FOREST DYNAMICS AT THE EPICENTER OF AN OAK DECLINE EVENT IN THE BOSTON MOUNTAINS, ARKANSAS – YEAR ONE

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ABSTRACT.—Oak decline is a significant problem in the Boston Mountains and Ozark Highland region of Arkansas and Missouri which recently has resulted in mortality of oaks across thousands of hectares of forest. However, research plots at oak decline sites usually are established after the decline event is visually evident. Results of a case study in which we serendipitously established research plots at what became the epicenter of an oak decline event are presented. In August of 2000, standing trees greater than 14 cm in diameter were inventoried on twenty-four 0.3025 ha plots. By late summer of 2001 oak decline symptoms became visually evident at the site. In November 2001, overstory trees on six of those plots were remeasured. I compare survival and structural changes on those six plots. For instance, an average of 38 trees per ha died by the fall of 2001. In addition, basal area of standing dead trees (hereafter referred to as snags) increased from 1.8 m^2/ha in 2000 to 4.4 m^2/ha in 2001 ($p = 0.019$). Correspondingly, basal area of live trees decreased from 24.1 m^2/ha in 2000 to 21.2 m^2/ha in 2001 ($p = 0.022$). Mean values for diameter of snags increased from 20.4 cm DBH in 2000 to 24.3 cm DBH in 2001 ($p = 0.015$). All 24 plots are scheduled for remeasurement in 2004. The serendipitous establishment of permanent study plots on this site will provide a unique opportunity to examine an oak decline event before, during and long after visual evidence of the event has occurred, providing potential insights that are rarely available for such a disturbance event.

From 1856 to 1986, there had 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 (Toole 1960), one in 1980-1981 in Northwestern Arkansas (Bassett and others 1982, Mistretta and others 1984), and an event in Missouri from 1980 to 1986 (Law and Gott 1987). The current oak decline event in Arkansas and Missouri is severely affecting up to 120,000 ha in the Ozark National Forest of Arkansas alone (Starkey and others in press).

Stresses that lead to oak decline in the eastern US are complex interactions of many factors (Wargo and others 1983). Manion (1991) describes oak decline as the outcome of the interaction of three major groups of factors: predisposing factors, inciting factors and contributing factors. Predisposing factors include physiologic age and oak density; inciting factors include a long drought; and contributing factors include opportunistic insects such as oak borers and diseases like Hypoxylon canker.

In 1998-2000, a three-year drought occurred across the region. Drought is defined as an "inciting factor" of oak decline by Manion (1991) and by Starkey and others (in press). This, coupled with a forest of high tree density and old mature trees, has made Arkansas upland hardwood forests more vulnerable to oak decline (Oak and others in press). Drought, density and maturity likely were important factors in the current oak decline event in Arkansas and Missouri.

An oak decline event, such as we have now, has the potential to significantly alter forest structure and species composition. Based on previous oak decline events (Tainter and others 1984, Oak and others 1988, Starkey and others 1989), it is likely that oaks will remain an important component of these forests at the regional scale. Within many stands, however, oaks will no longer be the dominant tree without active management to encourage oak regeneration and recruitment. On sites where oak reproduction exists but competing species have the advantage, active management will be necessary to successfully grow a new cohort of oak into the tree canopy. An understanding of how species and forest structure are changing will aid our understanding of how to address these issues in the future.

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One year after measuring vegetation on permanent plots at a site in the Boston Mountains of Arkansas, oak decline symptoms became visibly evident. Although this meant the temporary loss of one replication of another study, it provided a serendipitous and unprecedented opportunity to establish a case study examining the dynamics of an oak decline event in which detailed early data are available for comparison.

The objective of this paper is to evaluate mortality by species and changes in forest structure one year after the first woody vegetation measurements were taken. The long-term objective is to compare stand dynamics among areas treated with a growing season prescribed fire, a dormant season prescribed fire and a control area.

Study Area

The study site is a 32 ha area in an upland oak-hickory stand which is approximately 80 years old. It is located in the Boston Mountains of Arkansas, part of the southern lobe of the Central Hardwood Region (Merritt 1980). More specifically the study is located in the northwestern corner of Pope County, approximately 3 kilometers southeast of Sand Gap, Arkansas. The forest stand is dominated by oak (*Quercus* spp.) and hickory (*Carya* spp.) and is now the epicenter of an oak decline event. In 2000, prior to identification as an oak decline site, basal area for all standing trees was 25.9 m^2/ha and there were 417 standing trees/ha, of which 1.8 m^2/ha of basal area and 53 trees/ha were standing dead trees (hereafter referred to as snags). Stocking for this stand was 88 percent in August of 2000.

