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Source: Castanea, 83(1):152-159.
Published By: Southern Appalachian Botanical Society
https://doi.org/10.2179/16-113
URL: http://www.bioone.org/doi/full/10.2179/16-113

CASTANEA 83(1): 152–159. FEBRUARY

Fifty-Five Years of Change in a Northwest Georgia Old-Growth Forest

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ABSTRACT Old-growth forests provide unique insight into historical compositions of forests in the eastern United States. Plots established within a mixed forest community within Marshall Forest in Rome, Georgia, in 1960 (and remeasured in 1989) were reassessed to determine changes in forest composition. The community has experienced approximately 10% increase in basal area since the previous measurement period. However, changes in species importance have occurred. Chestnut oak (*Quercus montana*), mockernut hickory (*Carya tomentosa*), white oak (*Quercus alba*), and flowering dogwood (*Cornus florida*) have all decreased in importance, while pignut hickory (*Carya glabra*), winged elm (*Ulmus alata*), yellow poplar (*Liriodendron tulipifera*), and red maple (*Acer rubrum*) have all increased in importance. Additionally, there are no *Pinus* spp. saplings in the study area, indicating seedlings are not being recruited into the midstory. These changes indicate continued succession to a composition increasingly dominated by shade-tolerant species. The mixed forest community appears to be transitioning to an oak-hickory community. The assessment of late successional dynamics may help managers of similar forests to determine the best plan of action if they desire to maintain a mixed forest ecosystem.
Key words: *Acer rubrum*, forest changes, importance value, old-growth forest, succession.

INTRODUCTION Southern Appalachian forests have historically been composed of some species combination of oak-pine-hickory (Braun 1950). In almost all forests in this region, as well as the eastern United States, oaks (*Quercus* L. spp.) have been a primary component, filling an important niche for timber production and forage for wildlife following the loss of *Castanea dentata* to chestnut blight (*Cryphonectria parasitica* (Murrill) Bar. Over the past 100 yr, these forests have been subject to fire exclusion, allowing for canopy closure and the establishment of shade-tolerant, fire intolerant species (e.g., *Acer rubrum* L.), which may lead to compositional changes in forests in the region (Abrams 1992). *Quercus* L. spp. have been declining throughout the eastern United States due to a lack of fire, clear-cutting hardwood forests, and forest pathogens (Burns and Honkala 1990, Abrams 1992, Abrams 1998, McDonald et al. 2002). A thorough understanding of biotic and abiotic factors involved in maintaining communities within these forests is imperative to develop an understanding of cascading impacts on biodiversity (Copenheaver et al. 2006, D'Amato et al. 2009).

Old-growth forests provide a unique opportunity to assess the impacts of fire exclusion and natural disturbance as they have been uncut since European settlement and allow for insights into historical patterns of composition, succession, and fire and disturbance patterns (Abrams and Copenheaver 1999, Copenheaver et al. 2006, Petrucelli et al. 2014). Permanently established plots within old-growth forests allow assessment of forest compositional changes over time. Disturbance can maintain these forests in a state

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Received October 6, 2016; Accepted December 12, 2017.
Published: February 23, 2018.
DOI: 10.2179/16-113

of subclimax (Lipps 1966, Copenheaver et al. 2006) by impacting understory composition and growth release as saplings grow as a result of canopy openings. However, in the absence of disturbances severe enough to cause canopy openings and in the absence of fire in the understory, compositional changes can occur.

The Marshall Forest

The Marshall Forest Preserve (hereafter Marshall Forest) is located in northwest Georgia and comprises approximately 120 ha of old-growth forest contained entirely within the city limits of Rome, Georgia. With elevations of between 200 and 300 m over varying terrain, it has experienced no commercial logging (Lipps 1966). It has been managed by The Nature Conservancy since 1966 when it was declared a National Natural Landmark. This forest provides an opportunity to assess compositional changes in an old growth system where no pines (*Pinus* spp.) have established since the 1940s and no oaks (*Quercus* L. spp.) have established since the 1950s (Petrucelli et al. 2014). Disturbance just prior to the beginning of the initial survey (Lipps 1966, Lipps and DeSelm 1969) likely allowed for the establishment of *A. rubrum* L. into the 1960s (Abrams 1998, Petrucelli et al. 2014). Since the 1960s, red maple and other species tolerant of shade and intolerant of fire continued to increase in importance (Fail 1991). This study reassessed plots in a mixed forest community to determine compositional changes since the previous survey and the likelihood of changes going forward.

