DOWN DEADWOOD DYNAMICS ON A SEVERELY IMPACTED OAK DECLINE SITE

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Abstract—Following a 3-year drought from 1998 to 2000, oak decline symptoms began to appear throughout many parts of the Ozark Highland region of Arkansas and Missouri. Changes in down deadwood that occurred at one site during the oak decline event are described and discussed. In 2000, 24 deadwood measurement plots 0.2025 ha (45 m by 45 m) in size were established. The down deadwood on all plots was remeasured in the spring of 2005. Because 6 plots were burned in March of 2004, changes on only 18 of the 24 plots are considered. In each inventory, all down dead woody material with a diameter of 10 cm or greater was measured on each plot. Changes in volume occurred across the site. Overall, median total volume increased from 15.8 m^3/ha to 22.9 m^3/ha ($p = 0.016$). Down woody material was further divided into decomposition classes 1 through 5, where class 1 represents the least decomposed and class 5 represents the most decomposed material. Decomposition class 1 increased from a median of 0 m^3/ha in 2000 to 0.13 m^3/ha in 2005 ($p = < 0.001$). Class 2 increased from a mean of 2.1 m^3/ha in 2000 to 4.7 m^3/ha in 2005 ($p = 0.013$). There were no significant changes in down deadwood volume for decomposition classes 3, 4, or 5. The number of pieces of down deadwood also increased from a mean of 184 pieces per ha in 2000 to 245 pieces per ha in 2005 ($p = 0.003$). Results show an increase in down deadwood input. However, at this stage increases are generally in the smallest, least decomposed material on this dry and rocky site. The diameters of down deadwood pieces are small because inputs are mostly from branches and small trees. Most large trees that died have remained standing.

INTRODUCTION

Large-scale oak mortality events have likely occurred for as long as there have been oak-dominated forests. Fifty-seven oak mortality events have been recorded in the eastern United States between 1856 and 1986 (Millers and others 1989). These include 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 mortality that occurred 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 U.S., 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 tree physiologic age and 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, an inciting factor of oak decline according to Manion (1991) and Starkey and others (2004), occurred across the Interior Highlands region of Arkansas and Missouri from 1998 to 2000. This, coupled with the fact that it occurred in a forest with high tree density and mature trees, made Arkansas' upland hardwood forests especially vulnerable to oak decline (Oak and others 2004).

An oak decline event of this magnitude has the potential to significantly alter forest structure. One important consequence of such an event is its effect on the amount and quality of coarse woody debris. Living trees complete only a portion of their ecological role by the time they die (Franklin and others 1987). Coarse woody debris from dead and dying trees provides important habitat for forest organisms

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(Cain 1996, Larson 1992, Maser and others 1988, Meyer 1986, Muller and Yan Liu 1991, O'Neill 1967, Thomas and others 1979, Van Lear 1993), provides both habitat and energy for detritivores (Lang and Forman 1978), and serves as a reservoir for nutrients and carbon (Bray and Gorham 1964, Harmon and others 1986, Edmonds 1987, Huston 1996, Lang and Forman 1978, Maser and others 1988).

The amount of living biomass in a dead log may be greater than that in a live tree (Franklin and others 1987). Meyer (1986) lists snags and down wood in Missouri as habitat for 26 bird species, 11 reptiles, 11 mammals, and 9 amphibians. In the Blue Mountains of Oregon and Washington, 39 bird and 23 mammal species use standing dead trees for nest sites and shelter (Thomas and others 1979). At least 98 species of land snails are associated with log habitats in the southeast (Caldwell 1996). In southern hardwood and pine forests, 45 bird species use standing dead trees and 20 bird species that use down woody debris (Lanham and Guynn 1996). In the southeast, at least 23 mammal species use standing dead trees and at least 55 mammal species use down wood (Loeb 1996). Ausmus (1977) found greater organic matter content, nematode density, and root biomass in soil beneath log litter than under leaf litter. Reptiles and amphibians are associated with coarse woody debris, and it has been suggested that their diversity may be linked with the quality and amount of coarse woody debris (Whiles and Grubaugh 1996). Earthworms use deadwood for cover and as a source of food from microbial biomass (Hendrix 1996). Additionally, a study by Barnum and others (1992) found that mice selected logs as the most widely used substrate for travel. However, little is known about inputs of deadwood during a severe oak decline event.

