THE STATUS OF OAK AND HICKORY REGENERATION IN FORESTS OF VIRGINIA

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Abstract.—Evidence suggests that eastern U.S. forests dominated by oak (*Quercus* spp.) and hickory (*Carya* spp.) may be shifting to more maple- (*Acer* spp.) and mixed-species dominated forests. Data from the U.S. Forest Service Forest Inventory and Analysis program were used to describe the status of oak and hickory regeneration in medium- and large-diameter stands that showed no evidence of artificial regeneration or harvesting since the previous survey (5 to 10 years). Oak saplings (d.b.h. 2.5 cm but <12.7 cm) were tallied on 32 percent of plots measured and represented 10 percent of all saplings tallied. Hickory saplings occurred on 19 percent of plots measured and represented 5 percent of saplings tallied. In contrast, oak and hickory trees (d.b.h. ≥12.7 cm) occurred on 86 percent and 51 percent of plots, respectively. White oak (*Quercus alba* L.) and chestnut oak (*Q. prinus* L.) were the dominant oak saplings. Sapling-sized white and chestnut oaks occurred on 10 percent and 8 percent of plots, whereas tree-sized white and chestnut oaks occurred on 48 percent and 45 percent of plots, respectively. Density of chestnut oak saplings was less than one-half of that of trees (23 saplings ha^{-1} versus 58 trees ha^{-1}). Mockernut hickory (*Carya tomentosa* (Poir.) Nutt.) and pignut hickory (*C. glabra* [Mill.]) Sweet) were the most commonly tallied hickory saplings and both occurred on approximately 9 percent of plots. In contrast to the oaks and hickories, red maple (*Acer rubrum* L.) saplings occurred on 41 percent of plots. Given the status of regeneration of most oaks and hickories, it appears that these forests may be making a transition to a different species mix.

INTRODUCTION

The oak-hickory (*Quercus* spp.-*Carya* spp.) complex is the largest forest vegetation association in the eastern United States. Currently, it covers approximately 3,859,500 ha (60 percent) of all forest land in Virginia (Rose, in press). Chestnut oak (*Q. prinus* L.), at 3.4 m^2 ha^{-1}, is the dominant species across Virginia. White oak (*Quercus alba* L.), at 2.1 m^2 ha^{-1}, is the third most dominant species, and the second most dominant oak species (Rose and Rosson 2007). While oak is a major genus in forests of the eastern U.S., the loss of American chestnut (*Castanea dentata* [Marsh.]) Borkh.) may have contributed to an increase in the dominance of oak and hickory after 1900 (Keever 1953, Woods and Shanks 1959, McCormick and Platt 1980, Abrams 1992). Although oaks and hickories are still major overstory dominants, they are often under-represented in the understory (Stephenson 1986, McCarthy and Wistendahl 1988, Farrell and Ware 1991, Cole and Ware 1997, Abrams and Copenheaver 1999, Tift and Fajvan 1999, Copenheaver and others 2006, McEwan and Muller 2006). Additionally, several studies have reported a decrease over time in oaks or hickories, or both, and an increase in fire-intolerant and shade-tolerant species, especially in the understory (Christensen 1977, Rhoades 1992, Stephenson and Fortney 1998, Elliott and others 1999, Pierce and others 2006). This situation signals a potential transition from an oak and hickory species mix to more mesic shade-tolerant species. This shift in dominance is often attributed to the low shade tolerance of oaks and to the lack of disturbance, primarily from fire suppression (Burns and Honkala 1990, Abrams 1992). However, little or no benefit to oak has been reported from several prescribed burn studies (Wendel and Smith 1986, Hutchinson and others 2005, Blankenship and Arthur 2006). Notable among

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the potential replacement species are red maple (*Acer rubrum* L.), sugar maple (*Acer saccharum* Marsh.), and blackgum (*Nyssa sylvatica* L.) (Ross and others 1982, Abrams 1998, Pierce and others 2006). Whether these shade-tolerant, fire-sensitive species will assume a dominant overstory position in the future is uncertain. Some have speculated that oak may persist on xeric, nutrient-poor sites, even in the absence of fire, particularly in areas south and west of the northern hardwood forests (Orwig and Abrams 1994, Abrams and others 1997). If so, oak species adapted to these sites, such as chestnut oak and scarlet oak (*Q. coccinea* Muenchh.), may experience less successional pressure than oak species adapted to more mesic nutrient-rich sites, such as northern red oak (*Q. rubra* L.).