Most of Marshall Forest consists of a pine-oak community, although *Quercus montana* Willd. and mixed forest communities are present. The initial floristic survey was established in 1960 and began in 1961, with surveys occurring through all seasons (Lipps 1966, Lipps and DeSelm 1969). Additional studies have remeasured plots in the mixed forest community (Fail 1991), determined population levels (abundance) of *Scutellaria montana* Chapm. (Fail and Sommers 1993), assessed the presence and characteristics of longleaf pines (*Pinus palustris* Mill.) present within the forest (Sakulich 2011), and determined establishment and disturbance patterns of primary tree species (Petrucelli et al. 2014).

The goal of this study was to locate and assess plots from the initial floristic survey located within the mixed forest community (Lipps 1966). The primary objectives were to (a) determine species presence, (b) calculate importance value of major overstory species, and (c) determine changes in importance of species within the mixed forest community of Marshall Forest. Results of this study will allow insight into similar forest communities throughout the southeastern United States regarding future stand composition and structure.

METHODS

The study was conducted in an area known as Flower Glen, which comprises approximately 3.8 ha within Marshall Forest (Lipps and DeSelm 1969, Fail 1991, Figure 1). The area is in a valley, bound on both sides by ridges with slopes that approach 60% near the valley head where Flower Glen Creek begins and decrease nearing the eastern edge, which is bound by a road and, ultimately, by the Coosa River. Five permanent 0.04 ha (0.1 acre) plots were established within the study area in 1960 alternating between north- and south-facing slopes. Dominant trees within the community, based upon the current survey, are *Q. montana*, *Q. rubra*, *Q. alba*, *Carya tomentosa* (Lam.) Nutt., *C. glabra* (Mill.) Sweet, *P. taeda* L., *P. echinata* Mill., *Cornus florida* L., *Oxydendrum arboreum* (L.) DC., *Ulmus alata* Michx., and *Liriodendron tulipifera* L.

The plots were found, remarked, and remeasured. Plants were identified to species, and diameter at breast height (DBH) was measured for all trees greater than 1.5 m tall (data available as a supplemental file). Importance value (IV) was calculated based on relative dominance and relative density (Fail 1991, Fail and Sommers 1993, Equation 1) for all stems greater than 2.54 cm DBH. Percent change in IV between the 1989 and the current survey was calculated (Equation 2) to ascertain the degree of change between survey periods.

$$\mathrm{IV} = \text{relative density} + \text{relative dominance} \quad (1)$$

$$\%Change = \frac{IV_{2015} - IV_{1989}}{IV_{1989}} X100 \quad (2)$$

Percent cover for herbaceous species and shrubs/vines were estimated (based on the percentage of each plot occupied) to assess any changes in the occurrence of any understory species.

RESULTS

Flower Glen exhibits a basal area of 27.0 m^2/ha within the surveyed plots, an approximate 10% increase over the 24.6 m^2/ha

