OAK ECOSYSTEM RESTORATION AND MAINTENANCE IN SOUTHERN ILLINOIS

Charles M. Ruffner and John W. Groninger[1]

Abstract—Oak dominance in southern Illinois appears to be a consequence of long-term anthropogenic disturbances, including burning, grazing, and cutting. The increased prevalence of thin-barked, shade tolerant species, such as sugar maple and beech on presently oak-dominated upland sites appears to be a result of the extremely low-intensity disturbance regimes of the late 20th century. Our preliminary work indicates that moderate intensity fall burns top-kill 40 percent of pre-burn sugar maple and beech seedlings [< 2 inches in diameter at breast height (d.b.h.)] and increase herbaceous cover between 15-25 percent. However, sapling sized stems are largely undamaged suggesting that burning alone will not effectively restore oak dominance. Thus, a replicated study has been implemented to test the effectiveness of periodic burning and partial cutting, alone and in combination, to control mesophytic tree species and regenerate upland oak stands. Vegetation dynamics will be assessed on a long-term basis to document the effects of fire and cutting towards maintaining oak dominated ecosystems.

INTRODUCTION

Late Holocene forests of southern Illinois were comprised of oak-hickory and mixed mesophytic forests with inclusions of glades, prairies, and savannas. Braun (1950) classified regional forests as Oak-Hickory in the Ozark Hills of southwestern Illinois and Mixed Mesophytic across the Shawnee Hills of southeastern Illinois and western Kentucky. Küchler (1964) mapped the potential vegetation of this region as Oak-Hickory. Much has been published concerning the ecology of these forests, particularly species-site, productivity, and diversity relationships (Fralish 1988, 1997; Fralish and others 1991). While edaphic factors affecting vegetation structure have been explored, few studies have investigated the role that disturbances, particularly human disturbances, have had on these forest ecosystems.

Several key natural disturbance regimes have been characterized across the southern Illinois landscape. Primarily, these include tornado and wind damage, ice storms, periodic drought, and floods (Parker and Ruffner, in press). These occur rather sporadically, and the effects of single events are relatively localized on the landscape. While it is accepted that these natural disturbances have some impact on forest composition and structure, it is widely held that long-term human disturbances, including burning, grazing, and cutting, have been the primary forces shaping the oak-hickory forests of southern Illinois (Olson 1996, Fralish 1997, Ruffner and others 2003, Parker and Ruffner, in press).

Oaks have several biological adaptations to fire. Oak stems have thick, corky bark, a tenacious ability to repeatedly resprout following top-kill due to a high root:shoot ratio and dormant buds near the root collar, and the ability to compartmentalize wounds (Abrams 1992, Johnson 1993, Van Lear and Watt 1993, Smith and Sutherland 1999). In addition, oaks benefit from post-fire site conditions, such as the open understory and reduced impact of fire-intolerant competitors, and xerification of the site through consumption of duff and exposure of soil to greater solar radiation, allowing oak to dominate the advance regeneration pool (Van Lear and Watt 1993).

Despite the conceptual acceptance of the importance of anthropogenic disturbances, little fire scar evidence from the pre-settlement period exists because of the widespread logging of the primary forests and deterioration of cut stumps (Robertson and Heikens 1994, Olson 1996, Batek and others 1999). While pre-settlement fire scar data are likely lost forever, researchers have compiled substantial evidence of fire's role in post-settlement forests of southern Illinois by using an historical ecology approach including analysis of vegetation structure (Anderson and others 2000), witness tree distributions (McArdle 1991), fire scar analysis (Robertson and Heikens 1994), documentary evidence (Hall and Ingall 1910, Miller 1920), and land-use history studies (Ruffner and others 2002, van de Gevel 2002).

Historical accounts depict the region as heavily influenced by natives (Allen 1945, Temple 1966, Brown 1985). The landscape encountered by early European settlers reflected nearly 10,000 years of Native American manipulation and transformation. Native American use of fire and agricultural clearing was probably much greater prior to the 1500-1600s when large epidemics decimated regional native populations. Reduced disturbance regimes allowed an overall expansion of forest canopy cover. Thus, when European settlement began in the late 1700s-early 1800s, the anthropogenic landscape resembled a mosaic of oak-hickory woodlands and forests interspersed with small patches of barrens, savannas, and glades (Olson 1996, Dey and Guyette 2000, Parker and Ruffner, in press).