OBJECTIVES

Studies of vegetation composition are often limited in scale, and many times the selection of plot location is subjective and preferential. Preferential sampling emphasizes unique stands like old-growth forests or stands with unusual features, such as rare species. In contrast, this study utilized plots distributed systematically across Virginia. This approach allowed for the study of a wide range of stands across a variety of site and soil conditions and captured the most common stand conditions influencing vegetation across Virginia. The objective of this study was to describe the current regeneration status of oak and hickory species at the landscape scale across Virginia.

METHODS

This study was conducted in the state of Virginia, which has a total land area of Virginia is 10,255,000 ha. Approximately 62 percent of this total is forested (6,412,000 ha) (Rose 2007). The western portion of Virginia contains three mountainous physiographic regions, the Blue Ridge, the Ridge and Valley, and the Appalachian Plateau. To the east of these mountains is the Piedmont physiographic region, which ranges from rolling hills in the west to several nearly level basins in the east. The easternmost part of the state lies on the Coastal Plain, which extends inland approximately 200 km from the coast and is defined by the eastern Atlantic shoreline and the rolling and dissected area where it meets the Piedmont to the west (Fenneman 1938). The elevation in Virginia ranges from sea level to just over 1,737 m on Mt. Rogers in the George Washington and Jefferson National Forest.

Data for this study came from the forest survey conducted in Virginia between 1997 and 2001 by the U.S. Forest Service, Southern Research Station, Forest Inventory and Analysis (FIA) program. Surveys such as this have been conducted since the early 1930s, under the direction of several legislative acts. The survey mission originally was to estimate forest area, timber volume, growth, removals, and mortality, but it has since been broadened in scope to address other contemporary forest issues.

A hexagonal grid system was used to establish sample plots and derive forest statistics (USDA 2004). Within each 2430-ha hexagon, a randomly located sample plot was measured to determine individual tree and forest stand parameters. On each plot trees ≥12.7 cm diameter at breast height (d.b.h.) were sampled on four subplots, each with a radius of 7.3 m, spaced 37 m apart. Together these four subplots made up a sample plot with a sample area of 0.07 ha. Saplings (2.5 cm - 12.6 cm d.b.h.) were measured on microplots with a radius of 2.1 m nested within each subplot. The total sample area of the four microplots was 0.005 ha.

The plot population for this study was derived by means of a post-stratified plot selection based upon the following criteria: (1) each plot was internally homogeneous regarding stand size and forest type; (2) the plots were not artificially regenerated; (3) the plots showed no evidence of cutting since the previous survey (5 to 10 years); and (4) the plots were classified as either medium-diameter or large-diameter stands based on stocking. Large diameter trees are >27.7 cm d.b.h. for hardwoods and >22.6 cm d.b.h. for softwoods. Medium-diameter trees are 12.7 - 27.7 cm d.b.h. for hardwoods and 12.7 - 22.6 cm d.b.h. for softwoods. Out of 3,037 forested plots, 1,164 met these requirements.

Density for genus and species was calculated for all plots. The heterogenous distribution of trees across the landscape, with many plots having a value of zero for most species, may result in a standard deviation that equals, or exceeds, the mean. Relative density (density of species [or genus]/total density [in stems ha^{-1}] x 100) was also calculated for each genus and species for all plots. Taxonomic nomenclature follows Little (1979). FIA includes red hickory (*Carya ovalis* (Wangenh.) Sarg.) with pignut hickory (*Carya glabra* (Mill.) Sweet).

RESULTS

Sapling-size oaks (≥2.5 cm d.b.h., but <12.7 cm) occurred on 30 percent of plots and represented 10 percent of all saplings tallied. Hickory saplings were present on 18 percent of plots and represented 5 percent of saplings tallied. In contrast, oak and hickory trees (d.b.h. ≥12.7 cm) were found on 86 percent and 51 percent of plots, respectively, and accounted for 36 percent and 6 percent of trees, respectively. Sapling-size hickories were present on only 26 percent of plots where tree-size hickories occurred. Likewise, 33 percent of plots with tree-size oaks had sapling-size oaks. Conversely, hickory saplings occurred on 9 percent of plots that did not have hickory trees, and oak saplings occurred on 13 percent of plots that did not have oak trees.

Maple (*Acer* spp.) and tupelo (*Nyssa* spp.) were on the most plots and represented the most saplings tallied. Sapling-size maples occurred on 49 percent of plots and accounted for 22 percent of saplings tallied. Tree-size maples occurred on 71 percent of plots and represented 12 percent of trees. Tupelo saplings occurred on 31 percent of plots and accounted for 12 percent of saplings tallied. Trees of this genus occurred on 35 percent of plots and represented 3 percent of trees.