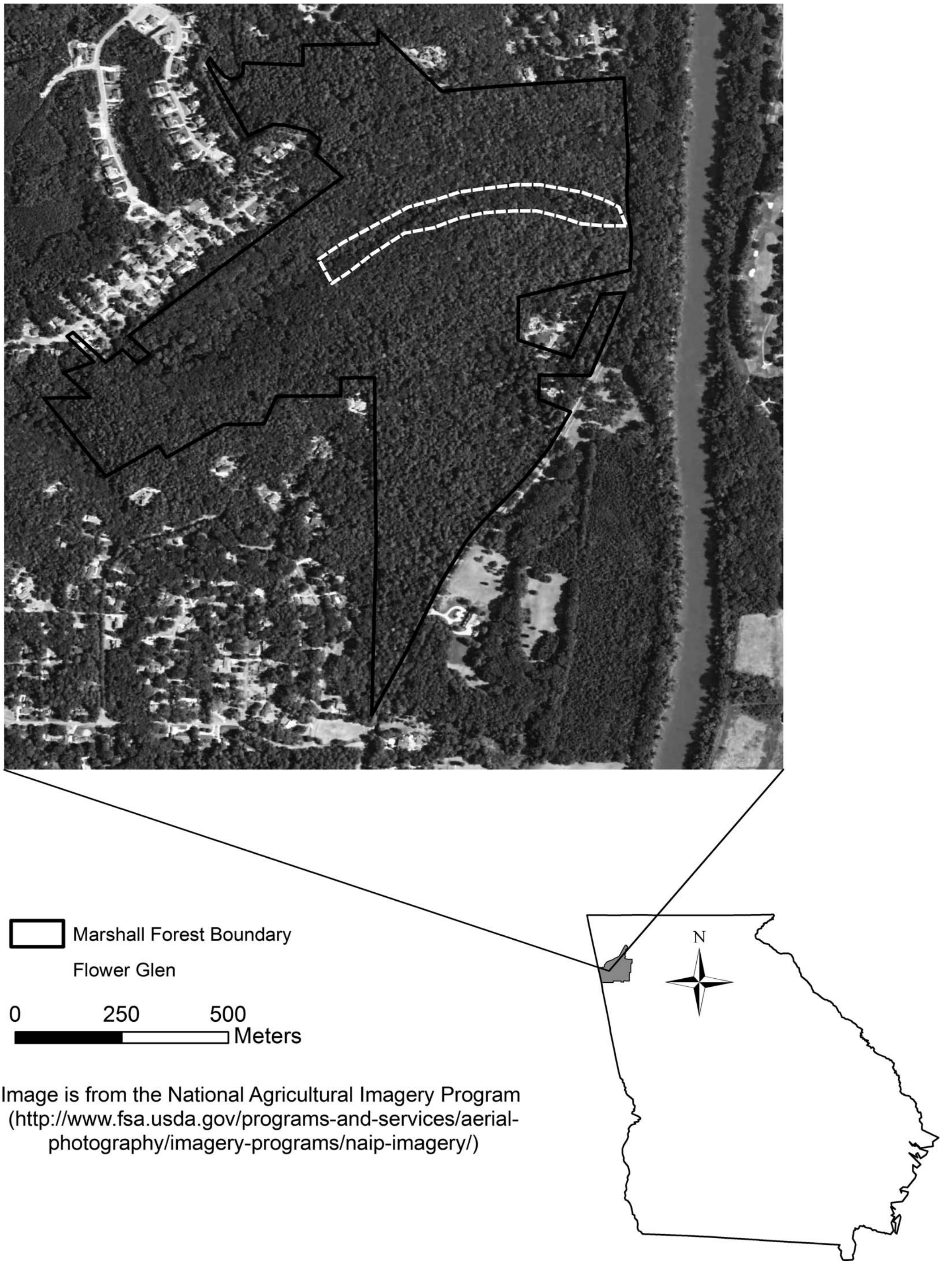

Figure 1. The location of Marshall Forest within the City of Rome, Georgia. Flower Glen is within the white dashed boundary. Image obtained from the National Agricultural Imaging Program (http://www.fsa.usda.gov/Internet/FSA_File/2013_apfo_webservice_10x.pdf).

Table 1. Mean importance values for dominant species in Flower Glen near Rome, Georgia. Importance values are only presented for species that match those presented by Fail (1991).

