LITTERFALL OF TWO SOUTHERN APPALACHIAN COVE HARDWOOD FORESTS

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The current study is a component of a larger study interested in determining ecological change of the mixed-mesophytic forest from the Southern Appalachian Mountains to its far most western branches occurring in Illinois. Although there are numerous reports in the literature on litterfall, no reports were found describing litterfall within undisturbed old growth cove hardwood forest of the Southern Appalachian Mountains. The main purpose of this study was to determine annual litterfall rates for an undisturbed old growth cove hardwood forest and second growth cove hardwood forest of the Southern Appalachian Mountains and to compare the findings for the two forests of different successional stages.

The mixed-mesophytic forest of southern Appalachia contains a floristic diversity unmatched by any other forest type in the eastern United States. Braun (1950) described the southern Appalachian region as the most complex and oldest association of the Eastern Deciduous Forest as well as the area where all other deciduous forests originated. This is further reinforced by Whittaker's (1956) statement that, "The greater ranges of elevation and moisture conditions of the Smokies imply greater floristic diversity, as well as greater variety of vegetation types" than other areas of the southern Appalachians. Thus, depicting the Great Smoky Mountains as the geographic center for the forests of the eastern United States.

Similar studies have been performed in the Southern Appalachian Mountains. Bray and Gorham (1964) gave litterfall rates for an oak (*Quercus*)-hickory (*Carya*)-tulip poplar (*Liriodendron tulipifera*) forest in Tennessee on a north facing slope, south facing slope, and level upland. Reported annual litterfall rates are 4,000 kg/ha for the north facing slope, 5,000 kg/ha for the south facing slope, and 5,400 kg/ha for the level upland. They also gave an annual litterfall rate for an oak-hickory-tulip poplar forest in a valley in North Carolina of 5,300 kg/ha and 2,900 kg/ha for a 78-year-old mixed oak stand in Tennessee.

The criteria for study site selection were based on the anthropogenic disturbance history of the stand and, in the selection of the second growth forest, the time in which that disturbance occurred (Pyle 1985, 1988). For this study, the term old growth follows Pyle's (1988) virgin forest definition of having "the absence of written records concerning human-related disturbances and the absence of mapped land use records." Other attributes of old growth cove hardwood forests included having high species richness and diversity, the majority of canopy trees with a minimum of 150 years of age, the presence of logs at various stages of decomposition, woody debris on the ground, standing snags, canopy gaps, trees of uneven age and size, and pit and mound microtopography (Ellison 2001). Second growth cove hardwood forest characteristics include young, 50 to 100 years old, primarily even-aged stands of tulip poplar due mainly to anthropogenic disturbance such as settlement, farming, or logging (Busing 1993).

Albright's Grove (35º 44′ N; 83º 17′ W) was selected as our old growth cove forest and is located in the northeastern section of the Great Smoky Mountains National Park in east Tennessee (USGS 7.5′ quadrangle: Mt. Guyot, Tennessee and North Carolina). The stand falls between two watershed-draining streams known as Dunn and Indian Camp creeks. Albright's Grove has an average elevation of 975 m and lies on a north-facing slope. The forest composition is characteristic of mesic old growth cove hardwoods, with the dominant canopy species being Eastern hemlock followed by Carolina

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silverbell (see table 1 for scientific and common names). Other important species include American beech, yellow buckeye, Fraser magnolia, yellow birch, white basswood, red maple, and tulip poplar. Some of the largest trees found at the site are tulip poplar.

The only known disturbance to have occurred at Albright's Grove is the infestation of chestnut blight. However, in his 30-year study of stand change, Busing (1993) indicated that given the lack of canopy opening, which in turn did not allow for abundant regeneration of tulip poplar, the disturbance caused by the effects of the blight was not as severe in Albright's Grove as found in other areas of the park.

The Tremont site (35º 42′ N; 83º 41′ W) was selected as our second growth cover forest and is located 30 km west of Albright's Grove. The Tremont site is found on a north-facing slope of Brier Ridge between the Thunderhead Prong of the Little River and Shut-in Creek (USGS 7.5′ quadrangle: Thunderhead Mountain, Tennessee and North Carolina). The average elevation of the Tremont site is 914 m. The Tremont site is unique in that it lies in the area of the Great Smoky Mountain Park where the final harvest was completed in 1939 (Defoe 1994). Being the last area of the park to be logged provides opportunity to compare an old growth cove hardwood forest with the most recently regenerated second growth cove hardwood stand.

