AMERICAN CHESTNUT, RHODODENDRON, AND THE FUTURE OF APPALACHIAN COVE FORESTS

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Abstract—By the mid 1930s, the southern Appalachians had been heavily cutover and the dominant hardwood, American chestnut (Castanea dentata), had succumbed to the chestnut blight (Cryphonectria parasitica). Forests that had been burned on a frequent basis for millennia were now protected and fire was excluded in large degree. We estimated the pre-blight importance of chestnut in cove forests and the recovery of the overstory canopy on these rich sites following the blight and logging early in the last century. The overstory has largely recovered from the blight, although chestnut is not longer a functional component of the cove forest ecosystem. Following the blight, the successional pathway on two unlogged, old-growth sites proceeded to an oak association; on two logged sites, succession proceeded to mesophytic forests. A gradual change in the understory has occurred in many coves that threatens their future diversity and productivity. Encroaching rhododendron (Rhododendron maximum) thickets are severely inhibiting hardwood regeneration and reducing herbaceous/shrub species richness. Neither shade-tolerant nor shade-intolerant hardwood species are becoming established in canopy-gaps where rhododendron is present in moderate to high densities. Rhododendron has become an ecologically dominant species because it thrives on disturbance and, once established, inhibits other species. New management techniques will have to be developed if diversity and productivity of cove hardwood forests are to be sustained.

INTRODUCTION

Throughout the past century, hardwood forests of the southern Appalachians have undergone major changes as they recovered from heavy logging, loss of American chestnut to a blight, and exclusion of frequent fires. Nearly all of the southern Appalachian Mountains were heavily cutover between 1880 and 1930. The chestnut blight (*Cryphonectria parasitica*), introduced in the Northeast in the early 1900s and regarded as the most devastating ecological event ever recorded in the southern Appalachians, essentially removed that species as a canopy dominant by the late 1930s. Recovery of the forest overstory following the blight is well documented (Keever1953, Nelson 1955, Woods and Shanks 1959, Runkle 1982); however, effects of chestnut's demise on shrub and herb synusia have rarely been described.

Another major disturbance that shaped the current composition and structure of the region's forests was the exclusion of frequent fire as an ecological process. Exclusion of fire is regarded as a disturbance because it is a deviation from the normal burning regime that existed in the southern Appalachians for millennia. Burning by native Americans would have created a mosaic of vegetative conditions but the general appearance would have been a more open forest with a greater abundance of herbaceous vegetation (Van Lear and Waldrop 1987, Barden 1997, Delcourt and Delcourt 1997). Exclusion of fire allowed rhododendron (*Rhododendron maximum*), an ericaceous woody shrub, to extend its influence far beyond the streamsides where it occurred at the turn of the past century (Ayres and Ashe 1902, Monk and others 1985).

Expansion of rhododendron is a concern for hardwood forest managers because recruitment of canopy tree seedlings is inhibited under the dense cover of rhododendron (Hedman and Van Lear 1994, Clinton and others 1994, Clinton and Vose 1996, Baker and Van Lear 1998). It is debatable whether hardwood seedlings, once established, can grow through rhododendron thickets and become overstory trees, thereby sustaining the diversity and productivity of cove forests. The density and size of rhododendron thickets determines whether hardwood seedlings can successfully become established.

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This paper summarizes results of several separate, but related, studies conducted over the past decade in cove/ riparian forests of the southern Appalachians. Our objectives were to: 1) quantify the importance of pre-blight chestnut in these forests, 2) describe forest recovery following logging and the chestnut blight, with special emphasis on the understory and regeneration layers, 3) identify relationships between density of rhododendron thickets and species richness/ regeneration, and 4) examine effects of rhododendron on canopy-gap dynamics and establishment of forest regeneration. All studies were conducted on the lower slopes of coves, i.e., riparian forests, within 35 meters of a stream. From this point, we will call these cove forests.

METHODS

Study Areas

All studies were conducted in the Blue Ridge physiographic province of the southern Appalachians. Study sites were located on the Sumter National Forests in South Carolina, the Chattahoochee National Forest in Georgia, and the Pisgah and Nantahala National Forests in North Carolina. Soils on these sites are classified as Typic Dystrochrepts, and are commonly 50-152 centimeters deep. This area experiences a temperate humid climate with a growing season of approximately 180 days. Most of the ample precipitation occurs in the growing season.

