UPLAND OAK ECOLOGY SYMPOSIUM: A SYNTHESIS

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Abstract—Recent changes in upland forests of the Interior Highlands have raised the interest of and questions from professional resource specialists and the public. This renewed interest in Interior Highland forests provided researchers an opportunity to update resource specialists on new knowledge regarding upland oak ecology. Symposium presentations and the papers presented in this volume offer up-to-date knowledge that can be applied to the management of upland oak forests and can help resource specialists keep the public better informed.

INTRODUCTION

This manuscript is a synthesis of major ideas presented at the Upland Oak Ecology Symposium held October 7–10, 2002, in Fayetteville, AR. More than 350 managers, scientists, landowners, and others gathered to discuss problems and opportunities common to upland oak (*Quercus* spp.) forests, focusing mainly on forests of the Interior Highlands. However, much of the information contained is applicable to upland oak forests in general. This paper highlights common threads among symposium papers and incorporates additional supporting information to help link the full range of ideas presented.

As the proceedings papers illustrate, upland oak forests are complex systems that have evolved over millennia. Both human and natural disturbances have played an important role in their development. In his keynote paper, Paul Johnson explains that the response of upland oak forests to disturbance can be anticipated by understanding the stages of stand development, and by recognizing that such forests are in a constant state of change. Dr. Johnson's presentation set the stage for a valuable, informative conference.

HISTORICAL PERSPECTIVES INFLUENCING THE ESTABLISHMENT AND SUSTAINABILITY OF UPLAND OAK FORESTS

Oak- and hickory- (*Carya* spp.) dominated forest communities of what is now known as the Central Hardwood Region (Merritt 1980) became established at least 5,000 years ago (Fralish, in press). The use of fire by Native Americans influenced development of this forest complex. Without modern fire breaks such as roads or fire lines, once set, fire would likely transform large landscapes on a regular basis.

Native Americans also intimately interacted with these forests in many other ways. For instance, hardwoods were the most important wood for native dwellings in northern Arkansas, and oak was the most important species for fuelwood. Thus, between 500 and 5,000 years ago, communities of at least 250 people were an important component of the forest ecosystem in the Boston Mountains of Arkansas, especially where wood, water, and productive soils existed (George Sabo III, in press).

The overall impact of Native Americans on the landscape varied with their historic population levels. DeVivo (1990) presents a convincing argument that presettlement Native American populations were much greater than previous estimates. He suggests that by the time Europeans began settling the interior, noncoastal areas of North America (nearly 200 years after Columbus landed on the continent), the diseases transmitted over the previous 200 years had depopulated the areas significantly. He and others have based their estimates on historical information about disease-caused depopulation of Latin American regions. He further quotes Williams (1989): "There is the strong possibility that in the late 15th century the Western Hemisphere may have had a greater total population than Western Europe."

By the early 1800s, European settlement of northern Arkansas had begun. Tree measurements taken then have allowed scientists to estimate relative forest species composition and structure of the period. During that time, General Land Office surveys were conducted in the Arkansas Ozarks. Based on those records, the Boston Mountains and the Springfield Plateau Subsection had more trees per acre than areas to the north. Today, the Boston Mountains have even more trees per acre than they did then, probably a result of fire suppression (Foti, in press). In fact, a fire-history study in the Lower Boston Mountains by Guyette and Spetich (2003) found major changes in the mean fire interval (MFI) since 1680. They divided the time since 1680 into four periods: the Native American period (1680 to 1820), Euro-American settlement period (1821 to 1880), regional development period (1881 to 1910), and fire suppression period (1911 to 2000), in which they found the MFI to be 11.2 years, 2.7 years, 2.9 years, and > 80 years, respectively. This provides quantitative evidence of how effective the past 80+ years of fire suppression has been in this region.

Over the past 80+ years, fire suppression likely has altered species dynamics of these upland hardwood forests. On medium- to high-quality sites, one impact has been a lack of successful regeneration and recruitment of oak into forest overstories while shade-tolerant species such as red maple (*Acer rubrum L.*) have become more dominant. For instance, in a study of four mature oak stands in north-central Arkansas, Soucy and others (in press) found that oak establishment has declined while establishment of

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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.

shade-tolerant species has continued successfully over the past 50 to 60 years. This likely is due to lack of disturbance. Based on the ecology and physiology of oaks, and the fire history of these forests, reduced fire disturbance and the resultant increase in competing species over the last 100 years appears to be a major factor in the loss of successful oak regeneration on these medium- and high-quality sites.