The Boston Mountains are the highest and most southern member of the Ozark Plateau Physiographic Province. They form a band 48- to 64-km wide and 320-km long from northcentral Arkansas westward into eastern Oklahoma. Elevations range from about 275 m in the valley bottoms to 760 m at the highest point. The plateau is sharply dissected. Most ridges are flat to gently rolling and generally are less than 0.8 km wide. Mountainsides consist of alternating steep simple slopes and gently sloping benches. Vegetation across the landscape is a forest matrix with inclusions of non-forest.

Methods

In late winter of 2000, twenty-four 55 x 55 m overstory plots (0.3025 ha) were established across the study area. During the summer of 2000, all standing live trees and snags > 14 cm DBH (1.37 m above ground level) within each plot were measured, and azimuth and distances from plot center to each tree were recorded. Diameter was measured to the nearest 0.1 cm. Species, log grade, crown class, and multifactor damage codes were also recorded for each tree. A Hewlett Packard 200LX palmtop computer was used to record all data in the field.

In each of the twenty-four 55 x 55 m plots, four circular 0.01 ha plots were established to inventory midstory trees. Within each 0.01 ha plot, all trees from 5 cm to < 25 cm dbh (1.97 to < 9.84 in dbh) were measured in July of 2000. Diameter at breast height (1.37 m above ground level) was measured to the nearest 0.1 cm and recorded.

In each of the 0.01 ha plots, five circular 0.00054 ha plots were established to inventory regeneration. Within each 0.00054 ha regeneration plot, all trees < 5 cm dbh were measured in spring of 2000.

These plots were intended to be part of one replication of a periodic fire study, but by the late summer of 2001, oak decline symptoms were visibly evident at the site. At that point, this site became the start of a long-term case study of oak decline. In November and December of 2001, the overstory on six of the 24 plots was remeasured. Three plots are located at the northwest end and three at the southeast end of this southwest facing slope. These plots were chosen because they are located in areas where a growing season prescribed fire (southeast end) and dormant season prescribed fire (northwest end) will be applied in the near future. Only six plots were remeasured due to time constraints. This site is now the epicenter of a severe oak decline event covering hundreds of hectares.

The data were analyzed using the following methods. First a t-test was used to compare 2000 plot values with 2001 plot values. For one measure (mean DBH of snags) the equal variance test (Levene Median test) failed. In this case the Mann-Whitney Rank Sum Test was used. To model survival, logistic regression was used to estimate tree survival probability. A model building approach was used as described in Hosmer and

Lemeshow's (1989, p. 82) text on applied logistic regression. Logistic regression has been used in studies to predict growth and success of regenerated oak stems (Lowell and others 1987), to estimate the contribution of planted hardwoods to future stocking (Johnson and Rogers 1985), to model regeneration of oak stands (Dey and others 1996), and to model the competitive capacity of trees underplanted in shelterwoods (Spetich and others 2002).

Results

Changes in forest structure occurred within one year of the first measurements. For instance, an average of 38 trees per ha died by the fall of 2001. In 2000, the percent of all standing trees that were snags was 13 percent. This increased to 20 percent by 2001. Basal area of snags increased from 1.8 m^2/ha in 2000 to 4.4 m^2/ha in 2001 ($p = 0.019$). Correspondingly, basal area of live trees decreased from 24.1 m^2/ha in 2000 to 21.2 m^2/ha in 2001 ($p = 0.022$). Mean values for diameter of all snags also were statistically different, increasing from 20.4 cm DBH in 2000 to 24.3 cm DBH in 2001 ($p = 0.015$).

The number of snags increased across all diameter classes from 2000 to 2001, with a corresponding decrease in standing live trees (figs. 1A and 1B.). The percent of snags generally decreased with increasing diameter class in 2000 (fig. 2). By 2001 this percent increased over most diameter classes with a peak at the diameter class of 60 cm.

Northern red oak (*Quercus rubra* L.) had the highest mortality rate. In only one year (from 2000 to 2001), the number of northern red oak snags per ha more than doubled, increasing from 23 trees per ha to 51 trees per ha respectively ($p = 0.029$) (fig. 3). Other species (white oak, *Quercus alba* L.; hickory, *Carya spp*.; black gum, *Nyssa sylvatica* Marsh.; post oak, *Quercus stellata* Wangenh.; red maple, *Acer rubrum* L.; and black maple, *Acer nigrum* Michx. f.) remained near their 2000 levels. The increase in northern red oak mortality

