FORTY-TWO YEARS OF CHANGE IN AN OLD-GROWTH AND SECOND-GROWTH BEECH-MAPLE FOREST OF NORTH CENTRAL OHIO

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Abstract.—Using data collected in 1964 and 2006, we examined changes in the composition and structure of a second-growth and old-growth beech-maple forest of Crall Woods, located in Ashland County of north central Ohio. Over the 42 years, the old-growth forest (estimated to be at least 250 years old) experienced a significant shift in species composition as American beech, yellow-poplar, and red maple increased in importance while American basswood, sugar maple, and shagbark hickory all declined in importance. Similar changes were observed in the second-growth stand, except that the increases in importance were associated with shade-intolerant (e.g., yellow-poplar) and shade mid-tolerant (e.g., northern red oak) species. Despite the shifts in composition, stand structure remained fairly consistent over the 42 years and was similar between the second-growth and old-growth stand. We suggest that the old-growth stand will continue to have both shade-tolerant and intolerant species over time and that the composition of the second-growth stand will shift toward the more shade-tolerant species. These species will dominate the forest understory as they replace shade-intolerant and mid-tolerant overstory individuals that die.

INTRODUCTION

Of the original 140 million hectares of forests that once dominated the Central Hardwood Region, only 0.07 percent (100,000 hectares) remains as old-growth (Parker 1989). Since old-growth stands are often the least disturbed portions of current landscapes, they are often used as a baseline, or reference system, to plan and evaluate forest restoration projects (Stephenson 1999, Moore and others 1999, Goebel and others 2005). Additionally, a better understanding of how mature forest ecosystems change over time will help us understand and predict how disturbances will influence forests in the future (Goebel and others 2005), which ultimately will lead to better management techniques for younger, second-growth forests (Barnes 1989, Parker 1989, Acker and others 1998, Martin and Bailey 1999). However, to develop more ecologically-based management systems that emulate the outcomes of natural disturbance (i.e., ecological forestry as defined by Mitchell and others 2006), more information on the natural successional pathways is needed, particularly if we wish to understand how these natural shifts in composition and structure occur over time or wish to guide the successional pathways of younger stands.

A large portion of the Central Hardwood forest in Ohio is within the till plains, a physiographic region with low relief and minor changes in elevation (Braun 1956, McNab and Avers 1994, Dolan and Parker 2005). Across this region, beech-maple (Fagus-Acer) forests are characterized by species including American beech (Fagus grandifolia Ehrh.) and sugar maple (Acer saccharum Marsh.), and to lesser degree white ash (Fraxinus americana L.) and yellow-poplar (Liriodendron tulipifera L.). These beech-maple forests also historically occupied till plains in surrounding states, such as Indiana, Pennsylvania, and Michigan, as

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well as in Canada (Braun 1956). Although fire may have historically played a role in shaping these forests, in recent decades disturbances to these beech-maple forests have been primarily limited to canopy gaps caused by the death of one or a few trees. The rate at which canopy gaps are formed in eastern mesic forests averages 1 percent yr$^{-1}$, resulting in a natural stand turnover time of approximately 100 years (Runkle 1982). Unfortunately, very few old-growth beech-maple forests remain; those stands that do exist were preserved mainly because the land on which they are situated was unsuitable for agriculture (Braun 1956, Parker 1989).

Although many studies have examined how old-growth forests in the Central Hardwood Region change over time, most of these have examined the current composition and structure of old-growth mixed-oak ($Quercus$) forests, mixed-mesophytic forests, or mixed coniferous and hardwood stands (e.g., Whitney 1984, Martin and Bailey 1999, McCarthy and others 2000, Galbraith and Martin 2005). Studies conducted in old-growth beech-maple forests in the region are less numerous, but have included examining the environmental factors that define beech-maple forests (Whitney 1982), the changes in seedling composition in gaps over time (Kupfer and Runkle 1996), short-term changes in overstory and understory composition (Foré et al. 1997), gap dynamics and their subsequent effects on the herb layer (Moore and Vankat 1986), mortality and replacement patterns of the overstory (Forrester and Runkle 2000) and of the understory (Boerner and Brinkman 1996), and present stand composition and structure (Cain 1935, Pell and Mack 1977). However, few studies have actually examined the changes in composition and structure in the overstory and/or understory of old-growth beech-maple stands of the Central Hardwood Region (Abrell and Jackson 1977, Foré and others 1997, Forrester and Runkle 2000).

One study of an old-growth, beech-maple forest in the Central Hardwood Region that is often overlooked was conducted in 1964 by John Aughanbaugh, a silviculturist with the Ohio Agricultural Experiment Station (Aughanbaugh 1964). In this report, Aughanbaugh described the composition and structure of an old-growth and an adjacent second-growth beech-maple stand at Crall Woods. The objective of our study was to resample these stands at Crall Woods, and examine the changes in composition and structure over a period of 42 years. Specifically, we wished to determine: 1) if the composition and structure of the old-growth stand was relatively stable, and 2) if there has been a shift in composition and structure in the second-growth stand so that it more closely resembles the old-growth stand at Crall Woods.