Sapling-size oaks that occurred on at least 5 percent of plots were white oak (10 percent of plots), chestnut oak (8 percent), and northern red oak (5 percent) (table 1). In contrast, trees of these three oaks occurred on 48 percent, 45 percent, and 42 percent of plots, respectively. Mockernut hickory (Carya tomentosa (Poir.) Nutt.) and pignut hickory were the most commonly tallied sapling-size hickories and each occurred on approximately 9 percent of plots. Trees of these two species occurred on about one-third of the plots. The most frequently occurring sapling-size species were red maple, blackgum, and yellow poplar (*Liriodendron tulipifera* L.).

Although the density of tree-size oak species exceeded that of hickories, saplings of mockernut hickory and pignut hickory had higher densities than saplings of any oak species, with the exception of white oak (Table 2). In contrast to chestnut oak trees, density of chestnut oak saplings was higher in oak-pine stands (32 stems ha^{-1}) than in oak-hickory stands (24 stems ha^{-1}) (Table 3). Mockernut hickory was another species where sapling density was higher in oak-pine stands (33 stems ha^{-1}) than in oak-hickory stands (28 stems ha^{-1}). This situation was also true for several other species; however, in some cases, including white oak and scarlet oak, the density of trees was also higher in oak-pine than in oak-hickory stands. Density of chestnut oak saplings was less than one-half that of trees (22 trees ha^{-1} versus 58 trees ha^{-1}). White oak

Table 1.—Frequency of individual sapling and tree species, Virginia, number of plots=1,164. The 33,203 tree-sized stems included 94 species and the 6,475 sapling-sized stems included 76 species; only the top 15 species (for tree basal area) are included.

		Frequency			
Scientific name	Common name	Saplings[1]		Trees[2]	
		no.	%	no.	%
Acer rubrum	Red maple	483	41.5	764	65.6
Carya glabra	Pignut hickory	99	8.5	355	30.5
C. tomentosa	Mockernut hickory	110	9.5	341	29.3
Fagus grandifolia	American beech	90	7.7	159	13.7
Liquidambar styraciflua	Sweetgum	119	10.2	225	19.3
Liriodendron tulipifera	Yellow-poplar	124	10.7	569	48.9
Nyssa sylvatica	Blackgum	347	29.8	381	32.7
Pinus strobus	E. white pine	71	6.1	145	12.5
P. taeda	Loblolly pine	19	1.6	142	12.2
P. virginiana	Virginia pine	48	4.1	281	24.1
Quercus alba	White oak	119	10.2	562	48.3
Q. coccinea	Scarlet oak	48	4.1	369	31.7
Q. prinus	Chestnut oak	92	7.9	525	45.1
Q. rubra	Northern red oak	63	5.4	486	41.8
Q. velutina	Black oak	45	3.9	388	33.3

[1] d.b.h. ≥2.5 cm but <12.7 cm
[2] d.b.h. ≥12.7 cm

Table 2.—Average density and relative density of individual sapling and tree species (across all plots), Virginia. Values in parentheses are the standard deviation. The 33,203 tree-sized stems included 94 species and the 6,475 sapling-sized stems included 76 species; only the top 15 species (for tree basal area) are included.

	Saplings[1]		Trees[2]	
Species	Density	Relative Density	Density	Relative Density
	stems ha^{-1}	%	stems ha^{-1}	%
Red maple	182.7 (328.1)	16.3	44.6 (60.6)	10.6
Pignut hickory	22.3 (89.4)	2.6	10.5 (22.1)	2.8
Mockernut hickory	24.7 (89.6)	2.3	10.6 (23.7)	2.8
American beech	29.4 (132.8)	2.7	6.6 (23.1)	1.6
Sweetgum	42.5 (183.9)	3.2	14.8 (44.8)	3.2
Yellow-poplar	40.7 (181.3)	3.2	37.4 (61.6)	9.4
Blackgum	118.7 (253.0)	11.8	10.6 (25.2)	2.6
E. white pine	21.5 (105.0)	2.1	8.1 (32.8)	1.8
Loblolly pine	8.6 (101.3)	0.4	16.6 (72.4)	3.0
Virginia pine	17.7 (145.8)	1.1	22.5 (76.5)	4.3
White oak	29.8 (108.2)	2.2	33.6 (55.0)	8.2
Scarlet oak	10.0 (56.9)	1.0	19.1 (43.8)	4.3
Chestnut oak	21.8 (90.1)	2.3	57.7 (95.6)	13.5
Northern red oak	11.9 (54.4)	1.4	18.1 (38.3)	4.4
Black oak	8.1 (42.3)	0.7	12.4 (26.1)	3.0

