EARLY CHANGES IN PHYSICAL TREE CHARACTERISTICS DURING AN OAK DECLINE EVENT IN THE OZARK HIGHLANDS

Martin A. Spetich[1]

Abstract—An oak decline event is severely affecting up to 120 000 ha in the Ozark National Forest of Arkansas. Results of early changes in physical tree characteristics during that event are presented. In the fall and winter of 1999 and 2000, we established research plots on a site that would become a center of severe oak decline. In August 2000, standing trees > 14 cm in diameter at breast height on twenty-four 0.3025-ha plots were inventoried. By late summer 2001, oak decline symptoms were evident. In November 2001, overstory trees on six plots were remeasured and changes in physical tree characteristics between the inventories were compared. Standing dead trees (all species < 35 cm in diameter at breast height) increased from 52 to 70 trees/ha ($p = 0.049$). The number of northern red oak (*Quercus rubra* L.) trees exhibiting epicormic branching increased from 9 trees/ha in 2000 to 55 trees/ha in 2001 ($p = 0.009$). Evidence of red oak borer damage on that portion of the main stem extending through the tree crown increased from 2 trees/ha in 2000 to 31 trees/ha in 2001 ($p = 0.008$). The mean ratio of standing dead to live trees increased from 0.15 in 2000 to 0.25 by 2001. I term this ratio the "forest health quotient." In 2000 the quotient was already above expected values, evidence of its potential utility in early detection of forest health issues.

INTRODUCTION

Fifty-seven oak mortality events have been recorded in the Eastern United States between 1856 and 1986 (Millers and others 1989). This included one in 1959 in the Ozark Mountains of Arkansas (Toole 1960), one in 1980-81 in northwestern Arkansas (Bassett and others 1982, Mistretta and others 1984), and one event in Missouri from 1980 to 1986 (Law and Gott 1987). The current oak decline event in Arkansas and Missouri has severely affected up to 120 000 ha in the Ozark National Forest of Arkansas alone (Starkey and others 2004).

In the Eastern United States, oak decline is considered a complex set of interactions involving many factors (Wargo and others 1983). Manion (1991) describes it as resulting from the interaction of three major groups of factors: predisposing factors, inciting factors, and contributing factors. Predisposing factors include physiologic age, tree density, soil conditions, and topography; inciting factors include drought and defoliating insects; and contributing factors include opportunistic insects such as some wood boring insects and diseases, e.g., *Hypoxylon* canker (*Hypoxylon atropunctatum*).

A 3-year drought occurred across the region from 1998 to 2000, an inciting factor of oak decline according to Manion (1991) and Starkey and others (2004). This, coupled with the fact that it occurred in a forest with high tree density and mature trees, made Arkansas's upland hardwood forests especially vulnerable to oak decline (Oak and others 2004). Those factors were present in both Arkansas and Missouri.

Such an oak decline event has the potential to significantly alter forest structure and species composition. 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 a regional scale. Within some stands, however, oaks may no longer be the dominant tree without active management to encourage oak regeneration and recruitment. On sites where oak reproduction is present, but competing species have an advantage, active management will be necessary to establish and successfully grow a new cohort of oaks into the tree canopy. An understanding of physical tree characteristics that help lead to early detection of oak decline would aid our ability to address future oak decline events.

One potential early indicator of forest stress is the ratio of standing dead to live trees. I term this ratio the "forest health quotient." The quotient averages 0.08 in Midwestern second-growth forests (Spetich and others 1999). For Arkansas forests, the quotient's mean value is 0.089 with a 95 percent confidence interval of ± 0.009 (Spetich and Guldin 1999). Forests with quotients above these values may indicate forest stress. Because small changes in the quotient are often not visually detectable on site, it may be useful as an early data-evident indicator of forest health issues, prompting further investigation when the quotient is determined to be high.

One year after measuring vegetation on permanent plots in the Boston Mountains of Arkansas, oak decline symptoms were evident (Spetich 2004). Although this meant the temporary loss of one replication of the original study, it provided a serendipitous and unprecedented opportunity to examine oak decline event dynamics using detailed early data to make comparisons.

