reporting will be limited to the mean number of living, dead, and sprouting striped maple saplings per acre for the burned and unburned units at each site.

Results

The establishment timeline of oak species at the Bald Eagle site differed considerably from that of the other two sites (*fig.* 1). At Bald Eagle, the oak overstory trees originated on a continuous basis between 1875 and 1950, while oak recruitment ceased after the 1920s at the other two sites. Peak establishment and recruitment were between 1915 and 1950 but no distinct cohorts are discernible. Oak regeneration ceased in the 1950s. Establishment and recruitment of other hardwoods coincides with that of oak but continues on into the 1990s. The present striped maple understory began in the 1960s with maximum recruitment in the late 1970s and 1980s. Striped maple only lives for about 40 years, thus there is no evidence to determine whether striped maple was a component of these stands before the 1960s.

The Clear Creek and Moshannon sites were quite similar to each other (*fig. 1*). In both, the oaks and other hardwoods began as distinct cohorts between 1900 and 1915. Oaks ceased to regenerate in the early 1920s, and other hardwoods did likewise by 1935 at Moshannon, and by 1955 at Clear Creek. The striped maple understories in both stands originated in the 1960s, with peak establishment in the early 1970s at Moshannon and late 1980s at Clear Creek.

The mean density (stems per acre) of the striped maple understories varied among stands but was reasonably equivalent between treatments within each stand (*fig. 2*). Moshannon had the most striped maple, 1422 stems per acre, while Bald Eagle and Clear Creek had 798 and 787 stems per acre, respectively. At all sites, the burned and unburned treatments had similar densities of striped maple. Bald Eagle striped maple densities were 752 and 845 stems per acre in the burned and unburned treatments. At Moshannon, densities of striped maple were 1451 and 1393 stems per acre for the burned and unburned treatments, while Clear Creek had 820 and 754 stems per acre in the burned and unburned treatments.

There were clear differences between the burn and unburned treatments in all stands after the first post-burn growing season (*fig. 2*). In the unburned treatment, virtually all the striped maple saplings were alive. Conversely, the burn treatment, regardless of the stand, consistently had more dead and sprouting striped maples and fewer living ones than the unburned treatment. At Bald Eagle, densities of dead, sprouting, and live striped maple were 436, 282, and 34 stems per acre, respectively, in the burn treatment, while the corresponding unburned densities were 13 dead, 21 sprouting, and 811 live. The densities of living, dead, and sprouting striped maple in the unburned treatment at Clear Creek were 704, 19, and 31 stems per acre, while those of the burned unit were 160, 427, and 233 stems per acre. The unburned treatment at Moshannon contained 1347 living, 15 dead, and 31 sprouting striped maple stems per acre, while the corresponding densities in the burned treatment were 95, 338, and 1018 stems per acre.

