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Three Decades of Change at Albright Grove, Tennessee

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ABSTRACT

A 0.4 ha vegetation plot established in 1962 in Albright Grove, an old-growth cove forest in the Great Smoky Mountains, was resampled in 1992. A 0.6 ha plot encompassing the entire 1962 plot area was surveyed, mapped, and permanently marked in 1992. The diameter (dbh) and species of all live and dead tree stems >1.37 m tall were recorded in 10 0.04 ha contiguous plots in 1962, and in 60 0.01 ha contiguous subplots in 1992. Changes in the original 0.4 ha plot area over the 30-yr period are summarized here. The basal area of standing dead trees decreased from 15.7 to 3.5 m^2/ha. *Castanea dentata* accounted for 29% of the original, and 0% of the recent standing dead basal area. Live tree basal area and biomass increased from 47.3 to 57.7 m^2/ha, and 386 to 459 Mg/ha, respectively. Total stem density decreased from 642 to 563 stems/ha. Size-class distributions exhibited a gradual, log-linear decrease in stem density with increasing size at both sampling dates. No marked changes in species composition of the tree stratum were observed; *Acer rubrum* and *Tsuga canadensis* dominated at both sampling dates. Species-specific, radial growth rate means ranged from 0.7 to 2.2 mm/yr. Mortality rates for all canopy trees >30 cm dbh were in the 0.5 to 1.5%/yr range. Changes in the stand appeared to be driven by small canopy gap dynamics.

INTRODUCTION

Albright Grove is an old-growth stand of hemlocks and mixed deciduous tree species in the northeastern Great Smoky Mountains. Named after Horace M. Albright, a National Park Service director involved in the establishment of Great Smoky Mountains National Park, the grove is known for its large eastern hemlocks, tulip poplars, and red maples. The stand is representative of primeval cove forests of the southern Appalachians (Cain 1943, Braun 1950, Whittaker 1956).

Although forests in southern Appalachian coves are commonly termed "cove hardwoods," eastern hemlock (*Tsuga canadensis*) is a canopy dominant on moist sites in ravines and in flats along streams (Oosting and Billings 1939, Oosting and Bordeau 1955). Cain (1943) distinguishes primeval cove forest types in the

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Great Smoky Mountains on the basis of the dominant canopy species. The *Tsuga*-dominated segregates tend to have fewer deciduous woody plants in the understory and a less luxuriant herb layer than predominantly deciduous segregates (Cain 1943, Braun 1950). *Tsuga* is a major component of the canopy in much of Albright Grove, including the stand studied here. In many cove forests the shrub layer is a dense tangle of *Rhododendron maximum*, an evergreen species that appears to reduce the establishment of tree species that do not regenerate on fallen logs (Runkle 1985). The stand under study has a moderately dense layer of *Rhododendron* in the understory and the relative dominance of canopy species that regenerate on fallen logs (*Tsuga, Acer rubrum* and *Betula lutea*) is high.

Forest dynamics on southern Appalachian cove landscapes have been addressed in a variety of studies (Barden 1980, Lorimer 1980, Della-Bianca 1983, Leopold et al. 1985, Runkle and Yetter 1987, Clebsch and Busing 1989, Busing 1989). Investigations of forest response to disturbance have shown that disturbance patch size has profound effects on forest composition, structure and dynamics (Runkle 1981, 1982, 1985). Patch size is small (<0.05 ha) when disturbance is in the form of individual tree-fall gaps. The smallest gaps (<0.01 ha) tend to occur in second-growth stands where individual tree crowns are small and in old-growth stands where wind and ice storms may damage only a portion of the crown of canopy trees. These gaps may allow the regeneration of shade tolerant species, but not of intolerant species (Clebsch and Busing 1989). Tree-fall gaps in old-growth stands are often somewhat larger (0.01–0.05 ha) because of the large crown sizes attained by canopy trees. Intolerant species such as *Liriodendron tulipifera* and *Prunus serotina* are able to regenerate in gaps at the upper end of this size range and gap phase regeneration is believed to be a key factor in the persistence of intolerants in old-growth cove forest stands (Barden 1979, 1981). Larger natural disturbance patches are rare on the cove landscape. Because of the rarity of catastrophic disturbances resulting from fire and large-scale wind storms, most large-scale disturbances (>1 ha) are caused by human activities. For example, the cutting of cove forests for timber and agriculture was common in the Smoky Mountains prior to federal protection in 1934 (Pyle 1988). These large disturbance patches are now typically dominated by young (50–100 yr old) stands of *Liriodendron tulipifera*.