[1] d.b.h. ≥2.5 cm but <12.7 cm
[2] d.b.h. ≥12.7 cm

Table 3.—Average density of individual sapling and tree species by forest-type group, Virginia. The 33,203 tree-sized stems included 94 species and the 6,475 sapling-sized stems included 76 species; only the top 15 species (for tree basal area) are included.

	Forest-type group[1]					
	Oak-Hickory (n = 856)		Oak-Pine (n = 146)		Other[2] (n = 162)	
Species	Saplings[3]	Trees[4]	Saplings	Trees	Saplings	Trees
	stems ha^{-1}					
Red maple	181.6	43.5	228.9	39.8	219.2	54.6
Pignut hickory	26.3	12.9	21.2	5.0	9.1	2.9
Mockernut hickory	28.1	12.7	33.1	7.3	6.5	2.9
American beech	33.8	7.7	21.2	2.7	24.8	4.5
Sweetgum	23.0	10.5	127.0	24.7	90.0	28.8
Yellow-poplar	46.4	43.2	17.2	23.2	48.3	19.8
Blackgum	135.5	10.9	103.2	11.6	86.1	7.8
E. white pine	14.0	3.5	80.7	30.4	15.7	12.7
Loblolly pine	1.6	2.7	22.5	34.8	39.1	73.2
Virginia pine	9.5	7.6	22.5	51.7	67.8	74.5
White oak	27.0	35.7	62.2	46.2	26.1	10.7
Scarlet oak	9.0	19.2	21.2	27.3	9.1	11.2
Chestnut oak	23.9	67.2	31.8	49.5	9.1	15.0
Northern red oak	15.8	22.1	1.3	9.1	5.2	5.4
Black oak	6.5	14.0	13.2	14.0	15.7	2.9

[1] Forest-type groups are similar in concept to associations as defined by Braun (1950).
[2] Other includes maple-beech-birch, bottomland-hardwoods, loblolly-shortleaf pine, and white-red-jack pine forest-type groups.
[3] d.b.h. ≥2.5 cm but <12.7 cm
[4] d.b.h. ≥12.7 cm

was the only oak species whose sapling-to-tree ratio approached 1 to 1 (Table 2). Pignut and mockernut hickory both had sapling-to-tree ratios of approximately 2 to 1. Blackgum and red maple ratios were 12 to 1 and 4 to 1, respectively.

Sapling-size chestnut oak, white oak, mockernut hickory, and pignut hickory all had relative densities ≥15 percent on 6 percent of plots. Trees of these four species had relative densities ≥15 percent on 30 percent, 20 percent, 5 percent, and 5 percent, respectively. Northern red oak saplings reached a relative density ≥15 percent on 4 percent of plots and both black oak and scarlet oak had relative densities ≥15 percent on only 2 percent of plots. Other potential overstory sapling-size species that had relative densities ≥15 percent were red maple (36 percent of plots), blackgum (24 percent), and yellow-poplar (8 percent). Relative densities of trees of these three species were ≥ 15 percent on 26 percent of plots, 4 percent, and 23 percent, respectively.

DISCUSSION

At the landscape scale across Virginia, the regeneration potential of oak species and, to a lesser degree, hickory species appears low compared to several other species. The canopy tree species with the highest sapling densities tended to be the mesic shade-tolerant ones, in particular red maple and blackgum. It is likely that without disturbance these species will increase in abundance and oak and hickory species will decrease. However, there is some evidence that a single disturbance on some sites may not be sufficient to increase the recruitment of oak and hickory (Clark and others 2007). Studies from the mountains and the Piedmont of Virginia have also found high amounts of oak in the overstory, but very little in the understory (Farrell and Ware 1991, Abrams and Copenheaver 1999, Copenheaver and others 2006). In addition, studies from West Virginia, Kentucky, and Indiana also found that stands dominated by oaks and hickories tended to have different species in the understory (Tift and Fajvan 1999, McEwan and Muller 2006, Pierce and others 2006). This study found that most oak and hickory species occurred on far fewer plots in the sapling size class than the tree size class. In contrast, Cole and Ware (1997) found that many of the oak and hickory species of the Piedmont of Virginia were present on most plots in the small tree and sapling size class where they also occurred in the overstory.