However, on low-quality sites, oaks can regenerate and successfully compete, even in the absence of fire. For instance, a study in the Ouachita Mountains comparing early records and recent data for a xeric site where fire had long been absent indicated a trend toward successful oak regeneration (Bragg, in press; Murphy and Nowacki 1997).

The 5,000-year history of these oak-hickory forests provides many lessons for the modern forest manager. New information is being used to better understand upland oak forest ecology and dynamics and, where appropriate, to mimic past disturbances.

UPLAND OAK FOREST ECOLOGY AND WILDLIFE ECOLOGY

The Central Hardwood Forest region (Merritt 1980) has been dominated by oak and hickory trees for thousands of years, with oaks being a keystone species (Fralish, in press; Spetich and others 2002). Disturbance and oak forest dynamics relative to disturbance are overriding themes in this section of the proceedings, and many papers focus primarily on disturbance by fire. Historically, these forests were regularly subjected to fire. Fire frequency and intensity were greatly influenced by humans (Dey and others, in press) and by topography (Guyette and Dey, in press).

Of all the disturbance factors that have shaped upland oak forests, fire probably is among the most important. Van Lear (in press) proposes that, because oaks adapt to low-intensity surface fires, it is possible to use prescribed fire to reach a variety of management goals in oak-dominated forests. Brose and Van Lear (in press) point out several reasons why oak is better at surviving surface fires than other species. For example, due to the hypogeal germination strategy of oaks and hickories, their root collars are closer to ground level than many other hardwood species. This helps protect their dormant buds from fire.

Acorns must survive predation if they are to become seedlings. Differences between red oak (*Q. rubra* L.) and white oak (*Q. alba* L.) acorns—such as the energy contained within them, palatability to wildlife, and masting time—help these species survive predation (Steel and others, in press). Acorns that survive and germinate have additional challenges. In forests of many Northern and Eastern States where white-tailed deer (*Odocoileus virginianus*) populations are high, browsing of oak seedlings has a significant impact on oak regeneration. However, in the large contiguous forest matrix of Arkansas's Boston Mountains, we have rarely observed oak-specific browsing damage to seedlings from deer. This likely is due in part to the preponderance of other species preferred by deer, such as poison ivy (*Toxicodendron radicans* L.), greenbrier (*Smilax Bona-nox* L., *S. glauca* Walt., *S. rotundifolia* L.), huckleberry (*Vaccinium vacillans* var. *crinitum* Fern.), red maple (*A. rubrum* L.), and Virginia creeper (*Parthenocissus quinquefolia* L. Planch.). When making management decisions, it is important to determine the existing mix of impacts on acorn and oak seedling survival.

Survival and successful competition of oak seedlings can lead to changes in forest composition and structure, which are important to bird communities. For instance, Patterson and James (in press) found that birds in this region used oaks more often than other tree species. Further, bird habitat can be improved through management activities such as prescribed fire, various harvesting techniques, and natural disturbances (Dickson, in press).

Management activities also can be used to provide a wide range of habitats. For instance, maintaining a wider range of successional stages in oak forests of the Interior Highlands likely would have reduced the impact of oak decline and enhanced habitat for a wide range of wildlife species, some of which need both mature forest and early successional habitat. For example, both oak mast found in mature forests and soft mast found in early successional habitats are needed by black bears (*Ursus americanus*) (Clark, in press). Natural disturbances such as wind, fire, and oak decline also can create early successional habitats, but unlike well-planned management activities, not necessarily at the time, place, or scale that would most benefit wildlife populations and the public.

Forest managers know the importance of predicting how mature oak trees respond to natural disturbances such as oak decline and associated factors like increased red oak borer (*Enaphalodes rufulus* Haldeman) populations. For instance, Muzika and Guyette (in press) present an innovative study that invites exploration of past oak borer events relative to tree age, ring width, and temperature. Such studies will help identify conditions that influence oak borer populations and lead to models that help managers predict future population levels and activity.