Regional studies reporting historic period fire histories indicate that fire ignitions were high following European settlement due to farmers clearing underbrush from the forest to enhance regeneration of browse and increase ease of travel and hunting (Hall and Ingall 1910, Miller 1920). The amount of land cleared for agriculture peaked in

[1] Assistant Professors, Department of Forestry, Southern Illinois University, Carbondale, IL.

Citation for proceedings: 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.

the early 1900s after which badly eroded lands were abandoned and either planted or naturally regenerated to forest. Many abandoned farms and cut-over lands were purchased during the 1920s-30s for public parks and forests and managed as timberlands throughout the 20th century (Parker and Ruffner, in press). With the development of an effective fire-suppression campaign in the 1930s-40s, human caused ignitions dropped, and fire was greatly limited as a force shaping vegetation.

The virtual elimination of fire from the landscape during the early 20th century fostered the expansion of mixed mesophytic species across the region (Fralish and others 1991). Numerous authors have studied central hardwood "old-growth" stands typified by the absence of cutting, burning, and most forms of management over the past several decades (Weaver and Ashby 1971, Nelson and others 1973, Schlesinger 1976, Barton and Smeltz 1987, Fralish and others 1991, Martin 1992, Robertson and Heikens 1994, Spetich 1995, Fralish 1997, Zaczek and others 2002, Ruffner and others 2003, and Groninger and others 2003). These studies report similar and significant shifts in species compositions and forest structure across a spectrum of forested sites. Overwhelmingly, sugar maple (*Acer saccharum*) and American beech (*Fagus grandifolia*) were found to be increasing in stand density and basal area at the expense of the oak and hickory species that dominated the overstory. In particular, still important, but declining overstory species such as black oak (*Quercus velutina*) and southern red oak (*Q. falcata*) are not represented in younger age classes. Age-diameter figures suggest that a large cohort of mixed maple, beech, ash, and black gum (*Nyssa sylvatica*) recruited only a few years after the control of understory fire and the reduction of harvesting in some forests of the Ozark and Shawnee Hills (van de Gevel and Ruffner 2002, Zaczek and others 2002).

The presence of an understory dominated by mesophytic tree species has been associated with poor oak seedling and sapling development (Loftis 1990, Lorimer and others 1994). However, removal of the mesophytic midstory has aided in the development of the advance regeneration needed for the perpetuation of upland oak ecosystems (Crow 1988, Johnson 1993). Despite this, operational methodologies to remove dense midstories are costly and of uncertain reliability (Miller 1984, Horsley 1990, Groninger and others 1998). The composition of the understory and midstory may play an especially important role in the development of the next overstory in many southern Illinois stands where overstory dominants such as black oak and southern red oak are approaching their maximum ages en masse.

Recent studies have conducted prescribed burns in several transitional forests across southern Illinois with mixed success (Ruffner 2001, Ruffner and others 2003, Ruffner and Davis 2002). Understory prescribed burns have been effective in top-killing seedlings of these mixed mesophytic species with little or no effect on sapling-sized stems, unless subjected to multiple burns. Further, these burns have been ineffective for promoting oak regeneration in these stands. From these initial results we posit that understory burning is not effective in top-killing the larger unwanted stems that are shading the understory and precluding the development of oak and hickory advanced regeneration. Thus, we have developed an experiment to test the effects of three silvicultural treatments on controlling unwanted species and inducing oak-hickory recruitment. Recent burning activities will be discussed in this paper and the current experimental design and possible implications for oak ecosystem maintenance will be explained.

PHYSICAL AND HISTORICAL CONTEXT OF STUDY AREA

The current project focuses on upland forests of the Ozark Hills of southwestern Illinois and the Shawnee Hills of southern Illinois.

Ozark Hills

The Ozark Hills region (113,340 acres) in southwestern Illinois is characterized by mature dissected topography capped with loess deposits and underlain with cherty limestone (Fralish 1997). Ridgetop sites are relatively narrow spur ridges capped with loess above steep sideslopes of colluvial materials, which descend to narrow riparian zones comprised of alluvial soils. Pre-European settlement forests were dominated by oak-hickory species with increased numbers of American beech, sugar maple, and tulip-poplar (*Liriodendron tulipifera*) across more mesic sites (McArdle 1991). McArdle argued that these forests developed under a moderate to infrequent disturbance regime based on the fact that oak-hickory importance increased after European settlement in response to the more intense disturbance regime of logging, clearing for agriculture lands, and increased grazing and burning. Indeed, much of the region's forests were extensively logged between 1880-1920 and frequent fire was identified as a major problem for forest development in the 1920s (Miller 1920, Miller and Fuller 1922, Fralish 1997). Fires continued through the 1940s until much of the Ozark Hills were purchased by the USDA Forest Service in the late 1930s and effective fire control measures were implemented.