Methods for each of the studies are summarized below. Refer to published papers by the authors for greater detail on methods. In this paper, rhododendron refers to *Rhododendron maximum*, which was by far the most dominant ericaceous shrub on study sites.

Chestnut's Importance in Cove Forests

Four forest sites containing chestnut were selected along first- or second-order streams (elevations 363 to 780 meters). Two of the sites, Thomas Creek and Tallulah River, showed signs of chestnut salvage logging and general logging in the past, while the other two sites, Slatten Branch and Little Santeetlah Creek, were remnant old-growth stands with no evidence of ever having been logged. All identifiable chestnut snags were measured for ground-line diameter (GLD) and diameter breast height (DBH), where possible, along stream reaches ranging in length from 363-780 meters. A total linear distance of 3.1 kilometers was surveyed on the four sites, representing 16.4 hectares of southern Appalachian cove forests (Vandermast and Van Lear 2001).

We identified 589 chestnut snags and stumps in the riparian forests of the four study sites, 207 of which were intact enough to obtain accurate DBH data. Using the derived linear relationship between DBH and ground-line diameter (R^2 = 0.947), we estimated DBH of the remaining chestnuts whose ground-line diameter only could be estimated.

Forest Recovery Following the Blight and Logging

Composition of the current cove forest at the four sites was determined by sampling 7x 7 meter plots centered around 58 randomly selected chestnut stumps or snags (10 percent of the 589 identified). Herbaceous vegetation was sampled within five 1 square-meter quadrats in each plot. Trees and seedlings were tallied by species on 0.04 hectare plots and saplings on 0.025 hectare plots using the Braun-Blaunquet cover class method. Rhododendron stems were counted in each 0.04 hectare plot.

Species richness was calculated and compared among sites and between old-growth and logged sites. Frequency values, i.e., the proportion of plots containing a species, were used to compare old-growth to logged forests and to compare plots with high and low rhododendron importance values. Regeneration of overstory hardwood species was regressed against rhododendron coverage (Vandermast and Van Lear 2001).

Relationships Between Rhododendron Coverage and Species Richness

Fifty-five 10x20 meter plots were randomly located along Wine Spring Creek in the Nantahala National Forest. All stems > l centimeter basal diameter were recorded by species in each plot. Average dbh, density, basal area, and importance value (relative density + relative basal area/2) were calculated for each species by canopy strata. Diameter of each rhododendron stem was measured and placed into I centimeter diameter classes. Biomass of rhododendron foliage and stems was estimated from allometric equations developed from 41 randomly chosen stems ranging from 1 to 4 centimeters basal diameter.

The regeneration layer (woody and herbaceous stems < 1 centimeter basal diameter) was inventoried on five transects, each 10 meter long, across the width of each plot. Frequency and percent cover of each species that intersected the transect were recorded by 1 meter intervals and importance values (relative frequency + relative coverage/2) were calculated. Discriminant analysis, using basal area and stem density, was used to quantitatively classify the 55 sample plots into four discrete rhododendron thicket-density categories (Baker and Van Lear 1998).

Effects of Rhododendron on Canopy-Gap

Dynamics

Twenty-two canopy gaps (elevations from 518 to 758 meters) resulting from wind-throws were selected in southern Appalachian cove forests. Eleven of the canopy gaps contained understories of rhododendron with a minimum density of 2000 stems/hectare and eleven other gaps contained no rhododendron. Selected gaps had to meet certain criteria, including 1) being less than 7 years old, 2) occupying only mesic site types, and 3) being within 35 meters of a stream. Gap size ranged from one-tree openings to larger gaps resulting from the death of up to six trees (Rivers and others 2000).

Vegetation was sampled along two gradients: 1) longest distance across the gap, and 2) a shorter distance perpendicular to the first. The two gradient lines intersected at the center of the gap. Advanced regeneration and new seedlings were inventoried in 1 meter wide transects located along each of the two principle gradient lines. Transects

Table 1—Mean diameter (DBH) and basal area (BA) for chestnuts and live trees on four southern Appalachian cove forest sites

Site	Chestnut		Live Trees	
	DBH (cm)	BA/ha (m^2)	DBH (cm)	BA/ha (m^2)
Old-growth				
Slatten Branch	56.2a[a]	8.9a	26.2a	22.7a
Little Santeetlah	73.7c	12.3c	28.6a	37.5a
Logged				
Thomas Creek	43.9b	8.4b	26.9a	28.8a
Tallulah River	53.6a	10.0a	27.6a	32.9a

[a] Means followed by the same letter within a column are not significantly different at the 0.01 level.

were divided into 1 meter sections to distinguish vegetative preference from the center of the gap towards the surrounding undisturbed forest. Percent cover of rhododendron was estimated and placed into Braun-Blaunquet category classes for each 1 square-meter section and averaged to determine total percent cover for each gap. The area of a gap was determined using the formula for an ellipse.

