SPECIES COMPOSITION OF DEVELOPING CENTRAL APPALACHIAN HARDWOOD STANDS FOLLOWING CLEARCUTTING

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Abstract--This study examined the species composition of 47 paired stands on submesic sites on the Appalachian Plateau of West Virginia. Paired stands consisted of a mature stand adjacent to a young clearcut that was < 20 years old. The species composition in the mature stands was compared to that of the upper canopy (dominant and codominant) in the clearcuts. The objective of this comparison was to determine if there was evidence of potentially lasting shifts in species composition resulting from clearcutting. This objective was addressed through three research questions related to common regeneration concerns in the region: (1) is there evidence of a shift towards more mesophytic species? (2) Is there evidence of an increase in red maple (*Acer rubrum* L.); and (3) is there evidence of a decrease in oak (*Quercus* spp.)? There were significant differences in species composition between the clearcuts and mature stands. These differences were largely due to increases in fast-growing, shade-intolerant pioneer species {e.g., black locust (*Robinia pseudoacacia* L.), pin cherry (*Prunus pensylvanica* L.), sassafras [*Sassafras albidum* (Nutt.) Nees], etc.}, black cherry (*Prunus serotina* Ehrh.), and yellow-poplar (*Liriodendron tulipifera* L.). Significant differences were not found for mesophytic species, red maple, or oaks. The results of this comparison suggest that future species composition of the young clearcuts may differ only slightly from previous rotations.

INTRODUCTION

Appalachian forests are among the most diverse in the United States. Intricate geologic, climatic, and anthropogenic influences have created mixed stands of species with vastly different characteristics (Braun 1950, Fenneman 1938, Yarnell 1998). More than 50 tree species may be present in these stands, and over 20 of these may be commercial (Miller and Kochenderfer 1998, Smith 1995). In many cases, the current incarnation of these forests originated early in the 20th century, following repeated, landscape-level exploitive disturbance (Yarnell 1998). As a result, vast acreages throughout the Appalachians have reached or are approaching typical rotation ages (Oswalt and Turner 2009). This makes regeneration an important and relevant topic for foresters in the Appalachians.

The diversity and complexity of Appalachian forests create potential for many silvicultural systems to be adopted to regenerate these maturing forests depending on management objectives. However, it also presents challenges for foresters interested in regenerating oak-dominated (*Quercus spp.*) forests back to a similar state (Loftis and McGee 1993). Due to changing disturbance regimes, forest managers and researchers have been concerned about the potential for drastic shifts in species composition from existing conditions following regeneration harvests. It is believed that the absence of late-rotation disturbance, particularly fire, leads to the mesophication of productive sites (Abrams 1992, Nowacki and Abrams 2008). This trend could favor a mixed-mesophytic species composition over the currently oak-dominated forests in parts of the Appalachians.

Increasingly, shifts in species composition of oak-dominated stands towards more mesophytic species and red maple (*Acer rubrum* L.) are being reported and predicted across the Appalachian landscape, particularly on productive sites (Abrams and Downs 1990, Fei and Steiner 2007, Schuler 2004, Schuler and Gillespie 2000). Such shifts could have far reaching consequences for timber markets and ecosystem services and should be considered prior to prescribing regeneration techniques on mature forests throughout the region (Duffy and Meier 1992, Homyack and Haas 2009, McShea and others 2007, Miller and Kochenderfer 1998).

Many acres of public land were regenerated using the clearcut method in the late 20th century, but public scrutiny eventually lead to its decline on public lands. Nonetheless, clearcutting remains a widely practiced regeneration technique on managed private forests. The existing literature on the effects of clearcutting on species composition in hardwood forests is considerable. Clearcutting in central hardwoods can often regenerate fully stocked stands of commercial species (Roach and Gingrich 1968, Sander and Clark 1971). The resulting composition is typically dominated initially by early successional species such as yellow-poplar (*Liriodendron tulipifera* L.), black locust (*Robinia pseudoacacia* L.), sweet birch

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(*Betula lenta* L.), and black cherry (*Prunus serotina* Ehrh.) (Hilt 1985a, McGee and Hooper 1975, Trimble 1973,). Red maple is also typically competitive following clearcutting in the Appalachians (Tift and Fajvan 1999). The potential for inadequate regeneration of oak following clearcutting, particularly on highly productive sites, has been the focus of extensive research throughout the Appalachians in the central hardwood region (Loftis and McGee 1993).