My objective was to evaluate both visually evident and data-evident changes in physical tree characteristics 1 year after taking the first woody vegetation measurements. The study's 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 SITE

The study site is a 32-ha area in an upland oak-hickory stand that is approximately 73 years old. It is in the Boston Mountains of Arkansas, part of the southern lobe of the Central Hardwood Region (Merritt 1980). More specifically, it is in the northwestern corner of Pope County, approximately 3 km

[1] Research Forester, USDA Forest Service, Southern Research Station, Hot Springs, AR 71902.

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southeast of Sand Gap, AR. The stand is dominated by oak (*Quercus* spp.) and hickory (*Carya* spp.) and has become the center of a local patch of oak decline. In August 2000, 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 comprised standing dead trees. Stocking was 88 percent.

The Boston Mountains are the highest and most southern member of the Ozark Plateau Physiographic Province (Croneis 1930). 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 are alternating steep simple slopes and gently sloping benches. Vegetation across the landscape is a forest matrix with nonforest inclusions.

METHODS

The site was located in the fall of 1999. During the winter of 2000, twenty-four 55- by 55-m overstory plots (0.3025 ha) were established across the study area. In summer 2000, all trees > 14 cm diameter at breast height (d.b.h.) were measured to the nearest 0.1 cm at 1.37 m above ground level within each plot; each tree's azimuth and distances from plot center were recorded. Species, log grade, crown class, and multi-factor damage codes were also recorded for each tree using a Hewlett-Packard 200LX palmtop computer to record all data in the field.

In each of the twenty-four 55-m-square 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 d.b.h. were measured in July 2000. Diameter at breast height was recorded to the nearest 0.1 cm.

Further, within each of the 0.01-ha plots, five circular 0.000539-ha plots (1.31-m radius) were established to inventory regeneration. Within each regeneration plot, all trees < 5 cm d.b.h. were measured in spring of 2000.

Initially, all 24 plots were intended to be part of 1 replication of a large, periodic, prescribed fire study, but by the summer of 2001, oak decline symptoms were clearly evident at the site. At that point, this site was designated for a long-term case study of oak decline forest dynamics. In November and December of 2001, the overstory on a quarter of the 24 plots was remeasured (only 6 plots were remeasured due to time constraints). This site is now the center of a local patch of severe oak decline covering hundreds of hectares in northwestern Pope County, AR. The data were analyzed using a paired t-test to compare 2000 plot values with 2001 plot values.

RESULTS AND DISCUSSION

Visually Evident Results

In 2000, most standing dead trees (all species) were < 35 cm d.b.h. at 52 trees/ha, while standing dead trees ≥ 35 cm d.b.h. averaged only 1 tree per ha. The small-diameter dead trees were not visually evident in 2000 because they were lost in a sea of small trees. By 2001, the number of both small- and large-diameter standing dead trees had increased. The number of < 35 cm d.b.h. trees had increased from 52 trees/ha in 2000 to 70 trees/ha in 2001. The difference was statistically significant ($p = 0.049$). Although the mean value of large standing dead trees, those ≥ 35 cm d.b.h., had increased from 1 to 12 trees/ha from 2000 to 2001, the change was not statistically significant ($p = 0.064$).

Of all tree species, northern red oak (*Q. rubra* L.) had the largest increase in the number of standing dead, and in 2001 that mortality was the most visually evident at the study site (fig. 1). Although the number of standing dead black oak (*Q. velutina* Lam.) doubled, the increase was only from 2 to 4 trees/ha, thus was not visually evident in the study area. By comparison, the number of standing dead northern red oak more than doubled from 23 to 51 trees/ha (Spetich 2004). Standing dead trees ≥ 35 cm constituted no northern red oak in 2000 but 11 trees/ha in 2001, although that change was not statistically significant ($p = 0.061$). On the other hand, the change in standing dead northern red oak < 35 cm d.b.h. was statistically significant ($p = 0.037$), increasing from 22 trees/ha in 2000 to 40 trees/ha in 2001. Nonetheless, large northern red oak were the most visually evident standing dead trees in 2001.