All stems < 10 centimeter ground-line-diameter were considered understory and all stems > 10 centimeter gld were considered either midstory or overstory. Stems < l centimeter were considered part of the regeneration layer. Importance Values were calculated as described above.

Statistical Analyses

Chestnut and current live stem diameters and basal areas were compared among logged and old-growth sites using PROC GLM and Analysis of Variance in SAS (SAS Institute,

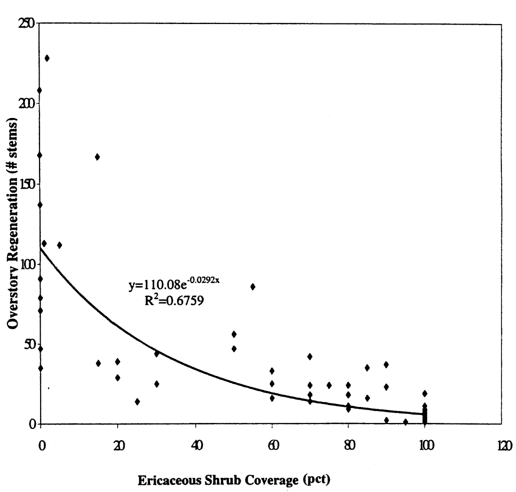

Figure 1—Effects of increasing ericaceous shrub coverage (predominantly *Rhododendron maximum*) on a number of regeneration stems (seedlings and saplings) of overstory tree species on 0.04 hectacre plots

Inc. 1987). Tukey's Least Significant Difference Test and orthogonal contrasts were used to make specific tests. Regression analysis was used to develop a model predicting chestnut DBH from ground-line diameters. Forest recovery plots were clustered based on similar vegetative composition using Detrended Correspondence Analysis (DECORANA) and Two-way Indicator Species Analysis (TWINSPAN) (Hill 1970). Discriminant analysis was used to categorize Wine Spring Creek plots into different levels of rhododendron-thicket densities using PROC DISCRIM (SAS Institute, Inc. 1987). Differences in regeneration layer richness and cover among rhododendron density categories were tested with PROC GLM. Non-linear regression was used to quantify relationships between species richness and rhododendron coverage in canopy gaps.

RESULTS

Chestnut's Importance in Riparian Forests

Chestnut was an important component of southern Appalachian cove forests (table 1). Average DBH of standing chestnut snags was about 2 - 2.5 times larger than that of live trees currently growing on old-growth and logged sites (Vandermast and Van Lear 2001). Chestnut basal area ranged from 8.9 to 12.3 square meters per hectare, suggesting that the species represented between 25 to 40 percent of the pre-blight lower cove forest if current conditions are similar. Old-growth sites tended to have larger diameter trees than logged sites, although only chestnuts on Little Santeetlah Creek were significantly larger.

Following the Blight and Logging

On unlogged, old-growth sites, current overstory composition indicates forest succession following the chestnut blight produced an oak association with a component of mesophytic species such as Eastern hemlock (*Tsuga canadensis*) and black birch (*Betula lenta*) (Vandermast and Van Lear 2001). On logged sites, current overstory composition is dominated by cove mesophytic species, such as yellow-poplar (*Liriodendron tulipifera*), black birch, red maple (*Acer rubrum*), and Eastern hemlock. Seedling-sized sprouts of American chestnut are still common in these riparian forests, although no sapling-sized sprouts were tallied. Chestnut sprouts were absent in rhododendron thickets, which were significantly denser in logged forests. Overstory regeneration (seedlings and saplings) was negatively impacted by rhododendron (figure 1), decreasing exponentially as rhododendron coverage increased. The only species capable of successfully regenerating in dense rhododendron thickets was Eastern hemlock, and even this shade-tolerant conifer had low stem densities when rhododendron density was high. Rhododendron was ubiquitous on both the logged and old-growth sites, occurring on 81 to 90 percent of the 58 plots. The two logged sites had significantly denser rhododendron thickets ($p = 0.0094$) than the two-old growth sites.