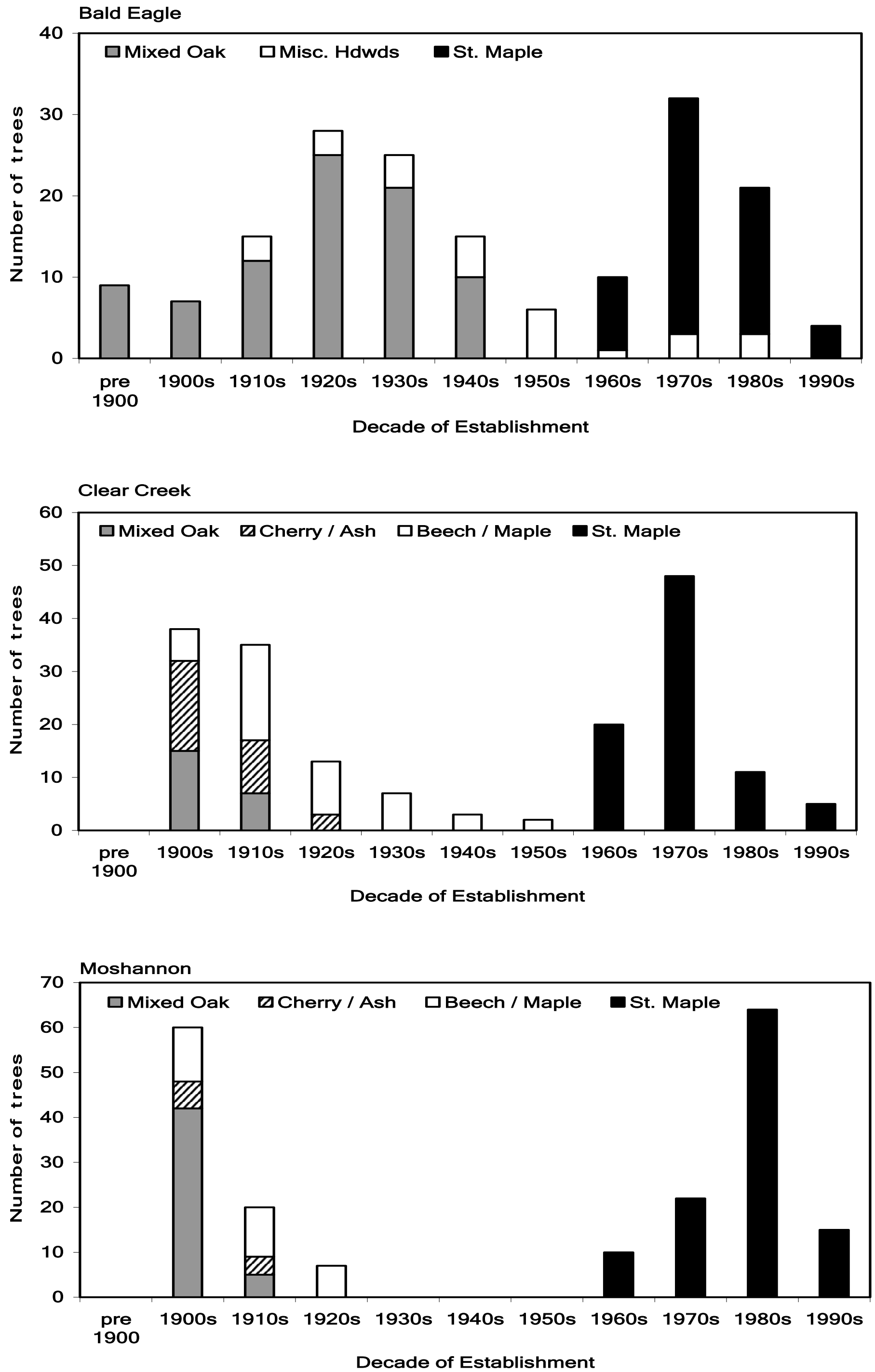

Figure 1—Species establishment timelines for the mixed oak stands at the Bald Eagle, Clear Creek, and Moshannon stands.