The Tremont site's composition is distinctive of a typical second growth cove hardwood forest (Busing 1993). The canopy is dominated by the pioneering tulip poplar, and interspersed with another known pioneer species, black locust. Other species occurring at the site but not as equally important in the canopy are yellow buckeye, yellow birch, sugar maple, red maple, Fraser magnolia, white basswood, Carolina silverbell, black cherry, and Eastern hemlock. Due to the relatively young age of the stand, Eastern hemlock has not become a canopy dominant, allowing more light to penetrate through the canopy and reach the understory vegetation. The increase in light allows for abundant growth of tree seedlings and saplings, shrubs, and herbaceous plants in this second growth site.

Table 1.—*Annual litterfall amounts by tree species and selected components in kg/ha. Species followed an * are significantly different ($p < 0.05$) between the two sites.*

Species		Albright's Grove	Tremont
Acer pennsylvanicum L.	Striped maple*	2.38	10.66
Acer rubrum L.	Red maple	23.70	64.82
Acer saccharum Marsh.	Sugar maple	81.92	68.48
Aesculus octandra Marsh.	Yellow buckeye*	34.24	232.39
Betula alleghaniensis Britton	Yellow birch	50.07	16.82
Fagus grandifolia Ehrh.	American beech*	102.59	0.28
Halesia tetraptera Ellis	Carolina silverbell*	756.85	123.77
	Herbaceous litter*	21.07	293.63
	Insects	9.82	6.16
Leucothoe fontanesiana (Steud.) Sleumer	Dog-hobble	0.06	0.83
Liriodendron tulipifera L.	Tulip poplar*	53.55	1,974.62
Magnolia accuminata L.	Cucumber tree	3.87	4.37
Magnolia fraseri L.	Fraser magnolia*	73.17	1.22
	Misc. petioles*	1.04	98.48
	Misc. plant parts*	74.30	405.63
Prunus serotina Ehrh.	Black cherry*	2.29	36.55
Quercus prinus L.	Chestnut oak*	0	0.29
Quercus rubra L.	Red oak*	0	3.38
	Reproductive litter	331.95	273.34
Rhododendron maximum L.	Rosebay	1.88	0.23
Robinia pseudoacacia L.	Black locust*	0	48.87
Tilia heterophylla Vent.	White basswood	50.89	11.61
Tsuga canadensis	Eastern hemlock*	899.75	29.29
Viburnum spp. L.	Viburnum spp.*	0	11.06
	Woody litter	1,541.23	1,569.35

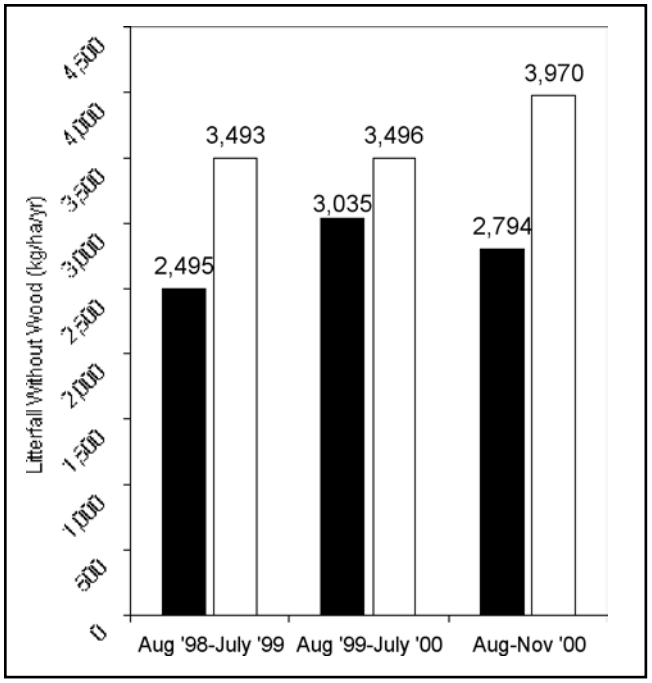

Figure 1.—*Annual litterfall excluding wood for an old growth cove forest (Albright's Grove, closed bars) and a second growth cover forest (Tremont, open bars).*

Aluminum littertraps were assembled and placed in the field at Albright's Grove and Tremont at the end of July 1998. Littertrap dimensions measured 1-m-square by 15-cm-deep. A bottom piece constructed of hardware cloth covered with window screen allowed precipitation and snow melt to drain through the trap. A total of 36 littertraps were placed at each site in 3 rows of 12 on north to south transects. Each littertrap was spaced 15 m apart encompassing a 4,950 m square area.