Changes in population structure, species composition, stand basal area, and stand biomass over the 30-year interval from 1962 to 1992 are presented in this paper for a 0.4 ha (1 acre) area in Albright Grove. Fates of individual canopy trees, alive in 1962, are determined, and rates of growth and mortality are estimated. In addition to yielding information on the dynamics and status of this particular stand, the analyses provide baseline information on change in old-growth cove forests of the southern Appalachians.

METHODS

The study site is located along the Albright Grove loop trail just east of Dunn Creek at 975 m above sea level (Mount Guyot USGS 7.5′ quadrangle map, Tennessee and North Carolina). The site is on a gentle (5–10°) north-facing slope with a slightly concave local topography.

A 0.4 ha area of forest was sampled with ten contiguous 20 × 20 m quadrats in 1962. A team of botanists from the University of Tennessee, including E.E.C. Clebsch, carried out the 1962 field work. At that time all live and standing dead individuals >1.37 m tall were measured for diameter at breast height (dbh) and tallied by species. Plot corners were not permanently marked in 1962, but the locations of landmark trees were noted.

In 1992 a 0.6 ha area encompassing the entire 1962 plot was sampled with sixty contiguous 10 × 10 m quadrats. The larger plot size ensured that the entire original plot area was sampled. The use of smaller quadrats in 1992 allowed higher spatial resolution and facilitated the creation of a stem map. Plastic stakes and aluminum tree tags were used to mark quadrat corners. As in 1962 live individuals >1.37 m tall were tallied by species; shrubs were not included. Live stems were separated into two size classes: 1) trees (>2 cm dbh), and 2) saplings (≤2 cm dbh). Diameters were recorded for live trees, but not for saplings. Numbered aluminum tags were attached to live individuals (>4 cm dbh) 10 cm below breast height and each tagged stem was mapped for future reference. Standing dead individuals >10 cm dbh were also tallied, measured, and mapped. In each quadrat, a radial increment core 2–3 cm in length was extracted from the largest tree and from the tree (>10 cm dbh) closest to the SW corner. Cores were subsequently mounted, sanded, and measured for radial growth increments.

Following data collection, boundaries of the 0.4 ha plot established in 1962 were drawn on the 0.6 ha plot map from 1992. Boundary locations were determined by noting which trees encountered in 1992 were in or out of certain quadrats of the 1962 plot. Except for the radial growth increment data, the information presented in the results section is from the 0.4 ha area sampled in 1962.

Mortality estimates were made by noting which live trees from 1962 no longer had a suitable live match. This could be done with confidence for trees >30 cm dbh in 1962. Percent annual mortality rates were calculated as a linear function of time where,

$$\text{Annual mortality rate} = 100(\text{No. dead/No. original/30 yr}).$$

Since the fates of all trees <30 cm dbh in 1962 could not be determined, all individuals in this size range were excluded from the mortality calculations.

Nomenclature follows Radford et al. (1968).

RESULTS

Stand level changes

One of the most notable differences in stand parameters over the 30-yr period is a sharp decrease in the basal area of standing dead trees from 15.7 to 3.5 m^2/ha (Table 1). In 1962, *Castanea dentata* accounted for 29 percent and *Tsuga* accounted for 65 percent of the dead tree basal area. By 1992 all of the dead *Castanea* trees and most of the dead *Tsuga* trees had fallen, resulting in much lower basal area of standing dead trees.

Live tree basal area and biomass increased moderately over the period, while live stem density declined (Table 1). Sapling layer density also decreased. Size-class analysis revealed a higher number of small stems (<15 cm dbh) in

Table 1. Stand parameter changes over the 1962–92 period

Stand Attribute	1962	1992
Leaf mass (Mg/ha)	4.64	5.48
Branch mass (Mg/ha)	90.81	102.38
Bole mass (Mg/ha)	290.12	350.87
Tree mass (Mg/ha)	385.58	458.73
Live tree basal area (m^2/ha)	47.3	57.7
Dead tree basal area (m^2/ha)	15.7	3.5
Tree density (>2 cm dbh, stems/ha)	642	563
Sapling density (0–2 cm dbh, stems/ha)	156	119

1962 than in 1992 (Figure 1). The number of moderately large stems (50–85 cm dbh) was lower in 1962, however. In general, both size-class distributions indicated a gradual, log-linear decrease in density with increasing size.