Shawnee Hills

The Shawnee Hills comprise a 950,495 acre, unglaciated east-west escarpment bisecting southern Illinois (Fralish 1997). Topography of this section is characterized by broad ridgetops bearing deep loess deposits dissected by moderately steep sideslopes opening onto broad flat valleys (Fenneman 1938). Pre-European settlement forests of this region were dominated by xerophytic species such as post oak (*Quercus stellata*), black oak, and white oak (*Q. alba*), with mesophytic species tulip-poplar (*Liriodendron tulipifera*), American beech and sugar maple having lower importance across most sites (Fralish 1997).

Stands disturbed during the early 20th century from harvesting, fire or grazing are 58-84 percent similar to pre-settlement oak hickory forests suggesting compositionally stable forests (Harty 1978, Fralish 1997). However, the reduction of harvesting on public land and the eventual near removal of fire from the landscape during the last century has caused a shift in importance values particularly across northern aspects and low slope positions (Fralish 1997). Reduced disturbance patterns have resulted in a distinct increase in sugar maple and American beech recruitment into the midstory and understory positions (Schlesinger 1976, Fralish

1997, Ruffner and others 2003). Still other midstory species such as winged elm (*Ulmus alata*), hophornbeam (*Ustrya virginiana*), and dogwood (*Cornus* spp.) appear capable of limiting oak recruitment on many sites.

Current management objectives of Illinois Department of Natural Resource agencies across this region focus on increasing oak-hickory advance regeneration while reducing mesophyte stem density with experimental prescribed burns coupled with timber stand improvement cuttings (Allen 2001, Ruffner and Davis 2002). Justification for this rests on the assertion that anthropogenic disturbances (either Native American or Euro-American) have been the driving force influencing forest structure and function across this region for at least the last four hundred years (Fralish 1997, Parker and Ruffner, in press).

PRESCRIBED FIRE TREATMENTS

Prescribed fire has been widely used to reduce competing vegetation, slow successional transition, reduce pest and pathogen populations, enhance wildlife habitat, facilitate site preparation, and encourage recruitment of resprouting species (Mutch 1994). Many authors have called for the reintroduction of prescribed burning in oak forests of the east, but few have documented the efficacy of this practice (Van Lear and Watt 1993, Brose and others 2001).

Perhaps the most successful experiments to date include those in oak forests of the Piedmont region of Virginia (Keyser and others 1996, Brose and Van Lear 1998, Brose and others 1999). Following shelterwood harvests with a 50 percent basal area reduction, these authors conducted repeated prescribed burns to significantly reduce tulip-poplar regeneration and increase advance oak regeneration. They suggest that this harvest/fire disturbance regime closely mimics the conditions that fostered the development of these oak dominated systems (Brose and others 1999). In addition, they report that allowing several years to lapse between the initial cut and burning is critical. This waiting period allows for several key components including the establishment and growth of vigorous oak seedlings and regeneration of the buried tulip-poplar seed pool. Although burns were also conducted in the winter and summer, spring appeared to be the best time period for burning because it presented the most favorable weather conditions such as warm temperatures, lower humidities, and sunny days (Brose and others 1999).

Within forests of southern Illinois, land managers have been utilizing prescribed fire since the mid 1980s. While the US Forest Service fire management program has largely been forced into a “suppression” mode due to extensive litigation, several Illinois Department of Natural Resources Divisions actively manage vegetation with prescribed fire (Ruffner 2001). The Divisions of Forest Resources and Natural Heritage both use fire to maintain unique vegetation and habitat types in glade and oak savannas, improve wildlife habitat, and foster oak regeneration while reducing competing mesophytic species in forestlands (Ruffner 2001).