Initially, all 24 plots in this study were intended to be part of one replication of a large, periodic, prescribed fire study. However, by the summer of 2001 oak decline symptoms were evident at the site (Spetich 2004), and the site became the center of a local patch of severe oak decline covering hundreds of hectares in northwestern Pope County, AR. At that point, this site was designated for a long-term case study of oak decline forest dynamics. Although this meant the temporary loss of one replication of the original study, it provided a serendipitous opportunity to examine oak decline dynamics using detailed early data.

The objective of this phase of the study was to examine the dynamics of down deadwood from 2000 to 2005. 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 (*Quercus-Carya* spp.) stand that was approximately 75 years old in 2005. It is located in the Boston Mountains of Arkansas, part of the southern lobe of the Central Hardwood Region (Merritt 1980). 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 non-forest inclusions.

More specifically, the study site is located in the northwestern corner of Pope County, approximately 3 km southeast of Sand Gap, Arkansas. The stand is dominated by oak and hickory and has become the center of a local patch of oak decline. In August 2000, mean 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. Stocking was 88 percent.

METHODS

The study site was located in the fall of 1999. Twenty-four deadwood measurement plots were established with permanent plot markers during the winter of 2000. Each plot was 45 m by 45 m in size (0.2025-ha).

Down deadwood in the plots was measured in September of 2000 and remeasured in the spring of 2005. Because 6 plots were burned in March of 2004, changes on only 18 of the 24 plots are considered here. Electronic data recorders were used to record measurement data in the field.

In each of the 24 plots, all dead and down coarse woody debris ≥10 cm in diameter was measured (fig. 1). Each section was measured for length and midpoint diameter. Decomposition class of each section (hereafter referred to as a piece) was also recorded and classified into one of five decomposition classes (table 1). The length and midpoint diameter of each piece of down wood ≥10 cm in diameter within each plot were measured to the nearest 0.1 m and 1.0 cm, respectively. The formula for the volume of a cylinder was used to calculate the volume of each piece from the piece's measured length and midpoint diameter.

The data were analyzed using paired t-tests to compare 2000 plot values with 2005 plot values. In cases where the normality test failed, a Wilcoxon signed rank test was performed to compare median values.

RESULTS AND DISCUSSION

Total volume of down deadwood increased from a median value of 15.8 m^3/ha in 2000 to 22.9 m^3/ha in 2005 ($p=0.016$). However, only two of the decomposition classes showed statistically different volumes in 2000 and 2005. Decomposition class 1 increased from a median of 0 m^3/ha in 2000 to 0.13 m^3/ha in 2005 ($p=<0.001$). Class 2 more than doubled from a mean of 2.1 m^3/ha in 2000 to 4.7 m^3/ha in 2005 ($p=0.013$). There were no statistically significant changes in down deadwood decomposition classes 3, 4, or 5. However, mean values of both class 3 and 4 appeared to increase (fig. 2).

