Detailed Studies of Old-Growth Forests in Versailles State Park, Indiana

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Abstract

Full censuses were taken for 17.46 and 6.44 acre segments of two old-growth upland forests located in Versailles State Park, Ripley County, Indiana. The stands have been designated as Jackson's and Potzger's Woods, respectively. Transects were also taken in the slope forests of Jackson's Woods and the forest composition of limestone sinks was studied.

Jackson's Woods had 28 species over 4 inches and 33 species over 2 inches dbh. Density per acre of stems over 4 inches was 109 with basal area per acre of 112 ft.[2] Beech and sugar maple ranked first and second in importance value with 32 and 25%, respectively. Tulip-poplar followed with 14%, and dogwood was fourth at 6.5%. In the sinkholes, beech and sugar maple decreased in importance, and walnut, elm and tulip-poplar increased in importance in larger and better drained sinks. The W-facing slope forest is mixed mesophytic; oak and hickory increases on excessively-drained NW and N-facing slopes; the NE and E-facing slopes are watered by subsurface seeps and have forests similar to floodplains.

Potzger's Woods had 24 and 27 species over 4 and 2 inches, respectively. The density per acre was 121 with a basal area per acre of 117 ft.[2] Sugar maple and beech ranked first and second in importance with 39 and 31%, respectively; walnut was third at 5% followed by white ash and black gum. Sugar maple was exceedingly dominant in the smaller size classes in both stands. The present full tally for Potzger's Woods indicates that sugar maple has increased in stand importance since 1956, most likely at the expense of beech which has declined slightly in importance.

The stands appear to be transitional between the mixed mesophytic forests of extreme southeastern Indiana and the beech-maple types of the flat uplands. As the physiography matures the woods will probably shift to a more mixed mesophytic composition.

Introduction

Plant ecologists have been interested in the forests of southeastern Indiana for a number of years. The Versailles State Park and Laughery Creek Valley areas of Ripley County have been of particular interest because the diverse topography of that region induces striking differences in forest types within very short distances. According to Potzger (9), the well-drained uplands and moderate slopes support a climax of mixed mesophytic forest dominated by beech (*Fagus grandifolia*) and sugar maple (*Acer saccharum*), and which includes twenty or more additional species of lesser importance. Beech is also an important member of the forests on the poorly-drained flat uplands, but sugar maple is replaced as a co-dominant on these wet sites by red maple (*Acer rubrum*) and sweet gum (*Liquidambar styraciflua*). On the excessively-drained slopes beech is absent; however, sugar maple continues as a dominant species, along with mesophytic oaks, ash and hickories (9).

The faculty and students of the Conservation Education Summer Camp, held at Versailles State Park for several years, focused their attention on this wide range of habitats and forest composition in the vicinity of the Laughery Creek Valley. Potzger (9) and Stearns (15) studied the ecological relationships of the forest communities within the State Park area. In addition, Potzger and Potzger (13) and Potzger and Liming (12) worked out secondary succession patterns on the flat uplands of Ripley County. The distribution patterns and associated species of beech were examined by Potzger and Chandler (10) in ten stands in the general Laughery Valley area. In a later study, Potzger and Chandler (11) described four oak-dominated forests of the same region.

The aims of this study were: *1*) to intensively study one of the best remaining old-growth upland and adjacent slope forests of the area that somehow had escaped earlier study; *2*) to compare the above stand to a frequently studied old-growth stand located in the southeast part of the Park; and *3*) to supplement the current search for and description of areas in Indiana that are suitable for preservation under the Natural Areas Act.

Location and Description of the Stands

Versailles State Park lies in the Illinoian Till Plain section of Indiana. Upland areas are flat to gently rolling, but Laughery Creek and its tributaries have cut deep valleys and ravines into the upland plateaus. There is about 300 ft. of relief in the immediate area with Laughery Creek dropping to about 700 ft above mean sea level and the highest flat uplands reaching slightly above 1,000 ft elevation. Laughery Creek cut a deep, broad steep-walled valley into the underlying Ordovician limestone as it carried Pleistocene meltwater. The region is very scenic with broad panoramas.