The effect of a fall prescribed burn in an oak-hickory forest stand was investigated using two 0.10 ha permanent plots at Ozark Hills Nature Preserve, Trail of Tears State Forest. Despite the low-to-moderate intensity of the burn caused by fall weather conditions, the burn effectively met the primary objectives of reducing understory competition from mesophytic tree species and increasing diversity of herbaceous species. Analysis of pre- and post-burn data indicates that nearly 40 percent of understory sugar maple and American beech seedlings were top-killed and herbaceous cover increased 15-25 percent within the plots. While these numbers indicate reduction of unwanted seedlings, sapling sized stems were left untouched by this level of burning. Thus, a replicated study similar to those conducted by Brose and his associates was designed to test the effectiveness of periodic burning and partial cutting of midstory, mesophytic trees on the development of oak-hickory regeneration.

This newest project evaluates and demonstrates the use of prescribed fire and partial cutting, alone and in combination with one another, on restoring oak forest health and sustainability. All study sites are in upland forest stands in southern Illinois with an oak-hickory dominated overstory and a midstory consisting of shade tolerant tree species. Site index ranges between 50-80 for upland oaks. Stand basal area averaged 110.1 ft^2 per acre ($\pm$ 4.5 SE) with an average stem density of 226.2 ($\pm$ 26.7 SE) trees per acre. A total of five, four acre blocks (each comprising a burned only plot, a cut only plot, a burned and cut plot, and an unmanaged control) have been installed across southern Illinois. Block compartments have 30-50 percent of standing basal area reduced by cutting stems <12 inches in d.b.h., favoring healthy oak-hickory stems for the residual stand. Burn compartments will be treated three times in five years beginning spring (2003) with a typical fuel model 9 prescription aimed at top-killing mesophytic resprouts and generating an advanced regeneration pool of oak-hickory stems. At each site, permanent plots have been installed to permit repeated measurement of the following variables:

- growth and fire damage for trees larger than 4 inches in d.b.h.
- tree species regeneration, shrub species, and tree saplings up to 4 inches in d.b.h.
- herbaceous species composition, cover, and quality for wildlife.

CONCLUSION

Perpetuation of oak dominated uplands is a priority among a wide range of constituencies in southern Illinois. Managers addressing this problem are faced with an incomplete understanding of past processes that produced the presently dominant oak overstory. Specific questions concern the timing, frequency, and intensity of anthropogenic and natural fires and the potential impacts of native and agricultural animals in stand establishment and maintenance. Equally puzzling is the extent to which overstory and midstory mesophytes must be controlled in order to carry a cohort of oak and hickory from seedling to overstory status. Also, with the prolonged absence of fire, some mesophytes have developed to the extent that they are now overstory trees. Removal of these now fire resistant individuals through cutting may be necessary to meet ecosystem restoration goals, but is inconsistent with esthetic expectations for public lands. Retention of these trees might necessitate

implementation of prescribed fires of greater than historic intensity and or frequency. These hotter fires may negatively impact the quality and value of maturing timber and thereby alienate some landowners with economic incentives for forest management. Alternatively, retaining large mesophytes may preclude adequate fuel development and result in the failure to secure oak and hickory recruitment.

In the face of these uncertainties, the establishment of demonstration plots such as those described here could serve as a focal point to help interested parties in southern Illinois determine where oak ecosystem restoration is desirable and how it may be effectively implemented. This empirical approach may also help address historical questions which often serve as a justification for ecosystem maintenance and restoration. A network of similar installations across fire-influenced oak dominated portions of North America may serve to increase public understanding of the fundamental roles played by humans and fire in the widespread occurrence of these ecosystems.

ACKNOWLEDGMENTS

The authors wish to thank James Zaczek and David Allen for their constructive reviews of the manuscript and to the members of the Saluki Fire Dawgs fire management crew for data sampling and burn implementation. This research is supported through grants from the McIntire-Stennis Cooperative Forestry Program and the Wild Turkey Federation.

LITERATURE CITED

Abrams, M.D. 1992. Fire and the development of oaks. Bioscience 42: 346-353.

Allen, D. 2001. Forest stewardship plan. Dixon Springs Agricultural Center, Illinois Forest Resource Center. Unpublished Report. IL. Dept. Nat. Res.

Allen, J.W. 1945. Jackson County notes. Southern Illinois University, Museum of Natural and Social Sciences, Contribution No. 21 Carbondale.

Anderson, R.C.; Schwegman, J.E.; Anderson, M.R. 2000. Microscale restoration: a 25-year history of a southern Illinois barrens. Restoration Ecology 8: 296-306.

Barton, J.D.; Schmelz, D.V. 1987. Thirty years of growth records in Donaldson's Woods. Proc. of the Indiana Academy of Science. 96: 209-213.