Monthly forest litterfall was collected from each littertrap beginning in August 1998 and concluding at the end of November 2000 for a total data collection period of 28 months. After each collection the litter was transported to the University of Illinois and dried 85º C for 48 hours. All litter for each trap was weighed to the nearest hundredth of a gram and totaled for the month. Every third bag of litterfall was separated by species and components. Litterfall components were separated by tree and shrub species, herbaceous leaves, woody material > 8 cm in diameter, reproductive material including flowers, seeds, and cones, as well as insects and insect frass. Each component of the litterfall was weighed and totaled for the month. Litterfall amounts were determined with and without woody material because of the variability in woody litterfall that occurred throughout a growing season.

Oven-dry weight data were analyzed using SAS (Statistical Analysis System, Inc., Cary, NC) to perform the two-way analysis of variance. Statistical tests for data normality, including the Shapiro-Wilk test, were administered as well as tests for variability among the data. Tukey's Studentized Range test was applied testing for differences in the amount of litterfall occurring between the two sites, among months, and an interaction of site and month.

An annual litterfall rate was calculated for Albright's Grove and Tremont by summing the oven-dry weight occurring in each month (g/m^2), averaging the amount for the complete 28 months of the study, and converting the total to kg/ha. In the yearly averaging of litterfall, the last 4 months of the study, August to November 2000, were weighted in proportion to the rest of the year based on the corresponding site's amount of litterfall that occurred in the previous 2 years of the study.

For all three litterfall seasons, August 1998 to July 1999, August 1999 to July 2000, and August to November 2000, litterfall without wood was consistently higher at the second growth site (fig. 1). This difference can be attributed to the second growth site's younger stage of succession.

An exceptionally large amount of litterfall occured in the third season August to November 2000, especially at the Tremont site. More litterfall accumulated in this 4-month time period than what was collected during one full year for the previous two seasons. This may be attributable to drought like conditions that occurred earlier in the year. As recorded at the Knoxville National Weather Service station northwest of Tremont, temperatures followed a normal cycle throughout the study period; however, precipitation was noticeably lower during the months of June and July 2000 than during June and July 1999 (fig. 2).

Calculated across the 28-month study, the old growth forest of Albright's Grove had an annual total litterfall rate of 4,808 kg/ha and an annual litterfall rate excluding wood of 3,028 kg/ha (fig. 3). Both the total and litterfall without wood for the second growth forest exceeded the amounts occurring in the old growth forest. The Tremont site had an annual total litterfall rate of 5,751 kg/ha and an annual litterfall rate excluding wood of 4,136 kg/ha.

Significant differences were found in the annual amount of litterfall for some but not all components between Albright's Grove and Tremont