Relations Between Rhododendron Coverage and Species Richness

Density and biomass of rhododendron were characterized in the understory of a second-growth riparian forest dominated by yellow birch (*Betula alleghaniensis*) and black birch (age about 42 - 44 years old) (Baker and Van Lear 1998).

Table 2—Range of rhododendron stem density and biomass in each thicket density category

Rhododendron thicket density	Stem density (thousands/hectare)	Above-ground biomass (tons/hectare)
High	8.0 - 17.4	18.1 - 34.0
Medium	5.1 - 10.5	8.7 - 18.3
Low	2.8 - 6.5	2.9 - 8.4
Scarce	0.0 - 2.6	0.0 - 3.0

Table 3—Effects of rhododendron density on species richness in the regeneration layer during Fall and Spring sampling periods

Rhododendron thicket density	Richness (# species)	
	Fall	Spring
High	6a[a]	7a
Medium	9ab	12b
Low	18c	22c
Scarce	26d	29d

[a] Means followed by the same letter within a column are not significantly different at the 0.01 level.

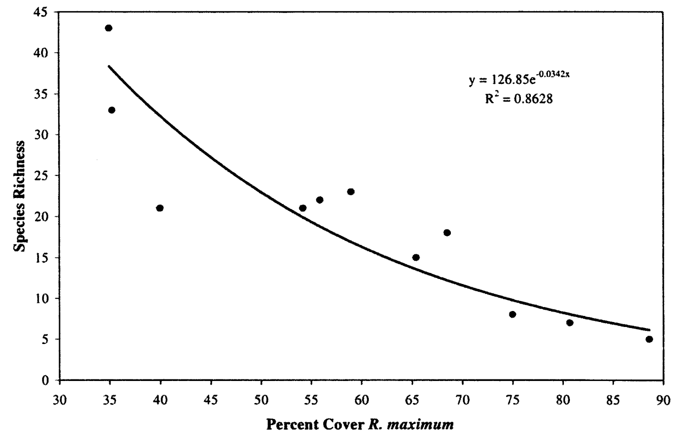

Figure 2—Relation between species richness and percent cover of rhododendron in southern Appalachian forest gaps

Rhododendron densities exceeded 17,000 stems per hectare in high coverage plots and biomass reached 34 tons per hectare (table 2). Basal area of rhododendron thickets averaged 11 - 22 square meters per hectare where thicket density was high.

Total species richness in the regeneration layer and percent rhododendron cover were inversely related (R^2 = 0.92) (Baker and Van Lear 1998). On average, 6-7 plant species were found on plots with high densities of rhododendron whereas 26-29 species were found where rhododendron was scarce or absent (table 3). Cover of species other than rhododendron ranged from 5 percent where rhododendron density was high to 43-62 percent where its density was classified as scarce. Similar relationships were found by Hedman and Van Lear (1994) and Vandermast and Van Lear (2001).

Based on aging of stems through ring counts, rhododendron apparently began to dominate the understory of this birch-dominated forest on Wine Spring Creek within 15-20 years after logging (Baker and Van Lear 1998). It has increased in density and coverage and is now so dominant in terms of number of stems, basal area and biomass that it appears doubtful that valuable hardwood species such as yellow-poplar, yellow and black birch, black cherry (*Prunus serotina*), sugar maple, basswood (*Tilia americana*), yellow buckeye (*Aesculus octandra*), Fraser magnolia (*Magnolia fraseri*), and others will be able to establish themselves. In the regeneration layer of rhododendron thickets on the Wine Spring Creek site, Eastern hemlock, red maple, American beech (*Fagus grandifolia*), yellow birch, and Northern red oak (*Quercus rubra*) were present in small numbers. However, rhododendron so dominated the regeneration and understory layers that it appeared unlikely that many of these will reach midstory and overstory strata.

Effects of Rhododendron on Canopy-Gap Dynamics

Average canopy gap size in this study was 157 square meters (range 41 to 286 square meters). Species richness decreased exponentially as rhododendron coverage increased in canopy gaps (figure 2). Average midstory density, an indicator of whether woody species are becoming established in the stand, was 10 fold less in gaps containing rhododendron. Where rhododendron was present prior to gap formation, there was little advanced regeneration and, if present, it was not developing into the midstory. Herbaceous density was even more adversely affected by the presence of rhododendron in gap understories.