Species	Lipps (1966)	Fail (1991)	2015	% Change
Acer rubrum L.	11.1	25.1	35.4	41
Carya glabra (Mill.) Sweet	1.1	3.7	11.8	218.9
Carya tomentosa (Lam.) Nutt.	24.7	24.6	22	−10.6
Cornus florida L.	5.8	3.7	2.9	−21.6
Liriodendron tulipifera L.	20.8	8.7	33.4	283.9
Oxydendrum arboreum (L.) DC.	17.8	19.1	4.8	−74.9
Pinus echinata Mill.	15.5	8.3	9.2	10.8
Pinus taeda L.	15.6	10.1	11.4	12.9
Quercus alba L.	6.7	9.9	8.2	−17.2
Quercus montana Willd.	22.6	49.2	36.9	−25
Quercus rubra L.	5.2	11.8	12.7	7.6
Ulmus alata Michx.	1.5	0.5	11.2	2140

reported by Fail (1991). The mean stem density (for stems at least 2.54 cm) decreased from the 1,077 stems/ha in 1989 to 915 stems/ha in 2015. Importance values (Table 1) were greatest for *Q. montana* (36.9), followed by *A. rubrum* (35.4) and *L. tulipifera* (33.4). Although there were only five plots available for remeasurement, there is a noticeable change in importance value over the past 27 yr. *Acer rubrum* and *L. tulipifera* increased in importance by 41% and 284%, respectively. The two pine species found in this community, *P. taeda* and *P. echinata*, experienced a modest increase in importance, likely due to the increase in diameter of large trees. The IV of *C. tomentosa* was stable between 1960 and 1989, but decreased in importance by greater than 10% between 1989 and the present. In contrast, *C. glabra* increased in importance by greater than 200%. *Ulmus alata* increased in importance by 2,000%, as a function of an increase in frequency and increase in size of several trees to greater than 8.0 cm. *Oxydendrum arboreum* (L.) DC., *Q. alba*, *Q. montana*, and *C. florida* L. all experienced decreases in importance value.

Additionally, it is worth noting the diameter distribution of various species within the mixed forest community (Table 2). Species with the greatest diameter trees (greater than 68.7 cm DBH) were *Q. montana* and *L. tulipifera*. There were no stems in the 61.1–68.6 cm range. It is important to note the number of stems/ha in the seedling/sapling classes as no *Pinus* spp. or *L. tulipifera* saplings were found. The majority of *Quercus* spp. found in the <7.62 cm class were seedlings (e.g., 98% of *Q. rubra* in the <7.62 cm class were seedlings; Table 2).

The understory composition was not addressed by Fail (1991), but Lipps and DeSelm (1969) reported 157 herbaceous taxa in the mixed forest community of Marshall Forest, owing to the microclimate/microhabitat created by Flower Glen Creek. In the summer of 2015, only 24 herbaceous taxa were observed. Lipps and DeSelm (1969) identified 24 taxa in the shrub/vine category but only 17 were observed in the current assessment. The most commonly occurring were *Calycanthus floridus* L., *Toxicodendron radicans* (L.) Kuntze, *Parthenocissus quinquefolia* (L.) Planch., *Vitis rotundifolia* Michx., and *Vaccinium* L. spp. The most prominent herbaceous taxa were *Tiarella cordifolia* L., several ferns (*Pleopeltis polypodioides* (L.) E.G. Andrews & Windham, *Athyrium filix-femina* var. *asplenioides* (Michx.) A.A. Eaton, *Polystichum acrostichoides* (Michx.) Schott, *Pteridium aquilinum* (L.) Kuhn), and a variety of *Dichanthelium* (Hitchc. & Chase) Gould species (e.g., *Dichanthelium boscii* (Poir.) Gould & C.A. Clark, *Dichanthelium depauperatum* (Muhl.) Gould, *Dichanthelium dichotomum* (L.) Gould). Two invasive species (*Lonicera japonica* Thunb. and *Hedera helix* L.) were also present in the study plots, and two others (*Microstegium vimineum* (Trin.) A. Camus and *Mahonia bealei* (Fortune) Carr.) were noted in proximity to the plots.