Many of the aforementioned studies on clearcutting were conducted on stands that were likely exposed to a disturbance regime that no longer occurs (Abrams 1992). The objective of this study was to determine if there was evidence of potentially lasting shifts in species composition resulting from clearcutting Central Appalachian stands under the modern landscape disturbance regime. Three research questions were adopted to address that objective: (1) is there evidence of a shift towards more mesophytic species? (2) Is there evidence of an increase in red maple (*Acer rubrum* L.); and (3) is there evidence of a decrease in oak (*Quercus* spp.)?

METHODS

A paired stand approach was used to address the research questions of this study. Paired stands consisted of a mature stand (≥ 70 years old) in the understory re-initiation stage located adjacent to a young clearcut of similar site characteristics that had reached crown closure but was still in the early stages of stem exclusion (5 to 20 years old). This approach assumed that the two stands were once contiguous with similar composition and productivity. It was further assumed that the mature stand, if harvested, would regenerate similarly to its paired clearcut. A total of 47 paired stands were located on the Appalachian Plateau in West Virginia (Fenneman 1938). Paired stands were located across six counties including Fayette, Greenbrier, Nicholas, Randolph, Tucker, and Webster (fig. 1). The paired stands were owned and managed by a variety of ownership groups including public and private entities. According to landowner records, the paired stands had been relatively free from known disturbance for several years before and since the regeneration harvest that created the clearcuts. The young clearcuts had an average age of 13 years since harvest. Slope, aspect, and landscape position were documented to indirectly estimate site index and help ensure similar site conditions existed between the paired mature and clearcut stands (Meiners and others 1984). Differences in upland oak site index (base-age 50 years) within paired stands ranged from 0 to 10 feet, with an average of 3 feet. The average site index across all stands was 77 feet. All paired stands in this report were categorized as submesic in terms of expected moisture availability using indicator species as proposed by McNab and others (2003).

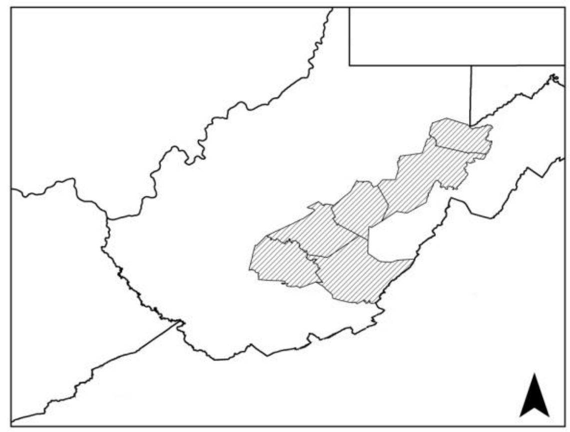

Figure 1--Location map of the study area on the Appalachian Plateau in West Virginia. Shaded areas represent counties in which sample stands were located.

Paired stands were sampled in 2008 from May to September. The mature stands were sampled using fixed area plots (0.01 acre) at a density of 1 plot per acre (maximum of 20 plots per stand). Within a stand, the initial plot location was randomly determined, and all remaining plots locations were determined using a systematic grid. The species and diameter at breast height (d.b.h.) of all stems ≥ 2 inches d.b.h. within the plot was recorded. Variable radius sampling points were also established at each plot location to measure the basal area of all stems ≥ 2 inches d.b.h. using a 10 BAF prism. The clearcuts were sampled using fixed area plots (0.001 acre) located in the same manner as the mature stands. Some of the older clearcuts were sampled using larger plots (0.01 acre). The species, stem origin (seed or sprout), and crown class (dominant, codominant, intermediate, suppressed) of all stems within the clearcut plot were recorded. Multiple stems originating from a single stump were tallied as individuals.