As density of the rhododendron understory increased under canopy gaps, shade- intolerant species such as yellow-poplar were eliminated and shade-tolerant species such as sugar maple were severely reduced to levels where little or no recruitment into the overstory occurred (Rivers and others 2000). Eastern hemlock, an extremely shade-tolerant conifer, was the only species capable of regenerating in canopy gaps where moderately dense rhododendron thickets occurred, and even here hemlock tended to regenerate in small patches where rhododendron coverage was lower. Maximum above-ground biomass of rhododendron measured in this study was 37 tons per hectare, similar to that estimated in an earlier study by Baker and Van Lear (1998).

Average tree seedling height was greater in gaps without rhododendron than in those with it, except for intolerant species near the gap edge where shading from the adjacent overstory reduced growth. Seedling height of intolerant species like yellow-poplar and sweet birch significantly decreased as distance from the center of the gap increased, whereas height of shade-tolerant species like red maple and Eastern hemlock varied little along gap gradients.

DISCUSSION

Due to its sensitivity to frost, glaze, and ice (Parker et al. 1993), American chestnut has been thought to be unsuited for ravines and valleys. Chestnut was most often listed as a dominant species on ridges (Abrams and Ruffner 1995, Abrams and McCay 1996) and mid-slope areas (Whitaker 1956). While recognized as a member of cove forests (Ayers and Ashe 1902, Woods and Shanks 1959, Lorimer 1980, McCarthy and Bailey 1996), chestnut had never been quantitatively described in cove forests.

American chestnut was clearly a dominant tree in southern Appalachian cove forests. The species had a larger average diameter and made a greater contribution to basal area than any species of the current live tree association. Results of the studies reported here support data from Hedman et al. (1996), who quantified the importance of chestnut as a major contributor of large woody debris to southern Appalachian streams. If chestnut comprises a large portion of a stream's large woody debris, the species must have been an important component of lower slopes in cove forests.

The demise of the chestnut has been implicated in the spread of rhododendron thickets (Woods and Shanks 1959, Clinton et al. 1994, Clinton and Vose 1996). Our results support this contention and also indicate that logging disturbance encourages the spread of rhododendron even more, as suggested by McGee and Smith (1967). Following the blight, the two unlogged, old-growth sites succeeded to an oak association dominated by white oak (*Quercus alba*), chestnut oak (*Q. prinus*), and Northern red oak, with a strong component of black birch and Eastern hemlock. The dominance of oak species on the two old-growth sites suggests that periodic fire had occurred in these stands prior to the blight, which allowed oaks to dominate the advance regeneration (Brose and Van Lear 1998, Brose and others 1999) and control rhododendron (Van Lear and Waldrop 1989, Van Lear 2000).

Logged sites succeeded toward a mixed mesophytic forest type dominated by yellow-poplar, Eastern hemlock, red maple, and black birch, with a small component of oaks and hickory. Logging disturbance, which provides a mineral soil seedbed and greater insolation, would be expected to favor pioneer species like yellow-poplar and black birch. Large canopy gaps (0.04 hectare and larger) are thought necessary for abundant regeneration of yellow-poplar (Busing 1993, 1995). Apparently, the deaths of individual chestnut trees in the two old-growth areas did not create gaps large enough for abundant yellow-poplar regeneration.

Rhododendron has replaced American chestnut as the ecological dominant in many cove forests of the southern Appalachians (Vandermast and Van Lear 2001). Following the chestnut blight, logging, and fire exclusion early in the last century, rhododendron has expanded far upslope and now tends to direct forest succession and development by affecting establishment and growth of advance regeneration and seedlings. With the exception of Eastern hemlock, no other woody species appeared to have the ability to attain overstory status on these study sites, although Phillips and Murdy (1985) and Clinton and Vose (1998) noted that red maple could regenerate and become established on some sites dominated by rhododendron. Herbaceous species richness declined markedly with increases in density of rhododendron thickets and after decades of rhododendron dominance may now be lost from certain sites in these riparian/cove forests.

The diversity of cove forests of the southern Appalachians is thought to be maintained through gap-phase disturbances (Barden 1981, Runkle 1982, Busing 1993). However, canopy gaps with medium density rhododendron thickets in the understory had no hardwood species in the midstory strata. Only Eastern hemlock was present in the midstory, indicating that most hardwood species will fail to become members of the overstory canopy.