Changes in species composition

No marked changes in composition over the period were evident. *Acer rubrum* and *Tsuga canadensis* dominated in 1962 and in 1992 (Table 2). The

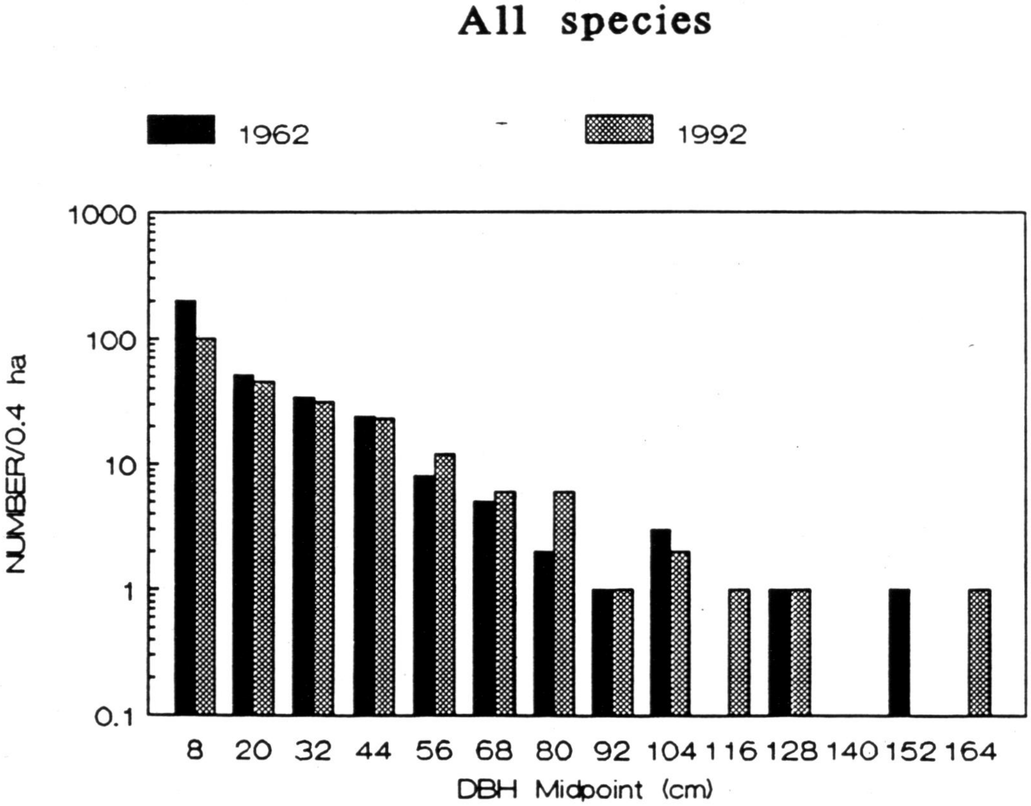

Figure 1. Size-class structure of the tree stratum in 1962 and in 1992.

Table 2. Changes in species composition over the 1962–92 period. All individuals >2 cm dbh are included

Species	Relative Basal Area (%)		Relative Density (%)	
	1962	1992	1962	1992
Acer rubrum	24	28	10	9
Tsuga canadensis	23	28	35	47
Halesia carolina	23	14	29	17
Betula lutea	8	9	6	7
Fagus grandifolia	8	5	8	4
Liriodendron tulipifera	3	5	2	1
Tilia heterophylla	3	2	3	2
Acer saccharum	3	1	2	6
Betula lenta	2	1	4	2
Prunus serotina	2	2	<1	<1
Magnolia fraseri	<1	1	<1	1
Fraxinus americana	<1	4	<1	1
Aesculus octandra	<1	<1	1	1
Ilex opaca	0	<1	0	<1

relative basal area of *Halesia carolina* exhibited a moderate decrease, as did that of *Fagus grandifolia.* Two intolerants, *Liriodendron tulipifera* and *Fraxinus americana,* increased in relative basal area. Notable changes in density included an increase in *Tsuga* relative density and a decrease in *Halesia carolina* relative density. The density of several species changed markedly in the sapling layer (Table 3). For example, *Acer saccharum* and *Tilia heterophylla* decreased sharply in relative density, while *Betula lutea, Fagus grandifolia,* and *Halesia carolina* increased.