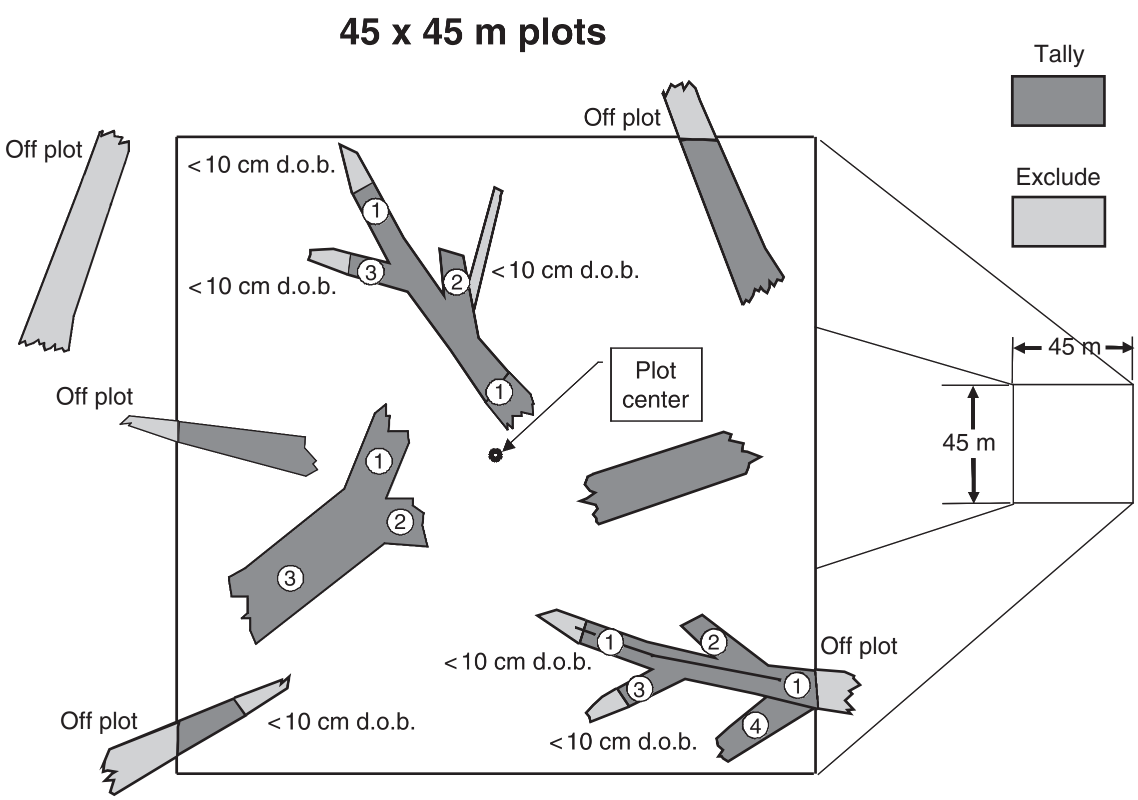

Figure 1—Layout of 0.02025 ha down deadwood measurement plot. Numbers indicate a section measured as one piece. All deadwood pieces ≥10 cm in diameter were measured for total length and midpoint diameter.

Table 1—Decomposition classes for down deadwood

Attribute	Decomposition class 1	2	3	4	5
Bark	Intact	Intact	Trace to absent	Absent	Absent
Twigs > 3 cm	Present	Absent	Absent	Absent	Absent
Texture	Intact	Intact, sapwood partly soft	Hard, solid interior, possible evidence of exterior decay	Soft, blocky pieces	Soft and powdery
Shape	Round	Round	Round	Round to oval	Oval
Color of wood	Original	Original	Original to faded	Original to faded	Heavily faded
Portion of log on ground	Log elevated on support points	Log elevated on support points	Log near or on ground	All of log on ground	All of log on ground

Numbers 1 through 5 indicate codes used for decomposition classes where class 1 is least decomposed and class 5 is most decomposed.
Adapted from Cline and others (1980) and Maser and others (1979).