Laughery Creek is the approximate dividing line between the Dearborn Upland Physiographic Provine characterized by Ordovician Age limestone and the Muscatatuck Regional Slope underlain by younger Silurian Limestone. One of the study sites is situated in each physiographic province. Both stands occupy well-drained Cincinnati silt loam soils. The study areas are located in the infrequently visited section of the Park that lies south of U. S. Highway 50.

The first stand, referred to as Jackson Woods, is located west of Laughery Creek on a high trapezoid-shaped upland promontory. (The stand names used in this paper follow the nomenclature used by Lindsey [6]). It is situated in the northwest corner of section 18, Twp. 7N, Range 12 E. There is about 100 acres of forest in the immediate area, but the old-growth upland stand covers less than 25 acres. The west, north, northeast, and east-facing slopes of the upland ridge are also clothed in good mixed forest. The upland area slopes gently toward the northeast, but drainage is largely internal into numerous sinkholes which then feed springs and seeps along the valley walls. The slopes that are watered by sub-surface seeps support a forest that is strikingly floodplain in character, although it occurs on a 75-80% slope.

The second stand is referred to as Potzger Woods in honor of the late, outstanding plant ecologist from Butler University. It is located on a gentle northeast-facing upland slope, which is drained by small ravines in the upper reaches of Turkey Creek, a tributary of Laughery Creek. The stand is situated east of Laughery Creek in the northeast quarter of Section 20, Twp. 7 N, Range 12 E. The least disturbed part of the stand covers less than 10 acres.

Both areas suffered some disturbance as a consequence of private ownership prior to park acquisition. Jackson Woods was lightly grazed by cattle for a number of years, and about 30 trees were cut in 1936. For about seven years prior to 1936, a few beech trees were cut each year for firewood. Little information exists concerning the history of Potzger Woods, but apparently only limited cutting occurred in the 1920's and 30's. The presence of abundant high grade walnut in both stands indicates that neither area was seriously damaged by logging.

Methods

A full census of all trees greater than 2.0 inches dbh (diameter breast high) was taken for the best sections of each stand. A total of 17.46 acres was tallied in Jackson Woods and 6.44 acres in Potzger Woods. Stand margins were excluded from the full tallies to avoid community transitions. All trees over 4.0 inches were measured to the nearest 0.1 inch with diameter tapes, and trees 2.0 to 3.9 inches were counted and recorded by species. Smaller trees, tree seedlings, shrubs and herbs were stratum ranked according to the method advanced by Lindsey, *et al.* (5) to establish the importance of each species within each stratum. Stratum ranking is a subjective assignment of numerical values to each species according to its contribution to the density and cover in its respective stratum. Values range from stratum rank 9 (a pure stand of a single species) to stratum rank 1 (a species with a single individual present).

In addition, the changes in forest composition on contrasting slope aspects of Jackson Woods were examined by laying a continuous one-half mile horizontal belt transect along the contour at mid-slope. Two 600-ft vertical belt transects were run from the upland to the floodplain to determine the effect of topographic position on forest composition. The transects were divided into sections 43.56 ft by 100 ft so that a 1/10 acre sample was obtained per 100-ft horizontal distance.

Six of the upland sinkholes in Jackson Woods were full tallied for trees to compare: 1) small sinks (ca. 0.15 acre each) that are subject to flooding during heavy rains; 2) small sinks (ca. 0.15 acre each) that apparently seldom or never contain standing water; and 3) large sinks (ca. 0.4 acre each) that apparently do not flood. The occurrence of ponding in small sinks was established by examination of the silt coatings on the leaf litter and by the absence of herbs, shrubs and tree reproduction in the flooding portion.

The soil reaction of upland and slope samples was determined with a Beckman pH meter; soil moisture values were expressed as percentage oven dry weight. Canopy heights were measured with an Abney level.

The field work was done in early July and mid-September. Full tally plot corners were marked with permanent iron rods and exact locations are available from the authors.