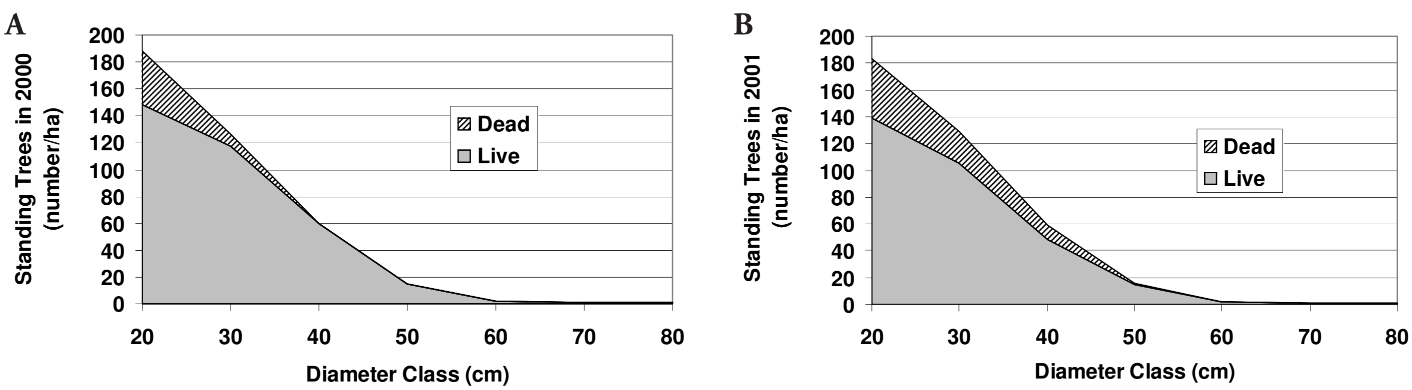

Figure 1.—A) Live and dead (snags) standing trees per ha in 2000 – all species. B) Live trees and snags per ha in 2001 – all species.

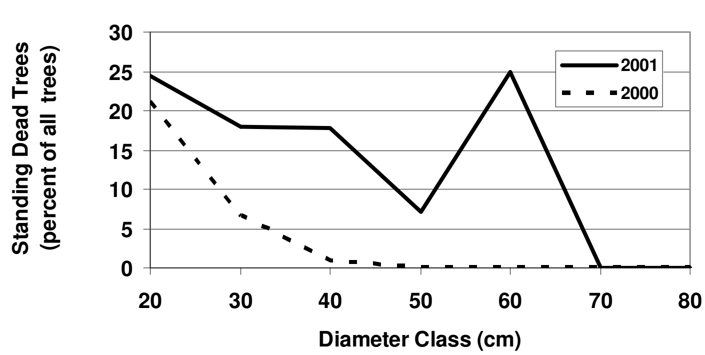

Figure 2.— Percent of all standing trees that were snags.

occurred over all diameters from 2000 to 2001 with the greatest number of dead trees increasing in smaller diameters (figs. 4A and 4B). Based on these results, a first-year survival probability model was developed for northern red oak using logistic regression (fig. 5). This model indicates that by the end of the first year (2001) of visible oak decline symptoms, survival was highest for large diameter trees while smaller trees were more likely to succumb to mortality.

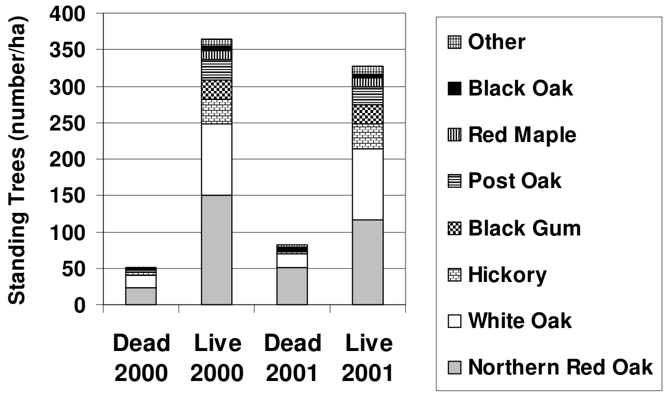

Figure 3.—Trees per ha by species and status. Other species include black cherry, *Prunus serotina* Ehrh.; black walnut, *Juglans nigra* L.; American elm, *Ulmus americana* L.; black locust, *Robinia pseudoacacia* L.; serviceberry, *Amelanchier spp*.; sassafras, *Sassafras albidum* Nutt.; and White ash, *Fraxinus americana* L.