Table 3. Species composition of saplings at both sampling dates. Individuals >1.37 m tall to 2 cm dbh are included

Species	Relative Density (%)	
	1962	1992
Acer saccharum	38	4
Betula lutea	10	19
Fagus grandifolia	11	23
Halesia carolina	16	42
Ilex montana	2	0
Magnolia fraseri	0	2
Prunus serotina	0	2
Tilia heterophylla	11	0
Tsuga canadensis	13	8

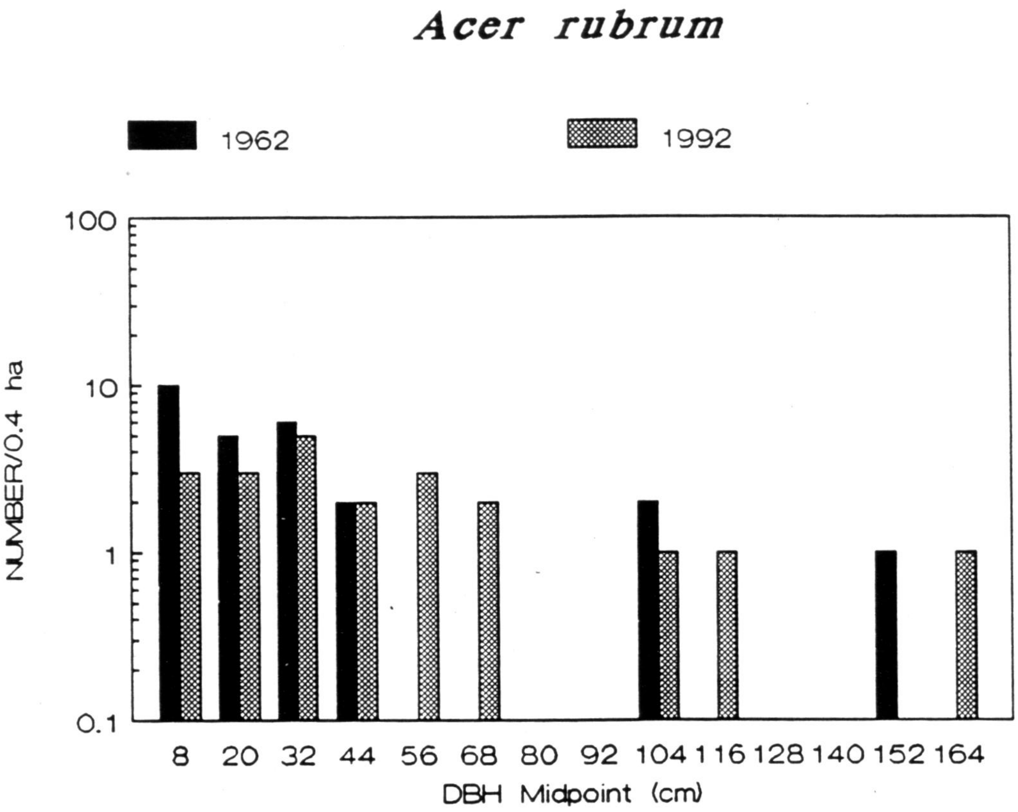

Figure 2. Size-class structure of *Acer rubrum* in 1962 and 1992.

Size-class structures of the dominant species

Acer rubrum exhibited a decrease in small trees (<35 cm dbh), and an advancement of individuals into larger size classes (Figure 2). Advancement was evident across all diameter classes. Individuals in the 50–75 cm dbh range showed particularly rapid advancement as they presumably were less than 50 cm dbh in 1962.

Tsuga canadensis exhibited an increase in the number of moderately small trees (15–40 cm dbh) and a decrease in the number of trees 40–75 cm dbh (Figure 3). This latter group of trees had apparently advanced to larger size classes as of 1992.

Halesia carolina size-class distributions were somewhat similar between sampling dates for individuals less than 50 cm dbh (Figure 4). However, larger trees have died over the interval and remaining individuals of *Halesia carolina* have not attained comparable sizes as of 1992.

Betula lutea regeneration (<25 cm dbh) decreased and individuals <65 cm dbh generally advanced to larger size classes (Figure 5). The largest tree (ca. 100 cm dbh) did not advance, however.