To accurately model upland oak forest systems, scientists need data that have been collected over a long time. In addition, standard, comparable, precise, quantitative data among species are necessary when modeling oak life-history characteristics (Guyette and others, in press). It is often difficult to discern significant changes over the short term in these forests; e.g., Demchik and Sharp (in press). Even in small, gap-size disturbances, seedling dynamics are highly variable during the first several years after a disturbance event; e.g., Berg (in press). At the stand scale, the stand-initiation stage is chaotic, making predictions of species and stand structure problematic (Johnson, in press). Even more broadly, when modeling large landscapes, ecologically discrete areas need to be well defined and evaluated (Kabrick and others, in press; McNab and others, in press).

To increase the predictive power of forest models, it will be necessary to make greater commitments to long-term studies. Mechanisms should be developed to continue orphaned studies; i.e., studies where the responsible researcher has retired or otherwise moved on. Such mechanisms will allow future generations of scientists and managers to examine stand dynamics throughout the life of a forest, rather than the life of an individual researcher. Such commitment will make future restoration and management of these forests possible and help maximize benefits to the public.

UPLAND OAK ECOSYSTEM RESTORATION AND MANAGEMENT

There was general agreement at the symposium that oak regeneration and appropriate disturbance factors, which allow successful survival and growth of oak regeneration, are critical to restoration of the upland oak forest. In fact, successful oak regeneration has been acknowledged as problematic in eastern forests for at least 25 years (Lorimer 1989). The potential for even larger losses of keystone oak species helped focus authors in this section on the success of oak regeneration and disturbance factors that could facilitate successful oak restoration. Without oaks, there would be no oak ecosystem. Effective management methods will be necessary to help guide oaks into a successful position relative to their interspecific competitors, so they may survive to become part of the future forest (Spetich and others, in press).

The outcome of interspecific competition between oak regeneration and other natural vegetation is a function of site factors, associated differences in growth rates of co-occurring species, the genetics of plant populations, and the state of the vegetation complex when silviculturally prescribed or naturally imposed disturbances occur. The competitive capacity of a species, therefore, may vary as those factors vary in time and space (Spetich and others 2002). This in turn influences the composition and structure of the next stand.

Understory and midstory structure and composition are important factors in species composition and dynamics of the next stand (Miller and others, in press; Ruffner and Groniger, in press). Managing these components properly is necessary for successful restoration of oak-hickory forests. This leads us to the two key requirements for successful oak regeneration: “(1) to ensure that competitive regeneration sources are present, and (2) to provide timely, sufficient release of these regeneration sources” (Loftis, in press).

In order to restore and maintain oak forests, we need a well-developed understanding of how they function and respond under various environmental conditions and disturbances. For example, we know there are major differences in relative competitive capacity of oaks across the spectrum from low-quality xeric sites to high-quality mesic sites (Loftis, in press; Spetich and others 2002). As site index increases, the competitive capacity of oak decreases because more and more species can survive and compete. Without disturbance, oaks are competitively excluded from the higher quality, more mesic sites.

Fire is probably the most widely recognized disturbance element missing from these upland forests today. This has led to increased research activity in prescribed fire with the intent of finding the best method(s) of restoring this disturbance agent. For instance, a study by Dey and Hartman (in press) examined the effects of repeated burning of oak forest vegetation, providing valuable insight into relative fire response among species in the Missouri Ozarks. They found that although repeated burns reduced survival of all species one growing season following the last fire, the overall effect resulted in favoring oak and hickory reproduction. Iverson and others (in press) demonstrated how a combination of sensors, data recorders, and landscape-level analysis helped them gain significant insight into fire behavior in an oak forest.

Once a stand has been successfully regenerated through natural or anthropogenic disturbance, an appropriate management regime will be necessary to keep the stand growing vigorously. Increased stand vigor can help reduce losses to oak decline, insects, and disease, as well as maximize yield. Shifley (in press) explains that an understanding of forest development stages will help practitioners administer appropriate thinning regimes to achieve vigorously growing forest stands. Practitioners can achieve the most successful thinning regime by starting early in the stem-exclusion stage and working with the stand’s natural dynamic as presented by Shifley (in press). Stages of stand development can be illustrated pictorially, which gives resource specialists an important visual reference of forest development. Such visual references can also provide deeper insight into structural changes caused by disturbance events, such as the current oak decline event.