Batek, M.J.; Rebertus, A.J.; Schroeder, W.A.[and others]. 1999. Reconstruction of early nineteenth-century vegetation and fire regimes in the Missouri Ozarks. J. Biogeography 26: 397-412.

Braun, E.L. 1950. Deciduous forests of eastern North America. McMillan, New York.

Brose, P.T.; Schuler, D.; Van Lear, J. Berst. 2001. Bringing fire back: the changing regimes of the Appalachian Mixed-Oak Forests. J. Forestry 99: 30-35.

Brose, P.T.; Van Lear, D.H. 1998. Responses of hardwood advance regeneration to seasonal prescribed fires in oak-dominated shelterwood stands. Can. J. For. Res. 28: 331-339.

Brown, M.K. 1985. The historic period. IN: Porter, J.W. and D.S. Rohn, eds. Illinois Archaeology Bulletin 1: Revised, 89-100.

Crow, T.R. 1988. Reproductive mode and mechanisms for self-replacement of northern red oak *(Quercus rubra)* –a review. Forest Science 34: 19-40.

Dey, D.C.; Guyette, R.P. 2000. Sustaining oak ecosystems in the central hardwood region: lessons from the past-continuing the history of disturbance. p. 170-183. IN: Transactions of the Sixty-fifth North American Wildlife and Natural Resource Conference, McCabe, R.E. and S.E. Loos, eds. Wildlife Management Institute, Washington, DC.

Fenneman, N.M. 1938. Physiography of eastern United States. McGraw-Hill, NY.

Fralish, J.S. 1988. Predicting potential stand composition from site characteristics in the Shawnee Hills forest of Illinois. American Midland Naturalist 120: 79-101.

Fralish, J.S. 1997. Community succession, diversity, and disturbance in the central hardwood forest. IN: M.K. Schwartz, ed. Conservation in highly fragmented landscapes. Chapman and Hall, New York, NY.

Fralish, J.S.; Crooks, F.B.; Chambers, J.L.; Harty, F.M. 1991. Comparison of presettlement, second-growth and old-growth forest on six site types in the Illinois Shawnee Hills. American Midland Naturalist 125: 294-309.

Groninger, J.W.; Ozier, T.B.; Ruffner, C.M. 2003. Stand compositional dynamics in a mature Illinois Ozark Forest: implications for management. Proc. 13th Central Hardwood Conference, Urbana-Champaign, IL. USDA Forest Service Gen. Tech. Rep. In Press.

Groninger, J.W.; Stein, H.D.; Zedaker, S.M.; Smith, D.W. 1998. Growth response and cost comparisons for precommercial thinning methods of Appalachian oak stump sprout clumps. Southern Journal of Applied Forestry 22: 19-23.

Hall, C.; Ingall, O.D. 1910. Forest conditions in Illinois. Illinois State Laboratory of Natural History, Springfield.

Harty, F.M. 1978. Tree species distribution, and herbaceous vegetation as an indicator of site quality for disturbed upland forest stands in the Greater Shawnee Hills of southern Illinois. Southern Illinois University, Carbondale. M.S. thesis.

Horsley, S.B. 1990. Tank mixing Roundup with adjuvants and other herbicides for striped maple control. Northern Journal of Applied Forestry 7: 19-22.

Johnson, P.S. 1993. Sources of oak reproduction. Pages 241-249 in D. Loftis and C. E. McGee, editors. Proceedings Oak Regeneration: Serious problems, practical recommendations. General Technical Report SE-84, U.S. Forest Service, Southeastern Forest Experiment Station, Asheville, North Carolina.

Keyser, P.D.; Brose, P.H.; Van Lear, D.H.; Burtner, K.M. 1996. Enhancing oak regeneration with fire in shelterwood stands: preliminary trials. Trans. N. Am. Wildl. Nat. Res. Conf. 61: 215-219.

Küchler, A.W. 1964. Potential natural vegetation of the conterminous United States. (Map) American Geographical Society. New York.

Loftis, D.L. 1990. A shelterwood method for regenerating red oak in the southern Appalachians. Forest Science 36: 917-929.

Lorimer, C.G.; Chapman, J.W.; Lambert, W.D. 1994. Tall understorey vegetation as a factor in the poor development of oak seedlings beneath mature stands. Journal of Ecology 82: 227-237.