DISCUSSION Historically, the primary factors influencing Marshall Forest have been fire and weather, primarily ice storms (Lipps 1966), which have acted to keep the forest in a state of subclimax and to maintain its species composition. However, fire prevention measures (Marshall Forest is within the city limits of Rome,

Table 2. Diameter distribution for tree species found in the Flower Glen near Rome, Georgia during summer 2015. For <7.62 cm class, seedlings are given in parentheses. All values presented are stems/ha.

	Diameter at Breast Height (in 7.62 cm classes)									
Species	**<7.62**	**7.63–15.2**	**15.3–22.9**	**23.0–30.5**	**30.6–38.1**	**38.2–45.7**	**45.8–53.3**	**53.4–61.0**	**61.1–68.6**	**68.7–76.2**
Acer rubrum L.	2,635 (2,355)	50	15							
Carya glabra (Mill.) Sweet	290 (250)	5	5					5		
Carya tomentosa (Lam.) Nutt.	395 (175)	20	15							
Cornus florida L.	15	5								
Liquidambar styraciflua L.	155 (135)	15	5							
Liriodendron tulipifera L.	10 (10)	15	15			15	5			10
Nyssa sylvatica Marshall	195 (100)	5								
Oxydendrum arboreum (L.) DC.	50 (15)									
Pinus echinata Mill.							10			
Pinus taeda L.								10		
Quercus alba L.	40 (35)	10		5	10					
Quercus montana Willd.	460 (450)	5	10	10	15	10				
Quercus rubra L.	295 (290)		5		5	5		5		
Quercus stellata Wangenh.	45 (45)									
Quercus velutina Lam.	5 (5)									
Tilia americana L.	10									
Ulmus alata Michx.	130 (55)	20								
Ulmus americana Michx.		5								

Georgia) and a long temporal lag since the last major ice storm have allowed successional changes to occur within the forest. These changes follow normal successional trends for forests toward the climax stage and have implications for other late successional mixed forest communities in the southeastern United States.

Changes in the Mixed Forest Community

Basal area in the initial survey (Lipps 1966) was 16.8 m^2/ha in the mixed forest community of Marshall Forest, increased to 24.6 m^2/ha in 1989 (Fail 1991), and is presently 27.0 m^2/ha. The low value in the initial survey is likely a result of a severe ice storm that impacted northwest Georgia in 1960; the resulting mortality, though not well documented, was likely significant and reduced basal area for the initial survey period. During the last 55 yr, trees have reestablished and grown, evidenced by the current increase in basal area and decrease in stem density over the last survey.

The changes in importance values and present diameter distributions are telling for the fate of the mixed forest community. *Quercus montana* decreased in importance by 25% since the 1989 study, likely due to the loss of a few large trees. While it was not observed, there is a concern for forest pathogens impacting forest communities such as those found in Marshall Forest (e.g., oak decline and oak wilt, *Ceratocystis fagacearum* (Bretz) Hunt; Rexrode and Brown 1983, Oak 2002, Jones et al. 2016). Analysis of the diameter distributions reveals *Q. montana* stems in most diameter classes and a high proportion of seedlings (Table 2). This is likely due to the success of *Q. montana* on sloped sites where it competes well (Abrams 2003), although McQuilkin (1990) noted that in more mesic areas *Q. montana* can be out-competed by *L. tulipifera*, *Q. alba*, and *A. rubrum* L. Further monitoring will be necessary to determine whether *Q. montana* continues to decline in this forest community. Other declines in IV were found for *C. florida*, *C. tomentosa*, *O. arboreum*, and *Q. alba*. *Carya tomentosa* only decreased by approximately 11%, likely the result of mortality for some larger stems. *Quercus alba* increased in IV between 1960 to 1989 from 6.7 to 9.9 (likely the result of growth release following the 1960 ice storm; Fail 1991), but IV has declined 17% through 2015, to 8.2. The increased IV for *L. tulipifera* is likely the result of continual sapling recruitment since 1960. *Liriodendron tulipifera* is not tolerant of shade, overcoming this by being a prolific producer of seedlings that grow into the midstory after disturbance (Olson 1969, Whitney and Johnson 1984, Rhoades 2002). There was a drastic decrease in *L. tulipifera* reported by Fail (1991); the resurgence since

Table 3. Seedling counts per hectare in Flower Glen near Rome, Georgia, during summer 2015.