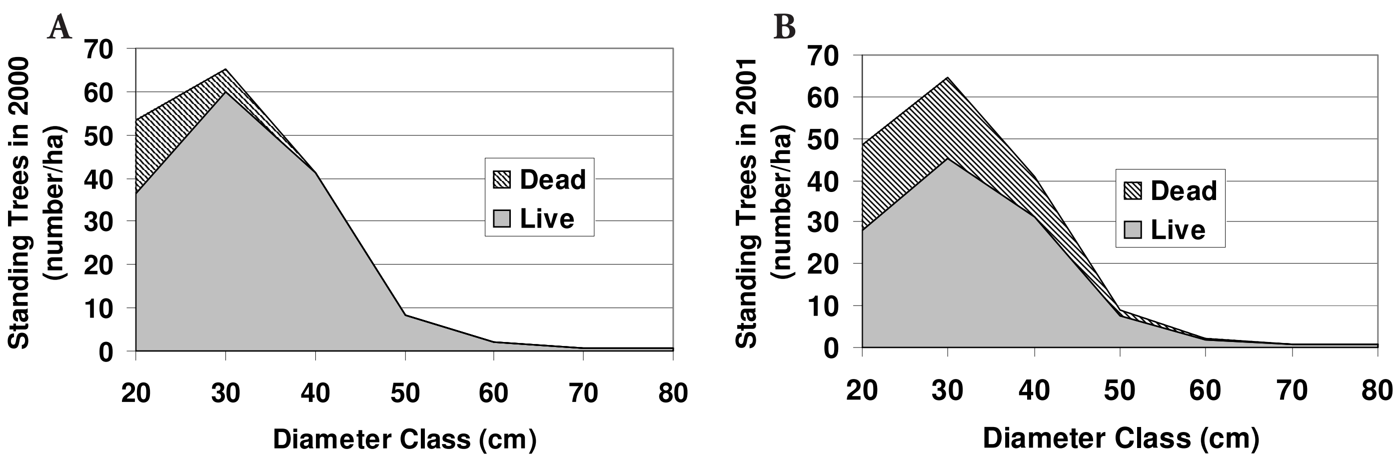

Figure 4.—A) Number of standing northern red oak trees per ha in 2000 by diameter class and status. B) Number of standing northern red oak per ha in 2001 by diameter class and status.

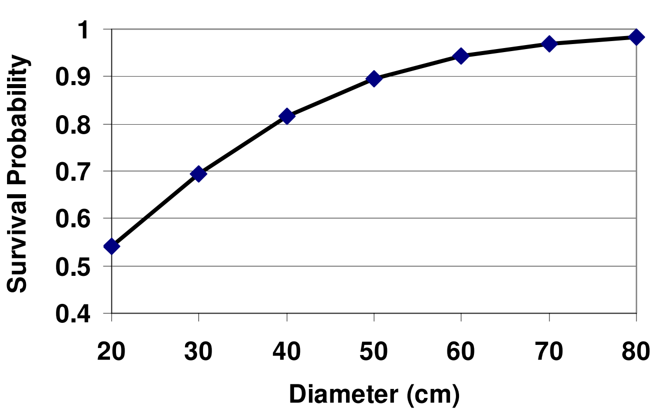

Figure 5.—Survival probability of northern red oak one year after oak decline symptoms were visually evident.

Discussion

Although the decline event wasn't visually identified in this stand until 2001, stresses on the stand began much earlier. These stresses included the three-year drought from 1998 to 2000 and stand density (364 trees/ha and basal area of 24.07 m^2/ha in 2000). Forest structure had been significantly altered by 2001. Increases in the number of snags along with corresponding changes in density will likely allow a greater amount of light through the canopy. Without intervention, many regenerating red oaks will be outcompeted by faster growing co-occurring species. However, because this is a xero-mesic site, some of the more drought tolerant advance regeneration white oak should survive on dryer microsites. On moister microsites, white oak will be more likely to succumb to competitors that exhibit more rapid height growth.

The percent of standing trees that were dead (snags) decreased from the 20 to 50 cm diameter classes in 2001. However, there was a dramatic increase around the 60 cm diameter class. This is likely due to the much smaller number of trees at larger diameters (fig. 1) and the corresponding increase in variability with a smaller sample size. For instance at the 60 cm class in 2000 there was an average of 2 standing live trees per ha and zero snags. The loss of only one tree per ha would result in a 50 percent increase in mortality in that diameter class.

It isn't surprising that northern red oak represented the majority of the mortality since, of the oak species at this site, it is the species most sensitive to drought. Figures 4A and 4B indicate that most of the mortality in red oak occurred in trees of relatively small diameter classes. These small trees are typically under more competitive stress than larger diameter trees and mortality rates for small trees are typically higher than for larger diameter trees (Harcombe 1987). At this site, this could lead to displacement of northern red oak by other co-occurring species.

Northern red oak in larger diameter classes generally survived through the first year of the oak decline event. However, overall mortality will likely increase for larger trees by the 2004 inventory since many overstory trees were already showing signs of stress by the fall of 2001.

In future inventories of this stand, we hope to have the resources to take more detailed measurements, as we did in 2000. These included litter weight, tagged regeneration, midstory trees, and down deadwood. We also plan to examine the effectiveness of summer season prescribed fire, dormant season prescribed fire and no fire options. Following forest dynamics of this site starting at a time before it was identified as an oak decline site should increase our understanding of oak decline dynamics.

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