Martin, W.H. 1992. Characteristics of old-growth mixed mesophytic forests. Natural Areas Journal 12: 127-135.

McArdle, T.G. 1991. Comparison of presettlement and present forest communities by site type in the Illinois Ozark Hills. M.S. Thesis, Southern Illinois University, Carbondale.

Miller, G.W. 1984. Releasing young hardwood crop trees- use of a chainsaw costs less than herbicides. U.S.D.A. Forest Service Research Paper NE-550. 5 p.

Miller, R.B. 1920. Fire prevention in Illinois. Forestry Circular No. 2. Illinois Natural History Survey, Springfield.

Miller, R.B.; Fuller, G.D. 1922. Forest conditions in Alexander County, Illinois. Trans. Illinois Acad. Sci. 14: 92-108.

Mutch, R.W. 1994. Fighting fire with fire: A return to ecosystem health. J Forestry 92: 31-33.

Nelson, R.E.; Young, R.A.; Gilmore, A.R. 1973. Twenty-two years of management of upland hardwoods in southern Illinois. Univ. Illinois Ag. Exp. Station Report 73-3.

Olson, S.D. 1996. The historical occurrence of fire in the central hardwoods, with emphasis on southcentral Indiana. Natural Areas Journal 16: 248-256.

Parker, G.R. 1989. Old-growth forests of the Central Hardwood Region. Natural Areas Journal 9: 5-11.

Parker, G.R.; Ruffner,. C.M. [In press]. Current and historical vegetative conditions and disturbance regimes in the Hoosier-Shawnee Ecological Assessment area. USDA Forest Service NC For. Exp. Stat. General Technical Report.

Robertson, P.A.; Heikens, A.L. 1994. Fire frequency in oak-hickory forests of southern Illinois. Castanea 59: 286-291.

Ruffner, C.M. 2001. Assessing the effects of prescribed burns on understory diversity, competing vegetation, and maintaining early successional characteristics of forests in southern Illinois. Unpublished Report submitted to Illinois DNR, Natural Heritage District 22.

Ruffner, C.M.; Davis, M.B. 2002. Assessing the effects of prescribed burning on understory vegetation in forests of southern Illinois. Published Abstract from 63rd Annual Meeting Association of Southeastern Biologists (ASB), Boone, NC. Southeastern Biology 49: p. 190.

Ruffner, C.M.; Trieu, A.; Chandy, S. [and others]. 2003. From savanna to campus woodlot: the historical ecology of farm woodlots in southern Illinois. 13th Central Hardwoods Conference Urbana-Champaign, IL. USDA For. Serv. Gen. Tech. Rep. In Press.

Schlesinger, R.C. 1976. Hard maples increasing in an upland hardwood stand. IN: Proceedings for 1st central hardwood forest conference, Carbondale, IL. 177-185.

Spetich, M.A. 1995. Characteristics and spatial pattern of old-growth forests in the Midwest. Purdue University, West Lafayette, IN. 276 p. Ph. D. dissertation.

Temple, W. 1966. Indian village of the Illinois County. Museum Scientific papers, Volume II, Part 2.

Thompson, F.R.; Dessecker, D.R. 1997. Management of early successional communities in central hardwood forests. North Central Forest Exp. Sta., General Technical Report NC-195. USDA Forest Service, St. Paul, MN. 33 p.

van de Gevel, S. 2002. The Influence of land-use history on the forest development of the Illinois Ozark Hills. Southern Illinois University, Carbondale. 77 p. M.S. thesis.

van de Gevel, S.; Ruffner, C.M.. 2002. Relating past land-use, topography, and forest dynamics in the Illinois Ozark Hills. Published Abstract from 63rd Annual Meeting Association of Southeastern Biologists (ASB), Boone, NC. Southeastern Biology. 49 p.

Van Lear, D.H.; Watt, J.M. 1993. The role of fire in oak regeneration. IN: Oak Regeneration: Serious problems, practical recommendations, 66-78. USDA Forest Service. General Technical Report SE-54. Asheville, NC.

Weaver, G.T.; Ashby, W.C. 1971. Composition and structure of an old-growth forest remnant in unglaciated southwestern Illinois. American Midland Naturalist 86: 46-56.

Zaczek, J.J.; Groninger, J.W.; Van Sambeek, J.W. 2002. Stand dynamics in an old-growth hardwood forest in southern Illinois, U.S.A. Nat. Areas. J. 22: 211-219.