Species/Group	Seedlings
Quercus spp.	845
Carya spp.	425
Pinus spp.	260
Acer rubrum	2,355
Other hardwoods	375

may be the resultant growth of continued recruitment of saplings. Without a disturbance producing canopy gaps, *Liriodendron tulipifera* is likely to decline in the future and should be monitored. The canopy has continued to close, impacting seedling recruitment in favor of *Q. montana*, *L. tulipifera*, and *A. rubrum* (McQuilkin 1990, Abrams 2003). In this study site, *Q. alba* has few saplings available in the event of release, although there are likely sufficient seedlings available at present (Tables 2 and 3).

Commonly associated understory species, *C. florida* and *O. arboreum*, have historically been found in abundance in the forest (Lipps 1966). *Cornus florida* has experienced a steady decline since the initial survey, which may be impacted by dogwood decline, the result of the fungus *Discula destructiva* Redlin. The Appalachian ecoregion was particularly impacted, with widespread decline throughout the area (Oswalt and Oswalt 2010). The state of Georgia alone experienced a decrease in *C. florida* populations of 42% between 1989 and 2007 (Oswalt et al. 2012). Since 1960, IVs for *C. florida* have decreased by 50%. The drastic decline (75% during the last 27 yr) in sourwood (*O. arboreum*) is intriguing, particularly given its increase in IV through 1989 (Table 1) and the favorability of the environment. Coder (2011) notes that mortality for *O. arboreum* is high by the time the trees reach DBH of 10.2 cm. *N. sylvatica* Marshall and *A. rubrum* may grow unchecked in this area as a result of competition and absence of fire (Thinsp and Evans 1997, McDonald et al. 2002).

Regeneration and Succession

To maintain a balance in forests, trees must regenerate and successfully recruit seedlings and saplings from the understory. Given that Marshall Forest has been considered a disturbance-dependent, subclimax forest, this is of particular importance as disturbance helps maintain the oak-pine forest (Whitney and Johnson 1984). In the absence of disturbance, such as fire, shade-tolerant species, such as *A. rubrum* and *N. sylvatica*, are allowed to establish. Then following crown openings, through windthrow or ice storms, the less shade-tolerant species could release into the midstory. The low basal area reported by Lipps (1966) was immediately following a devastating ice storm, which occurred just before the study began in 1960. As basal area increased and the number of stems decreased, canopy closure occurred and the shade-tolerant species were able to establish at the expense of less shade-tolerant species. In a dedrochronological analysis of Marshall Forest, Petrucelli et al. (2014) found that Marshall Forest has experienced no establishment of *Pinus* spp. since the 1940s and no establishment of *Quercus* spp. since the 1950s. This is verified in the mixed forest community for *Pinus* spp. as there are no sapling-sized *Pinus*, although there were a few *Quercus* saplings (Table 2). However, given that fire has been excluded from the landscape since the 1920s and the last large-scale disturbance being the ice storm in 1960 (Petrucelli et al. 2014), there have been no canopy openings to allow for sapling recruitment into the midstory or canopy.

Seed production is likely not the issue, but the lack of mature, seed-producing trees may be. Seedlings identified within the study area are telling regarding the future of the forest. On a per hectare basis, *A. rubrum* L. is, by far, the most abundant seedling, comprising greater than 55% of all seedlings, followed by *Quercus* spp., *Carya* spp., other hardwood species, and pine (Table 3). *Pinus* spp. historically made up a larger percentage of other forest communities, and it would be interesting to determine whether this trend in low seedling and sapling numbers occurs in other communities as well. The impacts of wildlife species is another consideration given the low seedling and sapling numbers, as wildlife feed on the seeds produced by hardwoods, as well as browse sapling-sized trees (Abrams 1998, Thomas-Van Gundy et al. 2014). While population levels (species and abundance) for wildlife, for example *Odocoileus virgnianus* Zimmermann, are unknown, they could have an impact via browse on sapling sized trees, seedlings, and seed in the study area.