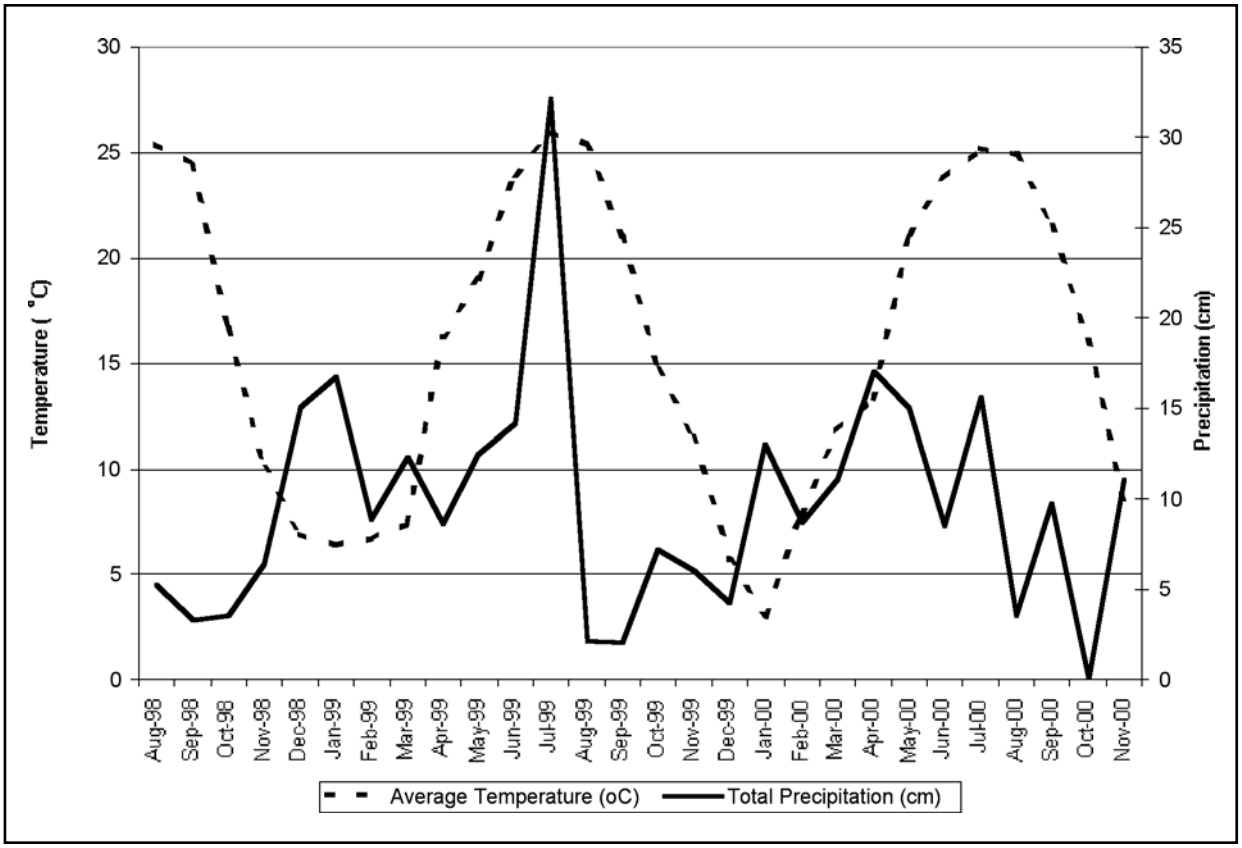

Figure 2.—*Precipitation (dotted line) and temperature (solid line) gathered by the National Weather Service in Knoxville, TN.*

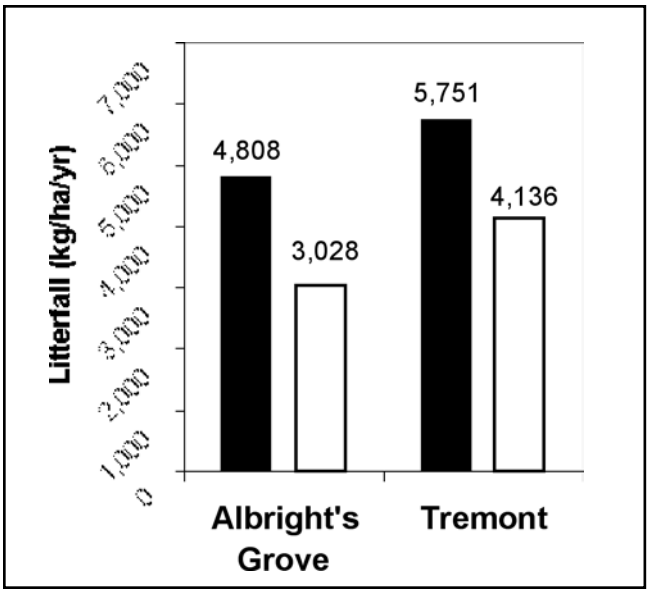

Figure 3.—*Annual litterfall rate with (solid bars) and without wood (open bars) for an old growth cove forest (Albright's Grove) and a second growth forest (Tremont) the Southern Appalachians.*

(table 1). Wood litterfall < 8.0 cm in diameter was not significantly different ($p < 0.05$) between the two sites. Albright's Grove accumulated 1,541 kg/ha/yr while Tremont averaged 1,569 kg/ha/yr. Woody material accounted for 37 percent of the total litterfall at Albright's Grove and 30 percent at Tremont. The greater amount of woody litterfall at Albright's Grove is to be expected due to the forest's advanced stage of succession.

Eastern hemlock litterfall, with an annual rate of 900 kg/ha, was significantly greater at the old growth site than at the second growth site, which had an annual rate of only 29.3 kg/ha (table 1). At Albright's Grove, Eastern hemlock accounted for 22 percent of the total litterfall and 35 percent of the litterfall without wood included. The percentage of Eastern hemlock litter in the litterfall with and without wood at Tremont was found to be 0.5 and 1 percent, respectively. Eastern hemlock is known as a climax species, thus these differences are attributed to the different successional stages of the two forests.