The species discussed above all had log-linear decreases in stem density with increasing diameter class. Understory stems were more abundant than overstory stems in these cases. Species in the stand that did not exhibit this size-class structure included *Liriodendron tulipifera, Betula lenta,* and *Fraxinus*

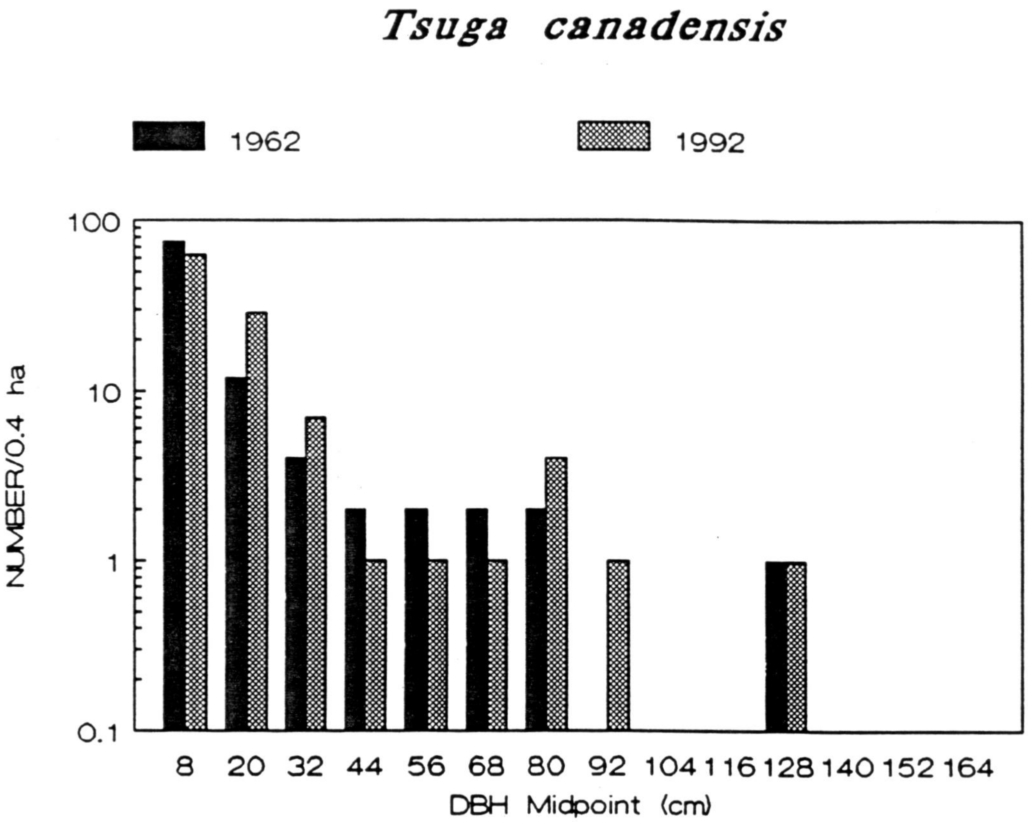

Figure 3. Size-class structure of *Tsuga canadensis* in 1962 and 1992.

americana. Total stem densities were relatively low for these species and the number of large, overstory stems exceeded the number of understory stems.

Species growth rates

Radial growth was high for *Fraxinus americana, Liriodendron tulipifera,* and *Acer rubrum* (Table 4). Maximum 10-yr growth increments of 26–32 mm were attained by these species, demonstrating their capability for rapid growth. The corresponding mean 10-yr growth increments were 22, 15, and 13 mm, respectively. *Halesia carolina* and *Tsuga canadensis* had moderate growth rates (mean 10-yr increments of 11 mm), while *Betula lutea* and *Fagus grandifolia* had relatively low growth rates (mean 10-yr increments of 7–8 mm). In general, the highly shade tolerant species, *Tsuga canadensis* and *Fagus grandifolia,* had the slowest radial growth and the lowest deviation about the mean. The slow growth of *Betula lutea,* only a moderately shade tolerant species, was a notable exception to the tendency of slow growth to be associated with high shade tolerance.

Canopy tree mortality rates

The average annual mortality rate for 63 trees >30 cm dbh was 0.7% (Table 5). Separating out *Tsuga canadensis,* a potentially long-lived species, and considering only deciduous species, a slightly higher mortality rate of 0.8%/yr was