Acer rubrum

Acer rubrum is viewed as a "super-generalist" by being able to behave as both an early and late successional species and by being able to survive in a wide variety of edaphic conditions, therefore promoting its increase in both disturbed and fire-suppressed landscapes (Abrams 1998, McDonald et al. 2002). The prevalence of *A. rubrum* has been historically checked by disturbance such as fire, to which *A. rubrum* has little tolerance, or the creation of canopy gaps through storm damage (e.g., ice, wind, etc.) or harvest that lead to greater opportunities for other species (i.e., oaks) to grow into the midstory and maintain dominance (McDonald et al. 2002, Thomas-Van Gundy et al. 2014). With no detectable fire since the 1920s (Petrucelli et al. 2014), *A. rubrum* is allowed to grow freely and has increased in both importance and sapling density over the past 55 yr (Lipps 1966). After the ice storm in 1960, *A. rubrum* became increasingly established (Petrucelli et al. 2014). It is likely that, at this point, even should gaps be created, *Quercus* saplings would be unable to compete and reestablish dominance, as seed production and sprouting abilities of *A. rubrum* provide overwhelming competition (Abrams 1998). Given the sparsity of *Quercus* seedlings, the trend toward dominance of *A. rubrum* and other more shade-tolerant species is likely (Lorimer 1984).

It would be difficult to remove or control *A. rubrum* and/or *N. sylvatica* in this forest as it lies within an urban center with slopes that approach 60% in places, making prescribed fire extremely difficult. Even in areas where the canopy is open, *A. rubrum* saplings are more abundant than other tree species. Comparisons with other forest types should also be considered.

Future research is needed regarding changes throughout the forest. The initial survey (Lipps 1966) covered the length of the forest and three distinct communities (i.e., oak-pine, *Q. montana*, and mixed forest). Additional work could offer insight into changes within and between these communities over the last 50-plus yr. This study was limited by virtue of only having five plots initially established in this study area. Given the changes in slope and aspect as one moves toward the interior of the forest, these variables should be analyzed to determine any effect on species composition. Future work in the forest will incorporate a greater number of plots stratified by slope position and aspect. This and future research can offer many insights into global managed and unmanaged forest systems in light of changing climate and management objectives.

LITERATURE CITED

Abrams, M.D. 1992. Fire and the development of oak forests. BioScience 42:346–353.

Abrams, M.D. 1998. The red maple paradox. BioScience 48:355–364.

Abrams, M.D. 2003. Where has all the white oak gone? BioScience 53:927–939.

Abrams, M.D. and C.A. Copenheaver. 1999. Temporal variation in species recruitment and dendroecology of an old-growth white oak forest in the Virginia Piedmont, USA. Forest Ecol. Managem. 124:275–284.

Braun, E.L. 1950. Deciduous forests of eastern North America. Hafner Publishing Company, New York, New York.

Burns, R.M. and B.H. Honkala (technical coordinators). 1990. Silvics of North America. USDA Forest Service Agricultural Handbook, No. 654. Washington, D.C.

Coder, K.D. 2011. Sourwood-*Oxydendrum arboreum*: the honey tree. Native Tree Series, Publication WSFNR11-13. Warnell School of Forestry and Natural Resources, The University of Georgia, Athens, Georgia.

Copenheaver, C.A., J.M. Matthews, J.M. Showalter, and W.E. Auch. 2006. Forest stand development patterns in the southern Appalachians. N. E. Naturalist 13:477–494.

D'Amato, A.W., D.A. Orwig, and D.R. Foster. 2009. Understory vegetation in old-growth and second-growth *Tsuga canadensis* forests in western Massachusetts. Forest Ecol. Managem. 257:1043–1052.

Fail, J. 1991. A 29-year resurvey of permanent plots in a northwest Georgia virgin forest. Castanea 56:176–180.