Because virtually all visually evident characteristics involved northern red oak, the rest of this section will focus on that species.

The most visually evident change in physical tree characteristics in this stand was the increase of epicormic branching on standing live northern red oak. In 2000, epicormic branching was observed on only nine northern red oak trees/ha. By 2001, the number had increased to 55 trees/ha (fig. 2). This increase was statistically significant ($p = 0.009$). Most trees exhibiting epicormic branching were codominant. In 2000, 8 of the 9 trees with epicormic branching were codominant, while in 2001, 48 of the 55 trees with epicormic branching were codominant.

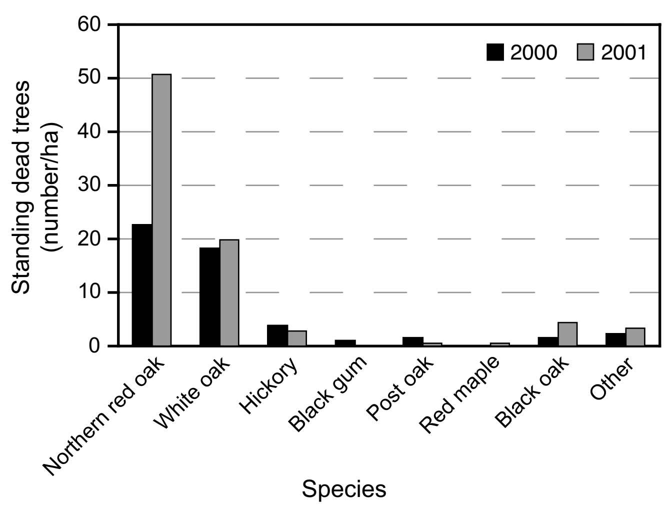

Figure 1—Number of standing dead trees/ha by species and year. "Other" includes black cherry (*Prunus serotina Ehrh.*), black walnut (*Juglans nigra* L.), elm (Ulmus spp.), black locust (*Robinia pseudoacacia* L.), serviceberry (*Amelanchier spp.*), sassafras (*Sassafras albidum Nutt.*), and white ash (*Fraxinus americana* L.).

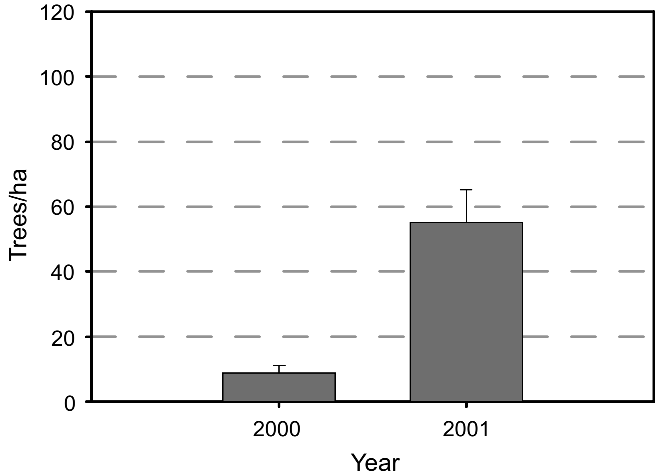

Figure 2—Number of trees/ha exhibiting epicormic branching in 2000 vs. 2001. Error bars represent one standard error.

Data-Evident Results

Dead-to-live ratio (forest health quotient)—In 2000, the mean ratio of standing dead to live trees for all species combined was 0.15, a value greater than we would typically expect. For that reason we examined the site for forest health problems the next growing season. By 2001, the ratio of dead to live trees had increased to 0.25. In upland hardwood forests of Arkansas, Spetich and Guldin (1999) found the typical ratio was 0.09. Earlier in 1999, Spetich and others found the mean ratio of dead to live trees in Midwestern second-growth upland hardwood forests to be 0.08. They suggested using the 0.08 ratio as a baseline indicator of forest health, which if exceeded should prompt further investigation.