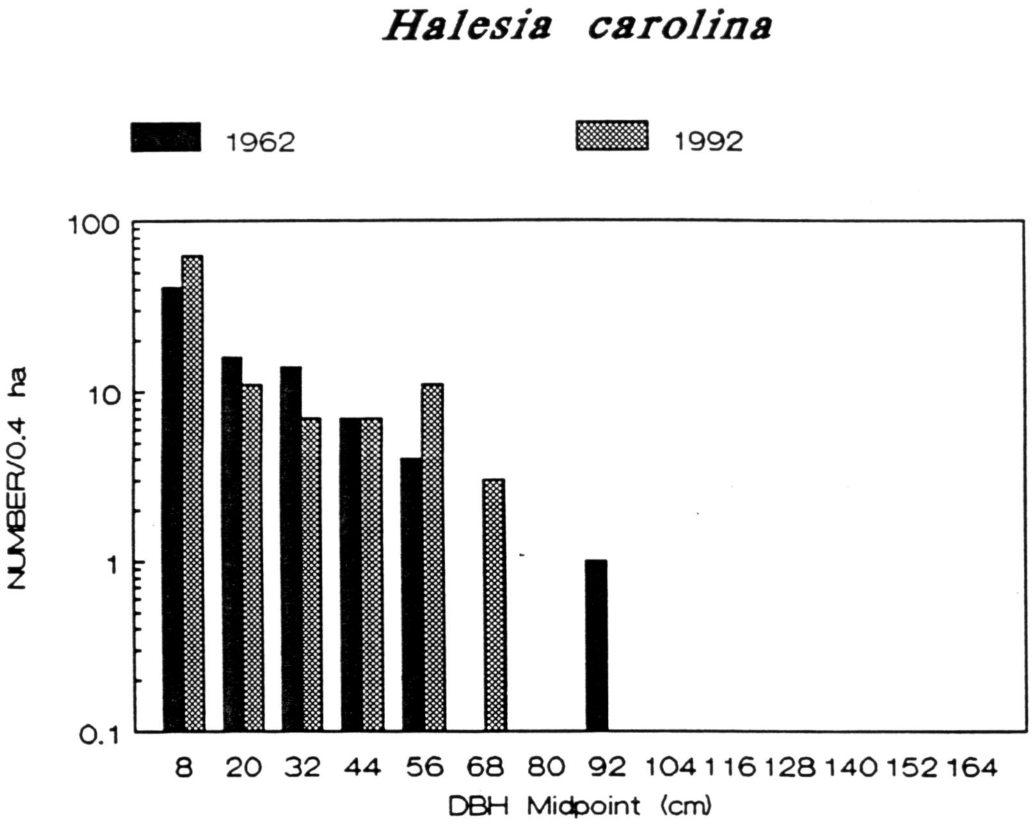

Figure 4. Size-class structure of *Halesia carolina* in 1962 and 1992.

obtained. All nine *Tsuga* canopy trees survived the 30-yr period. By contrast, canopy individuals of several deciduous species died over the interval. Size-specific mortality estimates indicated a trend of low mortality (0.5%/yr) among the smaller canopy trees (30–45 cm dbh). Otherwise, the mortality estimates ranged from 0.7 to 1.2%/yr.

DISCUSSION

Natural processes in old-growth stands include the mortality of individual canopy trees and the subsequent ingrowth of tree seedlings and basal sprouts in and around canopy openings. The stand- and landscape-level consequences of these small-scale disturbances can be conceptualized as a "shifting mosaic steady state" (Bormann and Likens 1979) with gap-sized patches as the mosaic elements. Major shifts in composition are not expected at the stand level (1–10 ha) unless environmental conditions change dramatically throughout the stand. At smaller scales, however, compositional shifts may result simply from processes driven by small gap disturbances. This appears to be the case in our 0.4 ha study area.

The chestnut blight was a minor disturbance event in the history of the stand under study. In 1962 the basal area of standing dead *Castanea* trees was 1.8 m^2 in the 0.4 ha study plot, and a few large individuals of *Castanea* were among the standing dead canopy trees. The *Castanea* mortality events presumably produced a set of canopy gaps by the late 1930s. Apparently, the gaps were