Fail, J. and R. Sommers. 1993. Species associations and implications of canopy change for an endangered mint in a virgin oak-hickory-pine forest. J. Elisha Mitchell Sci. Soc. 109:51–54.

Jones, J.C., B.N. Hodges, J. Tegt, and A.B. Butler. 2016. Invasive non-native species and wild turkey in the southeastern United States. *In:* Miller, D.A. (ed.). Proceedings of the National Wild Turkey Symposium 11:89–103. National

Wild Turkey Federation, Edgefield, South Carolina.

Lipps, E.L. 1966. Plant communities of a portion of Floyd County, Georgia: especially the Marshall Forest. Ph.D. dissertation. University of Tennessee–Knoxville, Knoxville, Tennessee.

Lipps, E.L. and H.R. DeSelm. 1969. The vascular flora of the Marshall Forest, Rome, Georgia. Castanea 34:414–432.

Lorimer, C.G. 1984. Development of the red maple understory in northeastern oak forests. Forest Sci. 30:3–22.

McDonald, R.I., R.K. Peet, and D.L. Urban. 2002. Environmental correlates of oak decline and red maple increase in the North Carolina Piedmont. Castanea 67:84–95.

McQuilkin, R.A. 1990. *Quercus prinus* L. chestnut oak. p. 721–726. *In*: Burns, R.M. and B.H. Honkala (technical coordinators). Silvics of North America. Vol. 2. Hardwoods. Agriculture Handbook 654. Department of Agriculture, Forest Service, Washington, D.C.

Oak, S.W. 2002. Native diseases and insects that impact oaks. p. 80–99 *In:* McShea, W.J. and W. M. Healy (eds.). Oak forest ecosystems: ecology and management for wildlife. Johns Hopkins University Press, Baltimore, Maryland.

Olson, D.F. 1969. Silvical characteristics of yellow-poplar (*Liriodendron tulipifera* L.). USDA Forest Service, Research Paper SE-48. Southeastern Forest Experiment Station, Asheville, North Carolina.

Oswalt, C.M. and S.N. Oswalt. 2010. Documentation of significant losses in *Cornus florida* L. populations throughout the Appalachian ecoregion. Int. J. Forestry Res. 2010:1–10. http://dx.doi.org/10.1155/2010/401951.

Oswalt, C.M., S.N. Oswalt, and C.W. Woodall. 2012. An assessment of flowering dogwood (*Cornus florida* L.) decline in the eastern United States. Open Journal of Forestry 2(2): 41–53.

Petrucelli, C.A., J. Sakulich, G.L. Harley, and H.D. Grissino-Mayer. 2014. Structure and dynamics of an old-growth pine-oak community of the southern Appalachians, Georgia, U.S.A. S. E. Geog. 54:161–182.

Rexrode, C.O. and D. Brown. 1983. Oak wilt. U.S. Forest Service, Forest and Insect Disease Leaflet No. 29. (http://www.na.fs.fed.us/spfo/pubs/fidls/oakwilt/oakwilt.htm, 10 July 2016).

Rhoades, R.W. 2002. Post-disturbance changes in the understory of an oak forest in southwestern Virginia. Castanea 67:96–103.

Sakulich, J.B. 2011. A dendrochronological approach for analyzing the geographic range structure of tree species. Ph.D. dissertation. University of Tennessee–Knoxville, Knoxville, Tennessee.

Thinsp, J.K.H. and J.P. Evans. 1997. Effects of anthracnose on dogwood mortality and forest composition of the Cumberland Plateau (U.S.A.). Conservation Biol. 11:1430–1435.

Thomas-Van Gundy, M., J. Rentch, M.B. Adams, and W. Carson. 2014. Reversing legacy effects in the understory of an oak-dominated forest. Canad. J. Forest Res. 44:350–364.

Whitney, H.E. and W.C. Johnson. 1984. Ice storms and forest succession in southwestern Virginia. Bull. Torrey Bot. Club 111: 429–437.