Table 1--Species groups used for this study on the Appalachian Plateau in West Virginia

Group	Species included
Black cherry	black cherry (*Prunus serotina* Ehrh.)
Mesophytic	ash (*Fraxinus* spp.), basswood (*Tilia* spp.), cucumbertree (*Magnolia acuminata* L.), Fraser magnolia (*Magnolia fraseri* Walt.), yellow buckeye (*Aesculus flava* Ait.), yellow birch (*Betula alleghaniensis* Britton)
Midstory	Am. chestnut [*Castanea dentata* (Marsh) Borkh.], Am. beech (*Fagus grandifolia* Ehrh.), Am. holly (*Ilex opaca* Ait.), blackgum (*Nyssa sylvatica* Marsh.) dogwood (*Cornus* spp.), e. hophornbeam [*Ostrya virginiana* (Mill.) K. Koch.] serviceberry (*Amelanchier* spp.), sourwood [*Oxydendrum arboreum* (L.) DC.], striped maple (*Acer pensylvanicum* L.)
Oaks	black oak (*Quercus velutina* Lam.), chestnut oak (*Quercus prinus* L.), northern red oak (*Quercus rubra* L.), scarlet oak (*Quercus coccinea* Muenchh.), white oak (*Quercus alba* L.)
Pioneer	Am. sycamore (*Platanus occidentals* L.), bigtooth aspen (*Populus grandidentata* Michx.), black locust (*Robinia pseudoacacia* L.), pin cherry (*Prunus pensylvanica* L.f.), sassafras [*Sassafras albidum* (Nutt.) Ness.], sweet birch (*Betula lenta* L.)
Red maple	red maple (*Acer rubrum* L.)
Sugar maple	sugar maple (*Acer saccharum* Marsh.)
Yellow-poplar	yellow-poplar (*Liriodendron tulipifera* L.)
Others	e. white pine (*Pinus strobus* L.), hemlock (*Tsuga* spp.), hickory (*Carya* spp.)

Given the magnitude of species that were recorded, nine species groups were created to facilitate data analysis. Species and genera that occupy reasonably similar stand structural and functional roles were grouped together, with the exception of a few individual species (table 1). The species groupings used in this study were: (1) black cherry; (2) mesophytic; (3) midstory; (4) oaks; (5) pioneer; (6) red maple; (7) sugar maple (*A. saccharum* Marsh.); (8) yellow-poplar; and (9) other.

The species composition of all stems ≥ 2 inches d.b.h. in the mature stands was compared to the upper canopy (dominant and codominant stems) species composition within the clearcuts. The upper canopy of young stands can provide insight into future species composition (Ward and Stephens 1994). Crown class was not recorded in the mature stands, thus a comparison of species composition by crown class between the mature and clearcut stands was not possible. Species composition was expressed as percent stems per acre so that an equitable variable could be compared between the mature and clearcut stands which had very different stem densities and stand structures.

The data did not meet the assumption of normally distributed errors required for most parametric statistics, so nonparametric statistics were used instead. The permutation test for matched pairs (PTMP) in Blossom version W2008.04.02 statistical software was used to test for overall differences in species composition between the mature and young clearcuts (Cade and Richards 2005, Cade and Richards 2008, Mielke and Berry 2001). The Wilcoxon Signed Rank test was used to test for differences between the mature stands and young clearcuts for individual species groups using the UNIVARIATE procedure in SAS® version 9.2 statistical software (Ott and Longnecker 2001, SAS 2007). One-tailed tests were used for the comparisons specifically outlined by the three research questions mentioned earlier. Two-tailed tests were used for all other comparisons.

RESULTS

The basal area of all stems ≥ 2 inches d.b.h. in the mature stands averaged 114 square feet per acre (table 2). The mature stands inventoried in this study, and most mature stands across the Appalachians, are generally described as oak-dominated, yet foresters have long realized that most stands contain relatively few but large oak stems. Indeed, oaks made up the largest proportion of basal area in the mature stands (30 percent) but only 14 percent of all stems. The oak-dominated description is reasonable for basal area, but in terms of stem density, another picture emerges. Maples (red and sugar combined) often make up the largest proportion of stems in mature Appalachian hardwood stands, as was found in this study. Maples also had the second highest basal area in the mature stands.

Table 2--Mean composition of stems ≥ 2 inches d.b.h. in 47 mature stands sampled on the Appalachian Plateau in West Virginia

Species group	Basal area (SE ±)	Density (SE ±)
	feet²/acre	*stems/acre*
Black cherry	08 (3)	15 (4)
Mesophytic	17 (2)	59 (7)
Midstory	03 (1)	27 (5)
Oaks	34 (4)	49 (8)
Pioneer	04 (1)	20 (4)
Red maple	14 (2)	57 (8)
Sugar maple	15 (3)	64 (9)
Yellow-poplar	11 (2)	21 (5)
Other	08 (2)	29 (7)
Total	114	341