Atypical infestation—One unique characteristic of this region-wide event is the preponderance of red oak borers (*Enaphalodes rufulus* Haldemann). The insect was noticeable at the study site by the end of the first-year inventory, and trees with evidence of oak borer were noted. In 2000, the number of trees/ha with oak borer evidence in the main bole below the tree crown was 33, but in 2001 there were 26 trees/ha. This decrease was not statistically significant ($p = 0.071$). In both years, the greatest number of trees/ha with oak borer evidence in this part of the bole was in the 30-cm or smaller diameter classes (fig. 3).

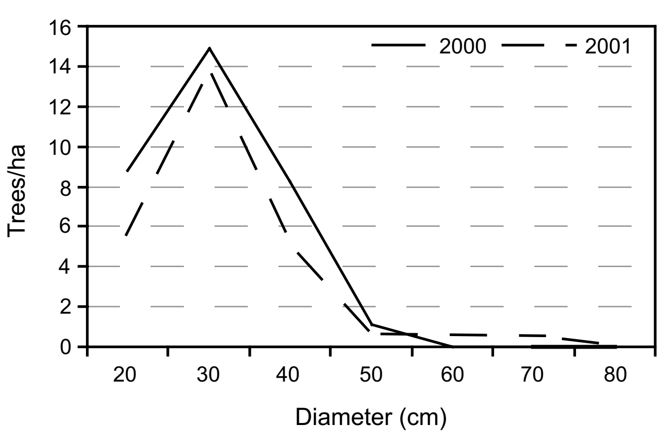

Figure 3—Number of northern red oak trees/ha by diameter class exhibiting oak borer damage in the main bole below the tree crown.

However, there was a significant increase in oak borer damage evident in the main stem portion within the crown area. In 2000, an average of only 2 trees/ha had oak borer damage in this portion of the main stem, but that number increased to 31 trees/ha in 2001. This increase was statistically significant at $p = 0.008$. It occurred in the 20- to 50-cm diameter class; no change was observed in the 60-cm diameter class (fig. 4).

Evidence of red oak borer damage on the main stem below the tree crown for trees ≤ 40 cm was likely an early indicator of small trees under additional competitive stress in the stand. However, these values included trees with scars from past oak borer damage; we did not discern between new and old damage, where old damage may have occurred up to 15 years earlier. The reduction in number of trees exhibiting damage was likely due to the number of small-diameter trees that died and fell to the ground prior to the second inventory. Small-diameter dead trees tend to fall sooner than large-diameter trees due to a more rapid loss of structural integrity.

Characteristics with Potential Utility for Early Detection

Of the characteristics examined here, the one with the potential for earliest detection of oak decline is the dead to live ratio that I term the "forest health quotient." The fact that the 2000 forest health quotient of 0.15 was much higher than usual (Spetich and Guldin 1999, Spetich and others 1999) and that it was determined prior to more visual evidence of oak decline is further evidence of the potential utility of the quotient. In forests with continuous forest inventory or other recent inventory data, this quotient can be quickly and easily calculated. Arkansas forests with quotients of > 0.09 and Midwestern forests with quotients of > 0.08 should prompt further investigation of potential forest health issues. The quotient also may be useful as a component of a more comprehensive, integrated forest health index.

Epicormic branching and standing dead trees were not extensive enough to be significant visual indicators until the second year. Oak borer damage was evident by the end of the first period of data collection. However, it was the epicormic branching and large dead trees that stood out visually during the second year.

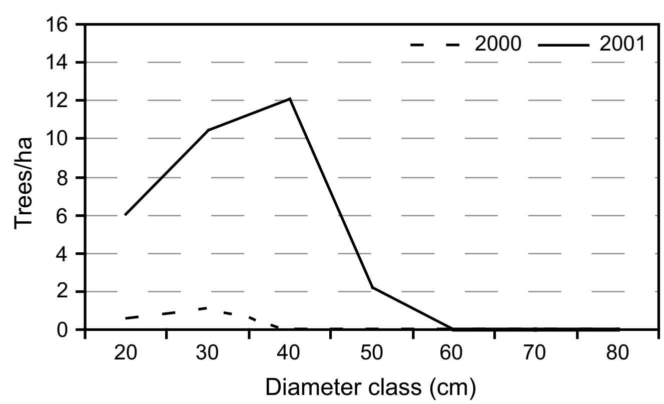

Figure 4—Number of northern red oak trees/ha by diameter class exhibiting oak borer damage in the main stem within the tree crown area.