Succession in rhododendron thickets appears to fit the Inhibition Pathway model proposed bv Connel and Slatyer (1977). In this model, certain plant species modify their environment so that recruitment of both early and late successional species is inhibited as long as current vegetation remains intact. Rhododendron dominates the regeneration layer and prevents successful recruitment of other species into other canopy strata because of its dense shade, acidic litter (Boettcher and Kalisz 1990) and possible allelopathic effects (Rice 1979, Nielsen et al. 1999). Without major disturbance, rhododendron will apparently occupy these sites indefinitely.

CONCLUSIONS

As overstories of southern Appalachian forests recovered from heavy logging, chestnut blight, and fire exclusion of the past century, rhododendron became the dominant understory component in many cove forests of the region. Rhododendron now poses a major threat to the sustained diversity and productivity of many cove forests. Recent research provides convincing evidence that expansion of rhododendron thickets has a detrimental effect on regeneration of high quality hardwood species, as well as adverse effects on the richness of the herbaceous layer. Canopy gaps created by various types of disturbances are not regenerating to hardwoods but are becoming denser and taller thickets of rhododendron. On some sites, successional trends indicate that thickets of this dense ericaceous shrub will become the climax vegetation.

Forest managers must find new methods to manage the hardwood resource in this region. A hands-off approach until final harvest will not regenerate diverse and productive hardwood forests on cove sites where rhododendron has become estabished. Ways to control the spread and reduce the biomass of rhododendron tickets must be found. Greater efforts are needed to understand community dynamics in Southern Appalachian cove forests and to learn how to direct successional patterns.

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REFERENCES

Abrams, M.D.; D.M. McCay. 1996. Vegetation-site relationships of witness trees (1780-1856) in the pre-settlement forests of eastern West Virginia. Canadian Journal of Forest Research. 26: 217-224.

Abrams, M.D.; C.M. Ruffner. 1995. Physiographic analysis of witness-tree distribution (1765-1789) and present forest cover through north central Pennsylvania. Canadian Journal of Forest Research. 25: 659-668.

Ayres, H.B.; W.W. Ashe. 1902. Description of the southern Appalachian forests, by river basins. Message from the President of the United States transmitting report of the Secretary of Agriculture in relation to the forests, rivers and mountains of the southern Appalachians. Appendix A. 192 p.

Baker, T.T.; D.H. Van Lear. 1998. Relations between density of rhododendron thickets and diversity of riparian forests. Forest Ecology and Management 109: 21-32.

Barden, L.S. 1981. Forest development in canopy gaps of a diverse hardwood forest of the southern Appalachian Mountains. Oikos 37: 205-209.

Barden, L.S. 1997. Historic prairies in the Piedmont of North and South Carolina, USA. Natural Areas Journal. 17: 149-152.

Boettcher, S.E.; P.J. Kalisz. 1990. Single-tree influence on soil properties in the mountains of eastern Kentucky. Ecology. 71: 1365-1372.

Brose, P.T.; D.H. Van Lear. 1998. Responses of hardwood advance regeneration to seasonal prescribed fires in oak-dominated shelterwood stands. Canadian Journal of Forest Research. 28: 331-339 p.

Brose, P.T.; D.H. Van Lear; P.D. Keyser. 1999. A shelterwood-burn technique for regenerating productive upland oak sites in the Piedmont region. Southern Journal of Applied Forestry. 23: 158-163.

Busing, R.T. 1993. Three decades of change at Albright Grove, Tennessee. Castanea. 58: 231-242.

Busing, R.T. 1995. Disturbance and the population dynamics of *Liriodendron tulipifera*: simulations with a spatial model of forest succession. Journal of Ecology. 83: 45-53.

Clinton, D.B.; L.R. Boring; W.T. Swank. 1994. Regeneration patterns in canopy gaps of mixed-oak forests of the Southern Appalachians: Influences of topographic positioned evergreen understory. American Midland Naturalist. l32: 308-319.

Clinton, B.D; J.M. Vose. 1996. Effects of *Rhododendron maximum* L. on *Acer rubrum* seedling establishment. Castanea. 61: 38-45.

Connell, J.H.; R.O. Slatyer. 1977. Mechanisms of succession in natural communities and their role in community stability and organization. American Naturalist. 111: 1119-1144.