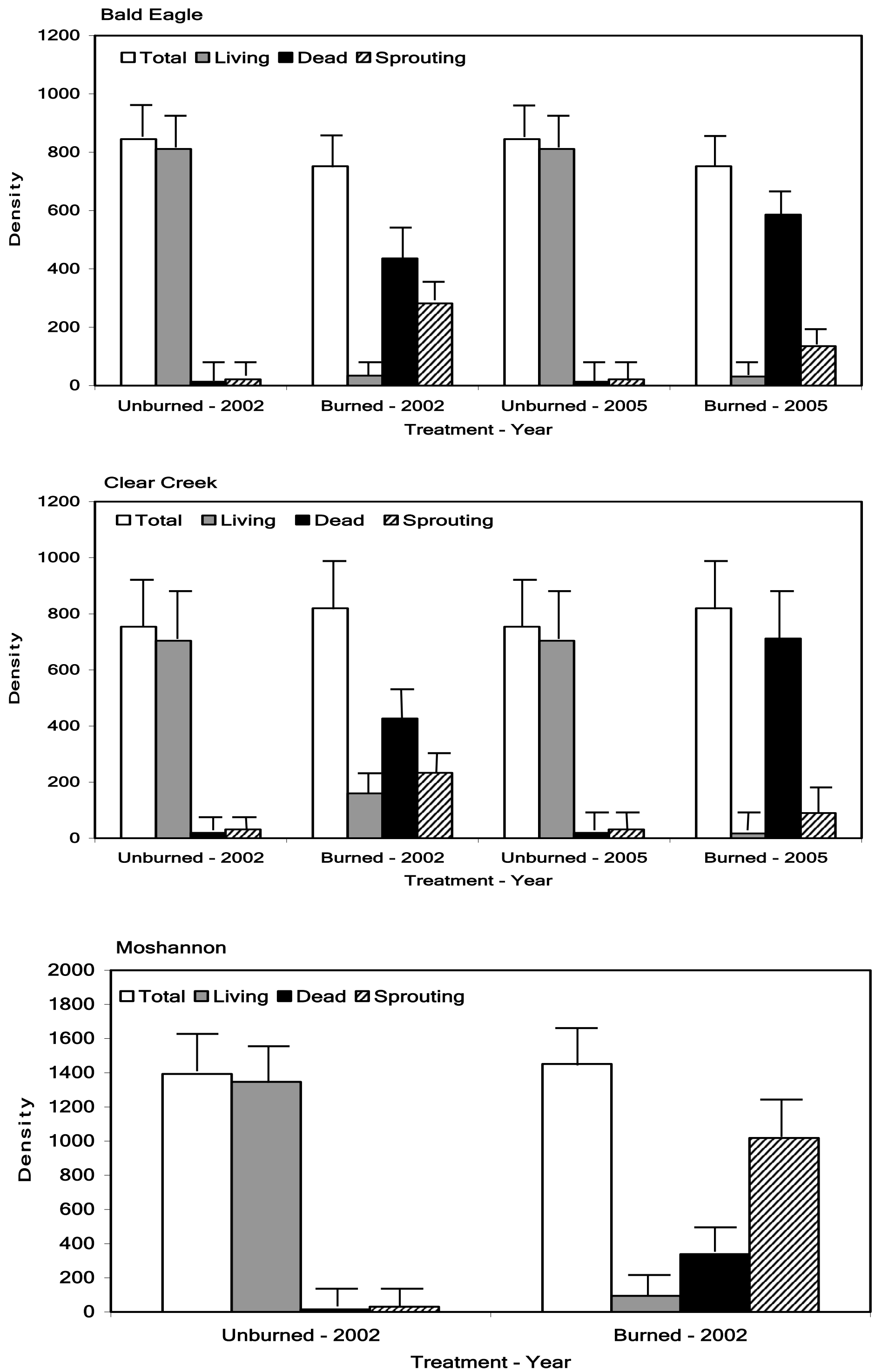

Figure 2—Density (mean number of stems per acre) of striped maple saplings of the Bald Eagle, Clear Creek, and Moshannon stands by type (living, dead, or sprouting), treatment (burned or unburned), and year (2002 or 2005). The bars on top of the columns represent one standard error.

Striped maple density data were available for the third post-burn growing season (2004) from the Bald Eagle and Clear Creek stands. For both stands, the number of dead striped maple in the burned treatments increased to 586 and 712 stems per acre, respectively. At Bald Eagle, this additional mortality appears to have come primarily from previously sprouted stems as those densities declined from 282 in 2002 to 135 in 2004, while the number of living striped maple saplings decreased by only three stems during that period. At Clear Creek, the increase in the number of dead striped maple saplings came from the demise of living and sprouting stems as these decreased from 160 to 17 and 233 to 90, respectively.

Discussion

One of the hindrances to restoring fire to mixed oak forests is a poor understanding of exactly how fire fit into their establishment and development a century ago. The oak establishment timelines of these three stands gives us some indication of the role fire and other disturbances played in their history. The Bald Eagle stand had continuous oak regeneration from 1875 to 1950. This long period of successful oak establishment and recruitment to the canopy was likely the result of several factors. First, the charcoal iron industry and subsistence farming caused repeated disturbances to central Pennsylvania forests. Farmers routinely burned forests to promote good grazing for their livestock and made repeated small-scale timber harvests for fences, tools, and fuel (Whitney 1994). The charcoal iron industry used copious amounts of wood, especially small diameter stems, and was the ignition source for many wildfires. The charcoal iron industry ceased in the 1870s and the 1915 fire exclusion law put an end to woodlot burning by farmers. Also in the early 1910s, the chestnut blight (*Cryphonectria parasitica*) swept through the state, killing virtually all American chestnuts (*Castanea dentata*), the major tree species of central Pennsylvania. Its demise also helped to promote oak. This was also a time when deer populations were quite low and they had little or no effect on forest regeneration. A disturbance regime of periodic surface fires mixed with partial harvests and other canopy disturbances creates and maintains the light environment young oaks need to grow while keeping their competition at bay (Brose et al. 1999).