**STUDY AREA**

Crall Woods is a 37.4-ha tract located in north central Ohio in Ashland County. In 1974, the National Park Service registered Crall Woods as a National Natural Landmark, one of only 587 registered sites in the United States and one of only 23 sites in Ohio. Crall Woods is located within the central till plains physiographic region (Dolan and Parker 2005), in the beech-maple forest region as determined by Braun (1956). The area is characterized by gently rolling topography, and ranges from 200 to 300 m in elevation (McNab and Avers 1994). The predominant soil series of the area is Bennington silt loam, which is a poorly drained Alfisol originating from glacial till (Aughanbaugh 1964). Precipitation averages 900 to 1,030 mm a year and annual temperatures range from 10 to 13 °C (McNab and Avers 1994).

There are four distinct forest stands at Crall Woods: a 17.8-ha eastern red cedar ($Juniperus virginiana$ L.) stand along the southernmost point of the forest; a 20.2-ha young mixed-hardwood stand at the northern end of the forest; a 4.0-ha mature second-growth stand south of the young mixed hardwood stand dominated by oaks and maples; and a 16.18-ha old-growth beech-maple stand. Recent human influence on the old-growth stand appears to have been minimal as no cut stumps were found. Also, there is little
indication of livestock grazing as evidenced by the remnants of an old fence separating the old-growth stand from other areas of Crall Woods and by the diverse spring and summer ground-flora.

Our study focused on both the mature second-growth and the old-growth stand. Increment cores show that the second-growth stand is between 130 and 140 years old and the old-growth stand is 200-250 years old. We speculate that the old-growth and second-growth stands most likely originated in the 1700s after some form of major stand-replacing disturbance. About 100 years later, around the time of European settlement, the second-growth stand was most likely harvested. For the past 140 years, both stands appear to have been allowed to develop with minimal human interference. During sampling, Crall Woods appeared to be unusually wet compared to the surrounding landscape, implying it was probably not as suitable for agriculture. Subsequent to 1981, a tornado damaged part of the old-growth stand, although it is unclear which part (Davis 1993). Presently, however, the most likely types of disturbance affecting both the second-growth and old-growth stands are canopy disturbances caused by natural tree mortality, and blowdowns caused by the wind.

**METHODS**

**Data Collection**

In 1964, John Aughanbaugh conducted a complete inventory of Crall Woods (Aughanbaugh 1964). He inventoried all stems >30 cm in the old-growth stand and all stems >5 cm in the second-growth stand. Measurements included the diameter at breast height (d.b.h) and species for each stem, as well as the volume of standing timber by species.

In 2006, we randomly established nine 2500-m² plots in Crall Woods with seven plots in the old-growth stand and two plots in the mature second-growth stand. We recorded species and d.b.h. of all trees >10 cm d.b.h. For comparisons of stand conditions between 1964 and 2006, we included only the range of tree diameters measured on both occasions: trees >30 cm for the old growth stand and trees >10 cm for the second-growth stand.

**Data Analysis**

Relative densities and relative basal areas for all species were calculated for both the old-growth and second-growth stands in 1964 and in 2006. Additionally, we calculated an importance value (calculated as the sum of relative basal area and relative density divided by 2) for each species. Basal area calculations for the 1964 data were limited as Aughanbaugh (1964) provided only abundance of individuals by species in each 5-cm d.b.h. class (>30.0 cm in old-growth stand and >5.0 cm in second-growth stand). Therefore, basal areas were estimated by d.b.h. class for these data using the midpoint of each d.b.h. class.

**RESULTS**

**Changes in the Old-Growth Stand**

In 1964, the old-growth stand was dominated by sugar maple, American basswood (*Tilia Americana* L.), American beech, shagbark hickory (*Carya ovata* (P. Mill.) K. Koch), American elm (*Ulmus americana* L.), and white ash, while in 2006 the stand was dominated by sugar maple, American beech, yellow-poplar, and American basswood (Table 1). In terms of importance values, the most significant changes included a 20.3 percent and 8.6 percent increase in American beech and yellow-poplar, respectively. Decreases in importance included an 8.9 percent, 8.8 percent, 6.3 percent, and 4.4 percent decline in American basswood, sugar maple, shagbark hickory, and American elm, respectively (Fig. 1).
Although significant shifts in species composition were detected over the 42-year period, few changes were observed in stand structure. Stem density (stems·ha$^{-1}$) remained consistent at 123 stems·ha$^{-1}$. Basal area values increased slightly from 25.1 m$^2$·ha$^{-1}$ in 1964 to 27.9 ± 2.99 m$^2$·ha$^{-1}$ in 2006.

**Changes in the Second-Growth Stand**

Species composition, as indicated by species importance values, remained more consistent in the second-growth stand over the 42 years compared with the old-growth stand. In 1964, the second-growth stand was dominated by six species: American basswood, northern red oak ($Q. rubra$), white ash, American beech, shagbark hickory, and sugar maple. In 2006, the stand was dominated by the same species with a reduction in shagbark hickory and an increase in American beech (Table 1). There were major shifts in importance values: an 8.6 percent increase for sugar maple, a 7.1 percent increase for northern red oak (Fig. 1), a 6.6 percent increase for white ash, and a 4.0 percent increase for red maple. There was a 9.1 percent decrease for American basswood and a 4.6 percent decrease for shagbark hickory.