The higher density of some oak saplings in oak-pine stands may be due to recent disturbance, or may be indicative of drier sites with relatively open canopies that allow sufficient light penetration for successful oak regeneration. In comparison, the density of white oak saplings was greater in stands dominated by Virginia pine (*Pinus virginiana* Lam.) than white oak-yellow-poplar stands in a study from the Piedmont and Coastal Plain of Virginia (Orwig and Abrams 1994). Additionally, southern red oak (*Q. falcata* Michx.) and black oak (*Q. velutina* Lam.) sapling densities were higher in the Virginia pine stands than in either the white oak-yellow-poplar or the white oak-scarlet oak forest groups. This case also held true for seedlings of southern red oak; however, black oak seedlings were not present in any of the forest groups (Orwig and Abrams 1994).

The dominance of red maple and/or blackgum in the sapling layer has been documented by many researchers (Ross and others 1982, Abrams and Downs 1990, Farrell and Ware 1991, Orwig and Abrams 1994, Cole and Ware 1997, Tift and Fajvan 1999). This dominance, however, has been found to vary along topographic moisture gradients. Ross and others (1982) found that for trees less than 7 years old, red maple outnumbered chestnut oak on mesic sites, while blackgum outnumbered chestnut oak on xeric sites. Whether red maple will become a canopy dominant is uncertain. Researchers have been noting relatively high or increasing occurrences for decades (Keever 1953, Woods and Shanks 1959, Stephenson 1974). However, the species has not yet assumed the overstory dominance that might be assumed given the high importance reported in under- and mid-story layers. Recruitment of red maple into the overstory nonetheless has been reported from a few studies (Rhoades 1992, Elliott and others 1999, Blankenship and Arthur 2006, McEwan and Muller 2006). Across all plots in this study, red maple trees ranked fourth in basal area, and second in density. This presence seems to support the idea that there is potential for red maple to assume a more dominant position in the forests of the eastern U.S.

Low numbers of oak saplings do not necessarily translate into a lack of future dominance by oaks (Abrams and other 1998). Reproduction of some species may be periodic (i.e., regenerating at irregular intervals) rather than continuously (Whittaker 1956). Decelerated height growth of maple over time, a relatively shorter life span (150 years for maple versus 200 to 500 years for several oaks and hickories), as well as high understory mortality of blackgum may limit the ability of these species to assume and maintain canopy dominance (Christensen 1977, Burns and Honkala 1990, Abrams 1992, Cole and Ware 1997).

Hickory saplings were more abundant than hickory trees, which is often true for many species. The density of mockernut hickory and pignut hickory saplings equaled or exceeded that of most other oak species, which was unexpected. Other studies from the northern Piedmont region of Virginia also found that hickory was more prevalent than oak in the understory, although oak dominate species in the overstory (Farrell and Ware 1991, Abrams and Copenheaver 1999). Whether hickory will become a dominant component of the overstory in the future is uncertain. In 1953, Keever predicted a substantial hickory component would exist in the former oak-chestnut forests in the southern Blue Ridge Mountains. McCormick and Platt (1980) confirmed that hickory had maintained a co-dominant position, and was the leading dominant in some stands in the same area. Further south, in the central Piedmont of Virginia, one study found that hickory was present, although less prevalent than in the northern Piedmont (Cole and Ware 1997). Studies from the Coastal Plain of Virginia found either little or no hickory in the understory or overstory (Monette and Ware 1983, Abrams and Black 2000). While the present study did not take into account spatial variability, it is likely that sapling densities of hickory were highest in the northern Piedmont region of Virginia. A related study found that hickory trees obtained their highest importance values in this area (Rose and Rosson 2007), perhaps in part because of the association of hickory species with soils of high Ca and high Mg as are found in the northern Piedmont region of Virginia (Farrell and Ware 1991).

In addition to spatial variability, some oak and hickory species tend to be correlated with topography (Racine 1971, Stephenson 1974, Ross and others 1982, McCarthy and others 1984, McCarthy and Wistendahl 1988, Collins and Carson 2004, Copenheaver and others 2006). Future studies that consider these factors will further clarify the status of regeneration of oak and hickory. Additionally, follow-up work that includes seedlings will provide insight into the future composition of these forests. Although only data from permanent plots without evidence of management in the past 10+ years were used in the analyses, natural disturbance and land use history may have had an effect on the status of regeneration of the species investigated in this study.

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