Delcourt, H.R.; P.A. Delcourt. 1997. Pre-Columbian native American use of fire on Southern Appalachian landscapes. Conservation Biology. 11: 1010-1014.

Hedman, C.W.; D.H. Van Lear. 1994. Structure and composition of Southern Appalachian riparian forests. Bulletin Torrey Botanical Club. 122: 134-144.

Hedman, C.W.; D.H. Van Lear; and W.T. Swank. 1996. In-stream large woody debris loading and riparian forest seral stage associations in the southern Appalachian Mountains. Canadian Journal of Forest Research. 26: 1218-1227.

Hill, M.O. 1979. TWINSPAN: A FORTRAN program arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. Ithaca, NY: Cornell University Department of Ecology and Systematics.

Keever, C. 1953. Present composition of some stands of the former oak-chestnut forest in the southern Blue Ridge Mountains. Ecology 34: 44-55.

Lorimer, C.G. 1980. Age structure and disturbance history of a southern Appalachian virgin forest. Ecology 61: 1169-1184.

McCarthy, B.C.; D.R. Bailey. 1996. Composition, structure and disturbance history ofCrabtree Woods: an old-growth forest of western Maryland. Bulletin of the Torrey Botanical Club. 123: 350-365.

McGee, C.E.; R.C. Smith. 1967. Undisturbed rhododendron thickets are not spreading. Journal of Forestry. 65: 334-336.

Monk, C.D.; D.T. McGinty; F.P. Day, Jr. 1985. The ecological importance of *Kalmia latifolia* and *Rhododendron maximum* in the deciduous forest of the southern Appalachians. Bulletin of the Torrey Botanical Club. 112: 187-193.

Neilsen, E.T., J.F. Walker, O.K. Miller, S.W. Semones, T.T. Lei, and B.D. Clinton. 1999.Inhibition of seedling survival under *Rhododendron maximum* (Ericaceae): Could allelopathybe a cause? American Journal of Botany. 86: 1597-1612.

Nelson, T.C. 1955. Chestnut replacement in the southern highlands. Ecology. 36: 352-353.

Parker, G.G., S.M. Hill, and L.A. Kuehnel. 1993. Decline of understory American chestnut (*Castanea dentata*) in a southern Appalachian forest. Canadian Journal of Forest Research. 23: 259-265.

Phillips, D.L. and W.H. Murdy. 1985. Effects of rhododendron (*Rhododendron maximum* L.) on regeneration in southern Appalachian hardwoods. Forest Science. 31: 226-233.

Rice, E.L. 1979. Allelopathy, an update. Botanical Review. 45: 15-109.

Rivers, C.T., D.H. Van Lear, B.D. Clinton, and T.A. Waldrop. 2000. Community composition in canopy gaps as influenced by presence or absence of *Rhododendron maximum*. In: Haywood, J.D., ed. Proceedings of the Tenth biennial southern silvicultural research conference; 1999 February 16-18, Shreveport, LA. Gen. Tech. Rep. SRS-30. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 57-60.

Runkle, J.R. 1982. Patterns of disturbance in some old-growth mesic forests of eastern North America. Ecology 63: 1533-1546.

Runkle, J.R. 1985. Disturbance regimes in temperate forests. The Ecology of Natural Disturbance and Patch Dynamics. S.T.A. Pickett ;P.S. White, eds. New York: Academic Press: 17-33.

SAS Institute, Inc. 1987. SAS/STAT guide for personal computers, 6th ed. SAS Institute, Inc.,Gary, NC.

Vandermast, D.B.; D.H. Van Lear. (In press). Riparian forest recovery in the southern Appalachians following the chestnut blight. Forest Ecology and Management.

Van Lear, D.H.; T.A. Waldrop. 1989. History, uses, and effects of fire in the Appalachians. USDA Forest Service, Southeastern Forest Experiment Station, General Technical Report SE-54. 20p.

Waldrop, T.A., ed. 1989. Proceedings of pine-hardwood mixtures: a symposium on management and ecology of the type; 1989 April 18-19; Atlanta, GA. Gen. Tech. Rep. SE-58. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 271p.

Whitaker, R.H. 1956. Vegetation of the Great Smoky Mountains. Ecological Monographs. 26: l-80.

Woods, F.W.; R.E. Shanks. 1959. Natural replacement of chestnut by other species in the Great Smoky Mountains National Park. Ecology. 40: 349-361.