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LITERATURE CITED

Bassett, E.N.; Fenn, P.; Mead, M.A. 1982. Drought-related oak mortality and incidence of hypoxylon canker. Arkansas Farm Research. 31: 8.

Croneis, C. 1930. Geology of the Arkansas Paleozoic area. Bulletin 3. [Place of publication unknown]: Arkansas Geological Survey. 457 p.

Law, J.R.; Gott, J.D. 1987. Oak mortality in the Missouri Ozarks. In: Hay, R.L.; Woods, F.W.; De Selm, H., eds. Proceedings of the sixth central hardwood forest conference. Knoxville, TN: University of Tennessee: 427-436.

Manion, P.D. 1991. Tree disease concepts. 2d ed. Englewood Cliffs, NJ: Prentice-Hall. 402 p.

Merritt, C. 1980. The central region. In: Barrett, J.W., ed. Regional silviculture of the United States. 2d ed. New York: John Wiley: 107-143.

Millers, I.; Shriner, D.S.; Rizzo D. 1989. History of hardwood decline in the eastern United States. Gen. Tech. Rep. NE-126. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 79 p.

Mistretta, P.A.; Anderson, R.L.; Lewis, R.; MacDonald, W.L. 1984. Annotated bibliography of oak wilt 1943-1980. Gen. Tech. Rep. WO-45. Washington, DC: U.S. Department of Agriculture, Forest Service. 132 p.

Oak, S.W.; Starkey, D.A.; Dabney, J.M. 1988. Oak decline alters habitat in southern upland forests. In: Proceedings of the annual conference of the southeast association of fish and wildlife agencies. [Place of publication unknown]: Southeast Association of Fish and Wildlife Agencies. 42: 491-501.

Oak, S.W.; Steinman, J.; Starkey, D.A.; Yockey, E.K. 2004. Assessing oak decline incidence, distribution, and severity in the southeastern U.S. using forest inventory and analysis data. In: Spetich, M.A., ed. Proceedings of the 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: 236-242.

Spetich, M.A. 2004. Forest dynamics at the epicenter of an oak decline event in the Boston Mountains, Arkansas, year one. In: Yaussy, D.A.; Hix, D.M.; Long, R.P.; Goebel, P.C., eds. Proceedings of the 14th central hardwood forest conference. Gen. Tech. Rep. NE-316. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station: 21-26.

Spetich, M.A.; Guldin, J.M. 1999. The spatial distribution of dead trees across Arkansas timberlands. In: Haywood, J.D., ed. Proceedings of the 10th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-30. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 53-56.

Spetich, M.A.; Shifley, S.R.; Parker, G.R. 1999. Regional distribution and dynamics of coarse woody debris in Midwestern old-growth forests. Forest Science. 45(2): 302-313.

Starkey, D.A.; Oak, S.W.; Ryan, G.W. [and others]. 1989. Evaluation of oak decline areas in the South. Protection Rep. R8-PR 17. Atlanta, GA: U.S. Department of Agriculture, Forest Service, Southern Region. 37 p.

Starkey, D.A.; Oliveria, F.; Mangini, A.; Mielke, M. 2004. Oak decline and red oak borer in the interior highlands of Arkansas and Missouri: natural phenomena, severe occurrences. In: Spetich, M.A., ed. Proceedings of the 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: 217-222.

Tainter, F.H.; Fraedrich, S.W.; Benson, D.M. 1984. The effect of climate on growth, decline, and death of northern red oaks in the western North Carolina Nantahala Mountains. Castanea. 49(3): 127-137.

Toole, E.R. 1960. Rootrot of white oak in Arkansas. Plant Disease Reporter. 44: 783.

Wargo, P.M.; Houston, D.R.; LaMadeleine, L.A. 1983. Oak decline. Forest Insect and Disease Leaflet 165. Washington, DC: U.S. Department of Agriculture, Forest Service. 8 p.