The Clear Creek and Moshannon stands originated en masse in the early 1900s. This corresponds to the era when this part of the state was extensively logged and subsequently burned (Marquis 1975). Oak regeneration already in place at the time of logging and fire disturbances sprouted and dominated the newly-forming forest. Fire has been excluded from these stands since the formation of the Bureau of Forestry in 1905, allowing succession to proceed along an altered pathway since the 1920s.

The presence of dense striped maple understories in the mixed oak forests of Pennsylvania is coincident with the exclusion of fire and thus likely a result of altered forest succession. The striped maple establishment timelines show these saplings to have originated since the 1960s. This is decades after the last fire in any of these stands. It is unknown if striped maple existed in these stands a century ago when fire was present, or if this species is a relative newcomer moving into these stands since the 1960s.

Another hindrance of restoring fire to the mixed oak forests of the eastern states is the lack of knowledge regarding fire effects on important competing hardwoods. Striped maple certainly falls under that heading as evidenced by the contradictory results reported in the few fire studies that included the species. This study helps clarify the picture, at least in term of spring fires.

Striped maple was extremely sensitive to spring fires, regardless of fireline intensity. It is more sensitive to fire than red maple and may be as sensitive as yellow-poplar--two other common eastern hardwoods (Brose and Van Lear 1998). Its paper-thin bark offers little or no protection against fire, as even the small flames at Clear Creek top-killed more than 80 percent of the saplings. The more intense fires at Moshannon and Bald Eagle increased top-kill to more than 93 and 95 percent, respectively. In fact, striped maples surviving the fire at Bald Eagle were only able to do so if they were growing in protected microsites that precluded burning.

Not only were striped maples easily top-killed, but substantial numbers of rootstocks also were killed by fire. More than 50 percent of the striped maples at Bald Eagle and Clear Creek failed to sprout the first year after the fires. This was apparently due to the fires being able to scorch the root collars, thereby killing the dormant basal buds. While this was not unexpected at Bald Eagle, given its relatively high fireline intensity, it was surprising at Clear Creek where the fire barely burned. In fact, after that fire, all the striped maples expanded their leaves as if there had been no fire. However within a few weeks, they began wilting in large numbers. Apparently the fire was sufficient to girdle these saplings and prevent carbohydrate and water flow through the cambial tissue. Given the sensitivity to fire displayed by striped maple in this study, it probably was not the major component of the understory when periodic surface fires occurred that it is now in the absence of fire.

The delayed mortality at Bald Eagle and Clear Creek is puzzling. Both stands showed an increase in the number of dead striped maples in the burn units from 2002 to 2004. The intervening two growing seasons were exceptionally cool and wet leading to a major outbreak of anthracnose. This foliar pathogen may have caused the additional mortality because many of the dead stems were sprouts close to the ground. *Armillaria mellea*, a root pathogen, may also be the causal agent, as this fungus is ubiquitous in eastern forest soils and routinely attacks trees weakened by a stress. Whatever that mechanism was, between it and the fire, more than 80 percent of the striped maple saplings were dead within 3 years after the burns.

From this study, it appears that prescribed fire is another means to control striped maples when it becomes a silvicultural obstacle. Fire can be used in lieu of herbicides when the latter is not feasible due to policy constraints or site restrictions, i.e. too steep or rocky for equipment, striped maple is too tall, it's a drought year, etc. Fire and herbicides can also be used in tandem with fire initially removing some stems and spot application of herbicide finishing the job.

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