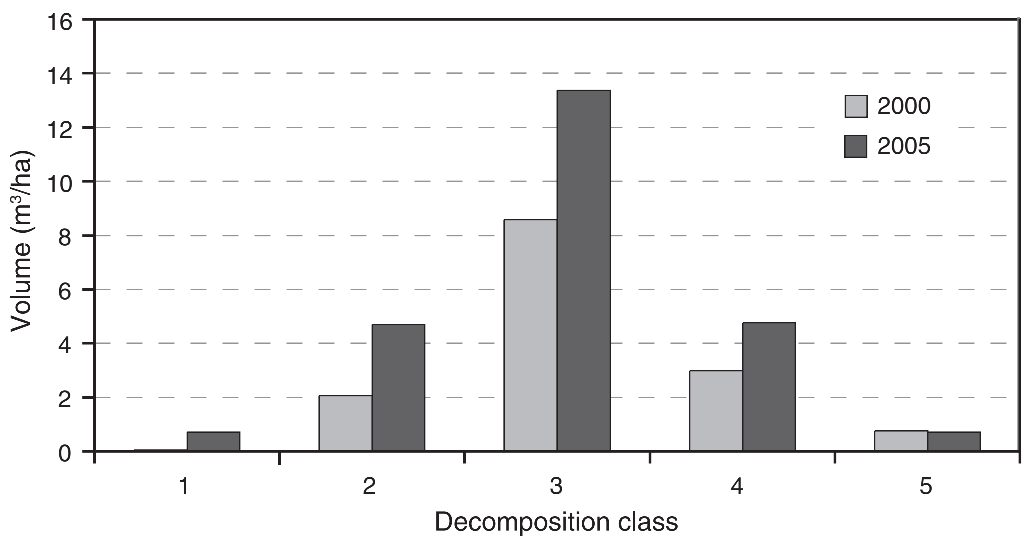

Figure 2—Mean volume of down deadwood by decomposition class (see table 1) and year for the down deadwood study in the Boston Mountains in Arkansas, n = 18.

Decomposition class 3 constituted the greatest proportion of down deadwood in both years. This is consistent with findings of other studies (Spetich and others 1999). One identifying characteristic of decomposition class 3 deadwood is lack of bark. Bark is often shed while the tree is standing or soon after the tree falls. Both Van Lear (1993) and Harmon and others (1986) suggest that when down wood loses bark early it dries quickly and may become case hardened, slowing the decay process. Additionally, fissures and excavations that develop in decomposition class 4 and 5 materials increase the total surface area and accelerate the rate of decay (Maser and others 1988).

In comparison, the average down deadwood volume for second-growth Central Hardwood forests is 20 m^3/ha (Spetich and others 1999). The mean values at the Arkansas site are below this value in 2000 and above it in 2005. As standing dead trees continue to fall, they will continue to add to down deadwood volume. Decomposition of these large woody materials progresses slowly. For example, MacMillian (1981) estimates that the average oak log takes 75 years to decay to 1/10 of initial density (density in grams dry weight per cubic cm fresh volume). Inputs of the relatively large stems of standing dead trees (up to 84 cm) at this oak decline site will likely provide nutrients, structure, and wildlife habitat for many years.

The number of pieces of down deadwood increased from a mean of 184 pieces per ha in 2000 to 245 pieces per ha in 2005 ($p=0.003$). In both years the majority of pieces were in the smallest diameter classes, decreasing in number exponentially with increasing diameter (fig. 3). The negative exponential distribution of the number of pieces of down deadwood by diameter class is likely linked to a negative exponential diameter distribution of live trees. In 2005 the largest increase in the number of pieces per ha was in the smallest diameter class. Small-diameter wood is likely to lose its structural integrity sooner than are large pieces.

The volume of down deadwood per ha also decreased with increasing diameter, but not as quickly as did number of pieces per ha (fig. 4). In 2005 the largest increase was in the smallest diameter class. However, there was also a small increase in two larger diameter classes, 55 cm and 65 cm, due to a few fallen trees. The diameters of down deadwood pieces are generally small because inputs are mostly fallen branches