OAK DECLINE

From 1856 to 1986 there have been 57 oak-mortality events recorded in the Eastern United States (Millers and others 1989). This included one in 1959 in the Ozark Mountains of Arkansas (Tool 1960), one in 1980-81 in Northwestern Arkansas (Bassett and others 1982, Mistretta and others 1984), and another in Missouri from 1980 to 1986 (Law and Gott 1987). The current oak-decline event in Arkansas and Missouri has been recognized as unique among other known oak-decline events due to the proliferation of oak borers, one of the contributing factors. Because of this extraordinary proliferation, the development has received widespread attention from experts around the country (Starkey and others, in press). However, many factors, such as drought, also influence oak decline.

Starkey and others (in press) have defined drought as an “inciting factor” of oak decline. Crook and others (in press) examine three drought events over the past 50 years. Even though the last drought (1998 to 2000) was not as severe as the previous two major droughts (one in the early 1950s and one in the mid-1960s), the authors suggest that it likely led to the current unprecedented outbreak of red oak borer. One of the major changes that occurred in upland forests over the last few decades is an increase in tree density and tree age, both conditions that make forests more vulnerable to oak decline (Oak and others, in press). Crook and others (in press) also did an extensive survey of 21 trees on a plot in the Ozarks and concluded that oak borers were responsible for tree death. Their conclusion that red oak borers are a main cause of tree death differs from the conclusion of others who view oak borers as one of several contributing factors (Law personal communication; Oak and others, in press; Starkey and others, in press). With or without oak borers, oak species across large landscapes die during an oak-decline event. There is little doubt that the additional stress of this large population of borers is helping to contribute to the demise of many trees, as are advanced stand age, high stand density, and drought. However, the latter three stresses predispose a stand to oak decline whereas oak borers are opportunistic organisms that take advantage of already stressed trees. For trees on the verge of death, additional stress from any one of these stress mechanisms could result in earlier mortality.

A regional oak-decline study covering 12 Southeastern States examined data from 26,907 forest inventory plots (Oak and others, in press). The authors found a total area of 104.7 million acres dominated by oaks. Of that total, 43.5 million acres constituted sites with trees large enough and with enough oak basal area to be considered susceptible to oak decline. Those results are based on the most recent Forest Inventory and Analysis inventory cycle (from 1991 to 1997). In Arkansas, they found that the area affected by oak decline more than doubled from 1988 to 1995 and that this was concurrent with increases in stand age and stand density.

An oak-decline event such as the current one has the potential to significantly alter forest structure and species composition, which in turn will affect wildlife. Both Smith and others (in press) and James (in press) addressed potential effects of oak decline on bird populations. Smith predicted that 10 to 20 species would decline, while 11 or more species would increase. However, James predicted that 21 bird species would decrease while 38 would increase. The difference between the two studies may be due in part to their interpretation of how extensively oak decline will impact tree species composition. For instance, Smith and others suggest elimination of red oaks while James appears to view this as a thinning of the forest with some areas of high oak mortality.

Based on previous oak-decline events (Oak and others 1988, Starkey and others 1989, Tainter and others 1984), it is likely that oaks will remain an important component of these forests at the regional scale, but that the species no longer will be the dominant tree in many stands without active management to encourage competitive oak regeneration. On sites where oak reproduction is present but competing species have the advantage, active management will be necessary to successfully guide a new cohort of oak into the tree canopy.

MANAGEMENT

We now recognize that there are often multiple management options in a given stand (Loftis, in press). Generally, more management options are available on low-productivity, xeric to xero-mesic sites where oak regeneration tends to be more successful than on more productive sites. Loewenstein and Guldin (in press) define such low-productivity sites as successionally stable oak stands. On more productive, mesic sites where fire or other disturbance mechanisms have been absent, long-term oak regeneration is seldom very successful. On those sites, competitive woody species (including shade-tolerant species that easily out compete oaks in the absence of disturbance) often are more abundant. If the management objective is to maintain oak as a major component of the stand, then management options typically are more limited and problematic on the more productive sites.