In terms of stand structure, stem densities decreased sharply from 685 stems·ha$^{-1}$ in 1964 to 394.0 stems·ha$^{-1}$ in 2006. Total basal area over the 42 year period in the second-growth stand increased slightly from 41.2 m$^2$·ha$^{-1}$ to 43.0 ± 3.48 m$^2$·ha$^{-1}$, values that are higher than those observed in the old-growth stand.

**DISCUSSION**

In forest ecosystems lacking frequent, large-scale disturbances, changes in species composition and structure are caused mainly by competition among individual trees for space and resources (Oliver and Larson 1996). By determining the changes in composition and structure that are experienced, we can draw a more detailed picture of forest succession that is specific to forest type. We can identify the successional pathways of old-growth forests as well as those of forests that have disturbed more recently.
During the 42-year period at Crall Woods, we observed minimal changes in the overall species composition of the old-growth stand. The two most important species (sugar maple and American beech) remained dominant over the 42-year period. Some shade mid-tolerants also increased in importance. The magnitude of change is typical of changes that occur in old-growth forests (Oliver and Larson 1996), with both shade-tolerant species and shade-intolerant species increasing in abundance in small gaps and later successional species (shade tolerants in closed canopy forests) remaining dominant in the overstory and understory.

These shifts in species composition vary in their consistency compared with other studies examining the

Figure 1.—Percent change in importance value, relative density, and relative basal area for selected species from 1964-2006 in the old-growth stand (A) and second-growth stand (B) at Crall Woods, Ashland County, Ohio.
changes in beech-maple, old-growth forest species composition over time. For instance, an old-growth beech-maple forest at the Holden Arboretum in northeastern Ohio experienced a 1.2 percent increase in the importance value of sugar maple and a 0.9 percent decrease in the importance of American beech over a period of 5 to 6 years (Forrester and Runkle 2000). Hueston Woods, an old-growth beech-maple forest in southwestern Ohio, also experienced minimal changes over a 7-year period (Foré and others 1997). The importance of sugar maple did not change and there was only a slight reduction (1.9 percent) in the importance of American beech. The importance of other species remained relatively constant (<1 percent changes) whereas the old-growth stand at Crall Woods experienced larger shifts in species composition over time. However, this difference may be related to the longer length of time between sample periods (i.e., 7 years versus 42 years).

There are examples of significant shifts in species composition in old-growth beech-maple forests. In Indiana, an old-growth beech-maple forest experienced a 10 percent increase in importance value of sugar maple and a 7.2 percent reduction in importance value of American beech over a 10-year period (Abrell and Jackson 1977), which are different from our results (i.e., we experienced a decrease in sugar maple and an increase in American beech). The stand also experienced an increase of 4.3 percent in the importance value of yellow-poplar, which is consistent with our findings. Abrell and Jackson (1977) report minimal changes in stand structure despite these shifts in species composition. Runkle (2000) conducted studies on compositional changes in old-growth stands in Ohio, Pennsylvania, Tennessee, and North Carolina. He also summarized changes in several old-growth stands in the region and found that American beech decreased in importance over most of its geographic range and that sugar maple increased. Runkle also found that, similar to our study, minimal changes in stand density and basal area in the old-growth stands occurred.

In the second-growth stand, over the last 42 years, the continued importance of both northern red oak and yellow-poplar, which are considered intolerant to mid-tolerant of shade (Burns and Honkala 1990), are most likely a result of the longevity of the species. We would not expect them to be able to maintain this strong presence as the mature individuals die and those regenerating are mostly outcompeted by more shade-tolerant species, such as sugar maple and American beech. The second-growth stand is still in the understory reinitiation stage (sensu Oliver and Larson 1996), in which understory individuals are ascending into the canopy and shade-tolerant individuals have not yet begun to dominate the overstory. The course of change in the second-growth stand, from shade intolerants and mid-tolerants to shade tolerant, has been documented in other studies in the Central Hardwood Region (Piussi 1966, Whitney 1984, Dodge 1997, Galbraith and Martin 2005). As the second-growth stand develops over time, we expect that it will more closely resemble the old-growth stand in terms of species composition, with an increase in importance of both sugar maple and American beech. However, we would anticipate that the structure of the stands will remain much the same as other studies have shown few differences in stem density and basal area between adjacent old-growth and second-growth stands of the same type (Angers and others 2005, Foré and others 1997, Forrester and Runkle 2000).

This study has shown that in the Central Hardwood Region, when younger stands containing shade-intolerant species are left unmanaged, their composition will shift, over time, to a species composition of more shade-tolerant individuals (in the absence of fire and other large disturbances). As a result, active management of these stands (e.g., thinning, herbicide treatment, and prescribed burning) is required if mid-tolerant or intolerant species composition is desired. Additionally, this study has provided one example of the time required for a recently cleared stand that is subsequently not managed, to attain the characteristics of an old-growth stand, in this case, about 150 years.
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LITERATURE CITED