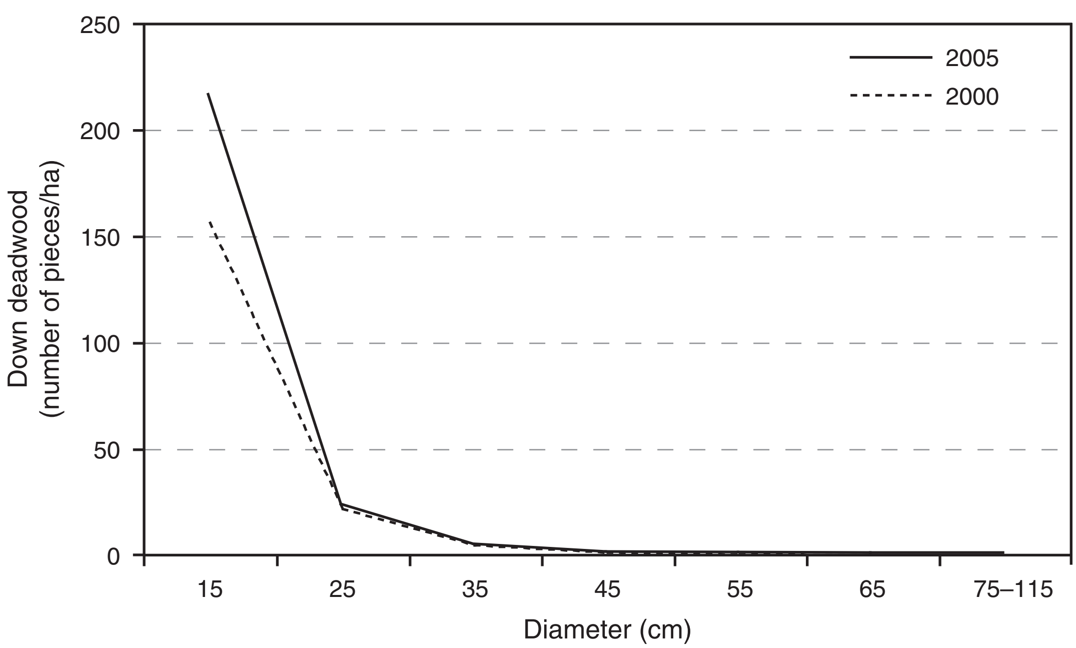

Figure 3—Number of down deadwood pieces per ha by 10-cm diameter class and year for the down deadwood study in the Boston Mountains in Arkansas, n=18.

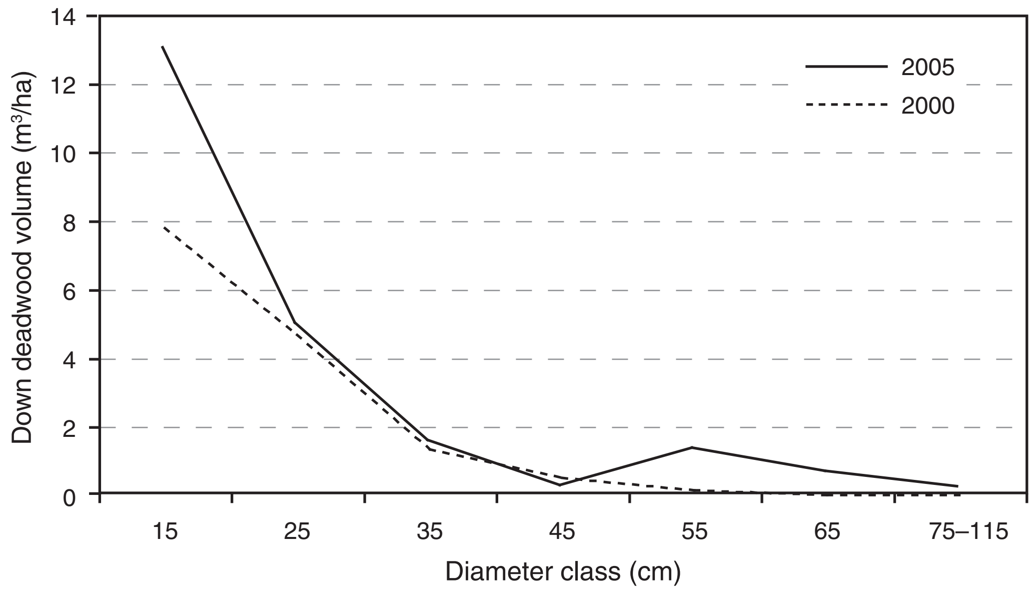

Figure 4—Down deadwood volume by 10-cm diameter class and year for the down deadwood study in the Boston Mountains in Arkansas, n = 18.

and fallen main stems of small trees. Although the 2005 overstory inventory was not completed by the time this paper was written, visual observations indicate that main stems of most large trees that died over the last 5 years remained standing.

Results show an increase in down deadwood input. However, at this stage increases are generally in the smallest, least decomposed material on this dry and rocky site. As main stems of the large dead standing trees fall they will continue to add to down deadwood for many years, likely changing the structure and dynamics of the down deadwood pool.

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