We often separate high-quality (mesic) and low-quality (xeric) sites when referring to a specific management technique. For instance, Loewenstein and Guldin (in press) describe a technique to convert even-aged oak stands to uneven-aged stands on sites where oaks are successionally stable (low- to medium-quality sites). Schweitzer and others (in press) modeled forest stands that fall into the low- and high-quality categories. They concluded that significantly different management regimes would be necessary on each site due to differences in the relative competitiveness of oaks. Prescribed fire is often suggested as a possible management option on high-quality sites. However, fire alone may not be sufficient because these forests have been without fire for so long that competing species can be large in diameter and therefore resistant to fire. In such cases additional work, perhaps through mechanical or chemical control, will be needed initially to control competing species, helping to restore the desired understory and midstory forest structure and species composition.

Brose (in press) describes optimal times and methods to apply prescribed fire. One method combines a shelterwood system with prescribed fire. This is supported by a recent study by Rebbeck and others (in press), who found that the number of fire top-killed seedlings was highest when overstory removal and fire were combined. Fire top-killed oak seedlings resprout under those conditions while accumulating energy in their root system, but shade-tolerant competitors do not. Additionally, results from a study by Dolan and Parker (in press) show that fire and silvicultural treatments can be combined to improve growing conditions for oak seedlings.

However, Brose (in press) also suggests that mechanical site scarification may be a better management strategy than fire for initial establishment of new seedlings. Lhotka and others (in press) review four studies on how scarification affects oak seedling establishment. For seedlings to survive, scarification would need to be combined with other management practices. On areas where scarification is operationally feasible, it likely would be most useful in small, defined areas. Studies suggest that future research also should consider time of scarification relative to time and amount of seed fall. For instance, Miller and Schlarbaum (in press) found that weevil predation on early-fall acorns differed from predation on acorns that fell later.

Fertilization is another seldom-used tool in management of upland oak forests, and it can be a useful option where the desire for increased growth rate outweighs costs. Happel and Sharp (in press) examined the use of fertilizer, lime, and herbicide, and found an increase in radial growth of oak on extremely acidic soils. DeWalle and others (in press) found that nitrogen fertilization can cause short-term soil acidification. A study by Graney (1986), in which a one-time fertilizer application of a nitrogen and phosphorus combination was applied to oaks, found significant increases in diameter growth over a 10-year period.

CONCLUSIONS

Upland oak-dominated forests are complex ecosystems that became established at least 5,000 years ago. Both human and natural disturbances have played a role in their development. Native American activities probably had a major impact on upland oak forest development, especially through the use of fire as a management tool. By the mid-1800s, European settlers began to substantially alter the landscape through forest clearing and increased fire frequency. Over much of the 20th century, massive and effective fire suppression efforts resulted in changes in forest structure and composition. Oak regeneration has changed the most on medium- to high-productivity sites.

Today's land managers face many challenges and difficult decisions in caring for upland oak forests. Competitive oak regeneration often is absent on productive sites; oak decline is changing forest structure and composition throughout the Interior Highlands; disturbance mechanisms are not yet thoroughly understood; and new problems such as gypsy moth and sudden oak death pose additional threats.

Nonetheless, a renewed commitment to research, as well as active management on a large scale over the next 15 years, could make the restoration of upland oak forests possible across the region. Development of models for predicting the competitive capacity of oak, relative to disturbance in specific plant communities and site-quality combinations, will greatly improve the chances for success in restoring and managing oak-dominated plant communities.

But a commitment to long-term and orphaned studies also will be necessary. For example, in the Boston Mountains of Arkansas the author has found (Spetich, unpublished observations) that tagged oak rootstocks that have been top-killed sometimes will lie dormant for 1 year or more before resprouting, a fact that short-term studies would not have captured. Monitoring rootstocks over time will allow better determination of their true survival and competitive success. In addition, long-term studies will improve the land manager's working knowledge of forest dynamics and benefit other components of the upland oak ecosystem.

As forests evolve, so does our knowledge of them. The papers in this volume represent views of various authors' knowledge at one point in time. But a caring, responsible stewardship will require a continuous monitoring of change—both in forest dynamics and in our knowledge of them. In carrying out such stewardship, the scientist and land manager both must be willing to use new information in ways that ensure the evolution of responsible decision-making.

ACKNOWLEDGMENTS

Thanks to Michael G. Shelton and Stephen R. Shifley for reviewing this manuscript and to Betsy L. Spetich for editorial guidance and insight.

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