Tulip poplar litterfall was also significantly different between the two sites (table 1). Tulip poplar litterfall accounted for 37 percent of the total litterfall occurring at the second growth Tremont site and only 1 percent at the old growth Albright's Grove. Tulip poplar litterfall at Tremont accounted for 53 percent of litterfall without wood and at Albright's Grove tulip poplar litter accounted for just 2 percent. The difference can be ascribed to tulip poplar being a pioneer species, which would explain its heavy influence at the second growth Tremont forest.

Litterfall rates for Carolina silverbell was also different between Albright's Grove and Tremont (table 1). Litterfall from this species was found to be the third most abundant form of litterfall at Albright's Grove. In the total litterfall occurring at Albright's Grove, Carolina silverbell composed 18 percent, and at Tremont the value was 2 percent. For litterfall without wood at Albright's Grove, Carolina silverbell attained a value of 29 percent and at Tremont there was 3 percent occurring.

The old growth cover forest produced less herbaceous litter than the second growth cove forest (table 1). Herbaceous litter at Albright's Grove, with a rate of 21.1 kg/ha/yr, comprised only 0.5 percent of the total litterfall and nearly 1 percent of the litterfall without wood. Herbaceous litter at Tremont, with a rate of 293.6 kg/ha/yr, comprised 5 percent of the total litterfall and 8 percent of litterfall without wood included. The greater amount of sunlight penetrating the younger canopy of Tremont would allow for the growth of more herbaceous plants than compared to the dense canopy of the undisturbed old growth forest of Albright's Grove.

No differences were found in the annual amount of reproductive litterfall between Albright's Grove and Tremont (table 1). Albright's Grove, with a rate of 332 kg/ha/yr, accumulated enough reproductive material litter to comprise 8 percent of the total litterfall. Tremont's annual accumulation of reproductive material, 273 kg/ha/yr, made up 5 percent of the total litterfall for that site. For litterfall without wood, reproductive material at the old growth site comprised 13 percent, and 7 percent at the second growth site.

In conclusion, the younger second growth forest at Tremont produced more litterfall annually than did the undisturbed old growth forest at Albright's Grove. Compared to the old growth forest, the second growth forest annually produced 943 kg/ha more total litterfall and 1,108 kg/ha more litterfall without wood. As observed, we expect more litterfall produced by the pioneering tulip poplar in the second growth forest. The same is expected of the climax species Eastern hemlock in the old growth Albright's Grove. Interestingly, there was no significant difference in reproductive and woody materials between the two sites. However in this study woody litterfall was limited to the parameters of fine litterfall, or woody material < 8 cm in diameter and the larger branches and fallen trees that occur more often in a climax stage of succession were not included.

The litterfall rates for both study areas, Albright's Grove and Tremont, were of comparable amounts to litterfall rates of similar studies in the area. Albright's Grove, with an annual litterfall rate of 4,808 kg/ha, has a greater litterfall rate than that of a study of a comparable forest type with the same north facing aspect reported by Bray and Gorham (1964). Tremont's annual litterfall rate of 5,751 kg/ha is greater than all of the studies reported by Bray and Gorham (1964) of similar forest types in the Southern Appalachian Mountains.

LITERATURE CITED

Braun, E.L. 1950. Deciduous forests of eastern North America. Philadelphia, PA: Blakiston. 596 p.

Bray, R.J.; Gorham, E. 1964. Litter production in forests of the world. Advances in Ecological Research. 2: 101-157.

Busing, R.T. 1993. Three decades of change at Albright Grove, Tennessee. Castanea. 58(4): 231–242.

DeFoe, D.; Giddens, B.; Kemp, S., eds. 1994. Hiking trails of the Smokies. Gatlinburg, TN: Great Smoky Mountains Natural History Association. 575 p.

Ellison, G. 2001. Exploring old-growth forests. Science Journal. 1(1): 3–5.

Pyle, C. 1985. Vegetation disturbance history of Great Smoky Mountains National Park: an analysis of archival maps and records. Res./Resour. Manage. Rep. SER-77. Atlanta, GA: U.S. Department of Interior, National Park Service, Southeast Regional Office. 69 p.

Pyle, C. 1988. The type and extent of anthropogenic vegetation disturbance in the Great Smoky Mountains before National Park Service acquisition. Castanea. 53(3): 183-196.

Whittaker, R.H. 1956. Vegetation of the Great Smoky Mountains. Ecological Monographs. 26(1): 1-80.