Adequate regeneration occurred in the clearcuts with an average 4,637 stems per acre (table 3). Shade-intolerant black cherry, pioneer, and yellow-poplar collectively made up about half of all stems in the clearcuts. Maples were the most common genera in the clearcuts, but most of the stems were in the lower canopy (intermediate and suppressed) of the clearcuts, particularly those of sugar maple. Approximately one-third of all stems in the clearcut were in the upper canopy. Pioneer species were the most numerous in the upper canopy (approximately 25 percent) followed by the red maple, yellow-poplar, black cherry and mesophytic species groups which each made up about 15 percent of all upper canopy stems. Oaks made up about 9 percent of the upper canopy stems. The majority of the stems in the midstory group were already occupying the lower canopy of the clearcuts.

The permutation tests for matched pairs indicated that there were significant differences in species composition between the upper

Table 3--Mean species composition of 47 clearcut stands sampled on the Appalachian Plateau in West Virginia. Lower canopy values are for stems classified in suppressed and intermediate crown positions. Upper canopy values are for stems classified in codominant and dominant crown positions

	-----------Density (SE ±)-------		
Species group	Lower canopy	Upper canopy	Total
	---------*stems per acre*--------		
Black cherry	380 (220)	250 (100)	630
Mesophytic	334 (48)	239 (96)	572
Midstory	398 (64)	98 (23)	496
Oaks	194 (29)	156 (33)	350
Pioneer	415 (57)	442 (97)	857
Red maple	391 (79)	264 (50)	655
Sugar maple	441 (76)	38 (9)	479
Yellow-poplar	325 (58)	223 (38)	549
Other	28 (6)	22 (6)	50
Total	2,906	1,731	4,637

canopy of the clearcuts and the mature stands (p-value < 0.0001). It appears that most of the difference between the mature and clearcut stands was the result of increasing shade-intolerant species. This increase in shade-intolerants was primarily at the expense of sugar maple which was significantly less prevalent in the upper canopy of the clearcuts compared to the mature stands (table 4). The results specifically related to the research questions in this study were surprising. There were no significant differences found for the mesophytic, red maple, or oak species groups.

About 75 percent of the upper canopy red maples and oaks were of sprout origin (table 5). Sprout origin reproduction was also a considerable component of upper canopy reproduction for sugar maple and the mesophytic species group. At least 60 percent of the upper canopy stems of black cherry, pioneer, and yellow-poplar in the regenerating clearcut stands were seemingly of seed origin. These species produce ample seed regularly and some, particularly yellow-poplar and pin cherry, can remain viable for several years in the forest floor (Burns and Honkala 1990).

Table 4--Species composition comparison across 47 paired stands sampled on the Appalachian Plateau in West Virginia. Mean values were calculated from individual stand proportions for each species group. P-values < 0.05 indicate significant differences between mature and clearcut stands as calculated by the Wilcoxon Signed Rank test. Species composition values for the mature stands consider all stems ≥ 2 inches d.b.h. Species composition values for the clearcut stands consider only dominant and codominant stems. Statistical tests were not conducted on the "other" species group

Species Group	Mature	Clearcut	P-Value
	-----(*% stems/acre*)----		
Black cherry	4	14	0.0197
Mesophytic	17	14	0.9988
Midstory	8	56	0.1390
Oaks	14	9	0.0655
Pioneer	6	26	<0.0001
Red maple	17	15	0.5890
Sugar maple	19	2	<0.0001
Yellow-poplar	6	13	0.0004
Other	9	1	-
Total	100	100	-

Table 5--Mean proportion of stems from sprout origin in the upper canopy of 47 clearcut stands on the Appalachian Plateau in West Virginia

Species group	Sprout origin stems
	% stems/acre
Black cherry	40
Mesophytic	68
Midstory	45
Oaks	74
Pioneer	17
Red maple	81
Sugar maple	66
Yellow-poplar	25
Other	-

DISCUSSION

The species composition of clearcuts in this study was similar to other studies reported in the literature (Beck and Hooper 1986, Hilt 1985a, Trimble 1973). It appears that under the modern disturbance regime of little late-rotation disturbance, successional trends can still be reset by providing opportunities for shade-tolerant and mesophytic species to be outcompeted by more aggressive shade-intolerants immediately following clearcutting. An exception may be red maple, which is typically competitive following disturbance across a gradient of site productivity, particularly from stump-sprouts (Hilt 1985a, Loftis 1989, Tift and Fajvan 1999).