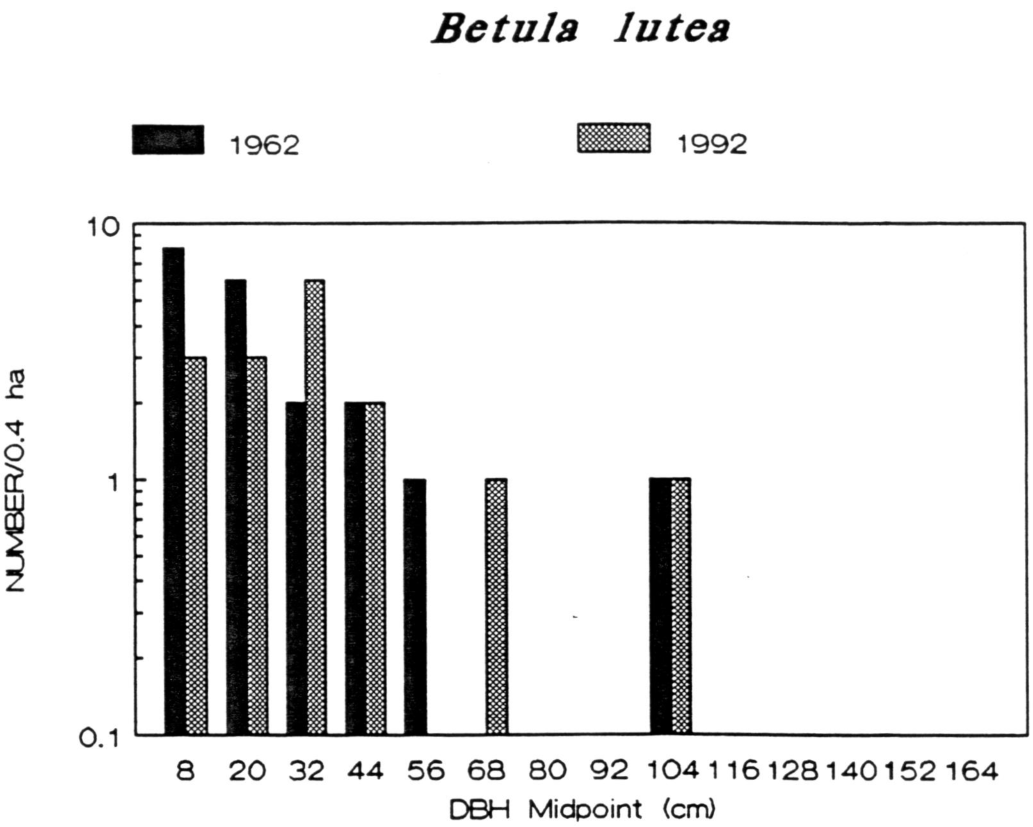

Figure 5. Size-class structure of *Betula lutea* in 1962 and 1992.

less than 0.04 ha in size as there was no evidence of prolific regeneration of intolerants. The lack of canopy openings around *Castanea* debris in 1992 indicated that the *Castanea* gaps have been closed by ingrowth or lateral growth from established trees. It is concluded that a few small gaps probably resulted from *Castanea* mortality in the 1930s. Given that *Castanea* comprised only a small fraction of the canopy cover prior to 1930, however, the mortality events were not castastrophic.

Table 4. Annual radial growth increments by species. These are average radial increment core measurements for 5–10 growth rings per individual >10 cm dbh

		Radial Growth Increment (mm/yr)			
Species	**N**	**Minimum**	**Maximum**	**Mean**	**SD**
Acer rubrum	11	0.72	3.24	1.34	0.67
Betula lutea	9	0.25	1.15	0.67	0.29
Fagus grandifolia	3	0.60	1.01	0.83	0.21
Fraxinus americana	2	1.81	2.60	2.21	0.56
Halesia carolina	12	0.66	1.86	1.14	0.37
Liriodendron tulipifera	4	0.69	3.00	1.52	1.03
Tsuga canadensis	19	0.38	1.53	1.05	0.29

Table 5. Annual mortality rates (%) over the thirty-year period by size class. The number of live trees in each class in 1962 is noted in parentheses. Total values in the right hand column are based on all individuals >30 cm dbh

	Diameter Class (cm)			
	>30–45	>45–60	>60	Total
All species	0.5 (32)	1.0 (17)	0.7 (14)	0.7 (63)
Deciduous species	0.5 (31)	1.2 (14)	1.1 (9)	0.8 (54)

Unlike many cove forests, this stand has a high canopy component of *Acer rubrum*. This is partly a result of ingrowth following *Castanea* mortality; however, there are several large individuals of *Acer rubrum* that clearly predate this disturbance event. Other factors, including the ability to regenerate on logs in the *Rhododendron* dominated understory, appear to responsible for the importance of *Acer rubrum* in this stand.

The presence of several large *Liriodendron* trees in the stand suggests a history of disturbance patches >0.04 ha in area (Runkle 1985). Presumably, these were single or multiple treefall gaps formed centuries ago. High ingrowth of *Liriodendron* after *Castanea* mortality was not evident in the study plot despite the presence of mature, seed producing *Liriodendron* trees. Apparently the canopy openings created in this stand by the blight were not large enough to allow abundant regeneration of *Liriodendron*.