No significant changes in species composition were found for red maple in this study. This was not expected, as red maple is widely recognized as a species increasing in abundance and importance throughout its natural range (Fei and Steiner 2007, but see Oswalt and Turner 2009). In addition to reduced fire frequency (Abrams 1992), increasing red maple abundance in the Appalachians has also been attributed to an increased use of diameter-limit and other partial harvesting systems (Deluca and others 2009, Fajvan and others 1998, Kenefic and Nyland 2006). The results of this study suggest that clearcutting in these stands has not promoted an expansion of red maple, at least not initially. Given the shade tolerance and density of red maple, it is possible that it will gradually make up a larger proportion of competitive stems as these young clearcuts continue to develop, but it is not a foregone conclusion (Oliver 1978).

The results for oak regeneration in this study were somewhat more optimistic than reports from the southern Appalachians (Beck and Hooper 1986), but were in line with Hilt (1985a), who found that oaks made up approximately 30 percent of the upper canopy on medium quality sites and about 10 percent on good quality sites in clearcuts across Indiana, Kentucky, and Ohio.

The competitive ability of the oak stems through the remainder of stem exclusion is not certain (Beck and Hooper 1986, Johnson and others 2009, Loftis 1989). Ward and Stephens (1994) found that between 45 and 68 percent of upper canopy northern red oaks at age 25 remained in the upper canopy at age 55 in southern New England. Oaks can persist and eventually become more competitive as clearcuts mature, but additional management activities such as precommercial release treatments are often suggested to improve the survival of existing upper canopy oak stems during the stem-exclusion stage (Elliot and others 1997, Morrissey and others 2008, Oliver 1978, Roach and Gingrich 1968). While such treatments have shown promise (Schuler 2008, Ward 2009), their success is not guaranteed (Heitzman and Nyland 1991, Smith and Lamson 1983, Trimble 1974).

Clearcutting should be used with caution on the most productive sites (Brose and Van Lear 1998, Loftis 1990, Sander 1979). However, there is a growing body of research that indicates greater success of oak regeneration following clearcutting compared to other harvest methods on many sites (Atwood and others 2011, Groninger and Long 2008, Morrissey and others 2008). Kabrick and others (2008) found that in Missouri, red oaks only regenerated successfully following clearcutting compared to single-tree selection, group selection, and single-tree/group selection combination systems. Partial-harvesting practices, including deferment and shelterwood harvests, reduce stump-sprouting of upland oak compared to clearcutting (Atwood and others 2009, Dey and others 2008). Large oak advanced reproduction in the mature stands in this study was well below that recommended by Sander and others (1976) for successful oak regeneration. Without adequate large advance reproduction, oaks are often less successful at regenerating except on sites of poorer quality (Bey 1964, Ross and others 1986, Sander 1972). The high proportion of oaks from sprout origin in the upper canopy of the clearcuts in this study reiterates the importance of stump-sprouting in oak, particularly in the Appalachians (Cook and others 1998, Johnson and others 2009).

Muller (1983) found that 35 years after clearcutting there were no significant differences in species composition on two adjacent watersheds on the Cumberland Plateau in southeastern Kentucky. It is possible that the clearcuts in this study will eventually be similar in composition and structure to that of the mature stands as they continue to develop (Oliver and Larson 1996). The pioneer group, which was composed of short-lived species, is expected to be only a minor component later in the rotation of these clearcuts. However, unlike more xeric sites where sporadic drought has been shown to drastically reduce temporal increases in yellow-poplar following clearcutting, the larger proportion of yellow-poplar on these submesic sites could be a lasting effect (Hilt 1985b, Morrissey and others 2008).

CONCLUSIONS

Clearcutting on submesic sites on the Appalachian Plateau in West Virginia successfully regenerated stands with numerous commercial species. The results of this study suggest that the future species composition of stands regenerating following clearcut harvests may differ only slightly from previous rotations. The current dominance of pioneer species is expected to be short-lived, but a larger presence of yellow-poplar may remain throughout the rotation. Gradual increases in the proportion of more shade-tolerant maples and mesophytic species may occur during later stages of stand development. The future for oaks on these submesic sites is not certain, but it appears likely that oaks will maintain a role as these clearcuts continue to develop. The results of this study do not provide evidence of forest-type shifts towards mesophytic species, increasing red maple abundance, or decreasing oak abundance in young clearcuts on submesic sites on the Appalachian Plateau of West Virginia.

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