One of the aesthetic features of Albright Grove is the presence of very large trees. Whether or not large trees will be perpetuated at this site over the long term is a pertinent question. If these trees established and grew to atypically large size because of unusual disturbance events or periods with exceptionally favorable growth conditions then one might predict that after they die, they will not be replaced with individuals of comparable size. The size-class data for all species combined suggest, however, that there are no wide discontinuities in the diameter distributions for the study stand and as the larger trees die, others will advance to comparable size.

The evidence for perpetuation of large individuals of certain species is not as clear. For example, the largest trees in Albright Grove are individuals of *Liriodendron*. This species requires disturbance patches on the order of 0.04 ha or more for abundant regeneration. In a study of the status of *Liriodendron* in Joyce Kilmer Memorial Forest, Lorimer (1980) concluded that large-scale disturbance events had allowed the establishment and growth of the species. While stand manipulation might promote long-term perpetuation of *Liriodendron*, Lorimer suggested that natural disturbances are sufficient to perpetuate the species at Joyce Kilmer. In the Albright Grove study plot we did not observe prolific regeneration of *Liriodendron* or disturbance patches large enough for its establishment, but this small-scale study does not necessarily represent dynamics of the Albright Grove forest as a whole. Long-term studies of canopy dynamics, disturbance patches and tree population responses by Runkle (1981) and Runkle and Yetter (1987) include transect samples across Albright Grove. Continuation of these long-term studies and a comparison of results between transect and plot studies may lead to stronger inferences about the future status of *Liriodendron* and other species approaching record size in the grove.

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LITERATURE CITED

Barden, L.S. 1979. Tree replacement in small canopy gaps of a *Tsuga canadensis* forest in the southern Appalachians. Oecologia 44:141–142.

Barden, L.S. 1980. Tree replacement in small canopy gaps of a cove hardwood forest in the southern Appalachians. Oikos 35:16–19.

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

Bormann, F.H. and G.E. Likens. 1979. Catastrophic disturbance and the steady state in northern hardwood forests. American Scientist 67:660–669.

Braun, E.L. 1950. Deciduous forests of eastern North America. Blakiston, Philadelphia, Pennsylvania.

Busing, R.T. 1989. A half century of change in a Great Smoky Mountains cove forest. Bull. Torrey Bot. Club 116:283–288.

Cain, S.A. 1943. The tertiary character of the cove hardwood forests of the Great Smoky Mountains National Park. Bull. Torrey Bot. Club 70:213–235.

Clebsch, E.E.C. and R.T. Busing. 1989. Secondary succession, gap dynamics, and community structure in a southern Appalachian cove forest. Ecology 70:728–735.

Della-Bianca, L. 1983. Sixty years of stand development in a southern Appalachian cove-hardwood stand. For. Ecol. and Manage. 5:229–241.

Leopold, D.J., G.R. Parker, and W.T. Swank. 1985. Forest development after successive clearcuts in the southern Appalachians. For. Ecol. and Manage. 13:83–120.

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

Oosting, H.J. and W.D. Billings. 1939. Edapho-vegetational relations in Ravenel's Woods, a virgin hemlock forest near Highlands, North Carolina. Amer. Midl. Naturalist 22: 333–350.

Oosting, H.J. and P.E Bourdeau. 1955. Virgin hemlock forest segregates in the Joyce Kilmer Memorial Forest of western North Carolina. Bot. Gaz. 116:340–359.

Pyle, C. 1988. The type and extent of anthropogenic vegetation disturbance in the Great Smoky Mountains before National Park Service acquisition. Castanea 53:183–196.

Radford, A.E., H.E. Ahles, and C.R. Bell. 1968. Manual of the vascular flora of the Carolinas. University of North Carolina Press, Chapel Hill.

Runkle, J.R. 1981. Gap regeneration in some old-growth mesic forests of the eastern United States. Ecology 62:1041–1051.

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

Runkle, J.R. 1985. Disturbance regimes in temperate forests. p. 17–33. *In:* Pickett, S.T.A. and P.S. White (eds.). The ecology of natural disturbance and patch dynamics. Academic Press, New York.

RUNKLE, J.R. and T.C. YETTER. 1987. Treefalls revisited: gap dynamics in the southern Appalachians. Ecology 68:417–424.

WHITTAKER, R.H. 1956. Vegetation of the Great Smoky Mountains. Ecol. Monogr. 26:1–80.

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