Stand attributes according to Lindsey (4) are as follows: D_2 = density per acre; D_3 = relative density; B_2 = basal area per acre; B_3 = relative basal area; and V_3 = importance value =

$$\frac{D_3 + B_3.}{2}$$

Species nomenclature follows Little (7) and Fernald (3) for trees and other species, respectively.

Results and Discussion

Jackson Woods

Upland Stand Description. The primary stand attributes of the full-tally section of this stand are shown in Table 1. Twenty-eight species greater than 4 inches dbh represent a stand density of 109.03 stems per acre and a stand basal area of 111.67 square ft per acre. Although these totals are slightly less impressive than those for the best old-growth stands in the state, they indicate a relatively undisturbed condition. The stand is of mixed composition, but heavily dominated by beech and sugar maple, which total 57.5% of stand importance value. Beech represents nearly a third of stand importance, largely because of its large size (over half of the stand basal area); whereas, sugar maple attains its one-fourth of the stand importance because of its high density (nearly 40% of the stand total), particularly in the small size classes.

Examination of the size-class distribution in Table 2 gives the impression that sugar maple is rapidly invading the stand, in large measure at the expense of beech. This is particularly noteworthy when the ratios of the number of stems less than 12 inches dbh to the number greater than 12 inches are examined for the two species. These ratios are 1675/40 or 41.88 and 26/242 or 0.11 for sugar maple and beech, respectively, when stems greater than 2 inches dbh are considered, and 699/40 or 17.48 and 8/242 or 0.03, respectively, for stems greater than 4 inches dbh. These ratios obviously are useful only for determining possible trends in stand composition since many beech-maple dominated stands exhibit a similar preponderance of young maples. However, beech usually maintains its position as a co-dominant and frequently increases its importance value as the stand matures. This natural process of selection toward beech dominance as successional maturity is reached is frequently enhanced by selective logging in which higher grade species such as oak, walnut and tulip-poplar are removed, leaving the lower quality beech. The differential rate of sugar maple reproduction when compared to beech is largely offset by differential survival of beech with respect to sugar maple. Most undisturbed stands seem to have much greater mortality of small maples than of small beech. Long-term detailed studies of a number of beech-maple dominated stands should help resolve this question. Notwithstanding these comments, the absence of any sugar maple stems greater than 24 inches in this stand indicates that sugar maple will undoubtedly increase in the larger size classes in the future, assuming the continued absence of disturbance. The projected increase in sugar maple may be partially at the expense of beech, but a replacement of less tolerant species such as tulip-poplar (*Liriodendron tulipifera*), walnut (*Juglans nigra*), sassafras (*Sassafras albidum*) and wild cherry (*Prunus serotina*) is more probable.

Tulip-poplar is the sub-dominant species with an importance value of 14.1%. Moderate selective cutting 30 to 40 years ago has apparently favored this relatively intolerant species. Although most of the 30 trees cut in 1936 (just prior to park acquisition) were tulip-poplar, the crown openings created by this cutting undoubtedly favored release, rapid growth and regeneration of tulip-poplar, serving to increase rather than decrease tulip importance. Nearly half (96 of 204) of the tulip-poplar stems over 4 inches dbh fall in the 12 to 24 inch size classes. Expected growth increments of thrifty tulip-poplars in canopy openings would be on the order of one-fourth to one-half inch diameter increase per year on the average. This growth rate would date the establishment of many of the middle-sized tulip-poplars as canopy trees at about 30 to 40 years ago.

Other species worthy of comment include flowering dogwood (*Cornus florida*) which represents 6.5% of the stand (Table 1), largely by virtue of its high density (13 stems per acre larger than 4 inches dbh), and walnut at 4.6% importance. Walnut is very well represented in the 12 to 24 inch sizes (49 of 66 total stems), indicating that it was also favored by the canopy openings created by cutting. Walnut is frequently clumped in the larger sinkholes (see Table 3) of the area. This contagious dispersal is favored by increased light, gravity seed dispersal and accumulation of fertile soil in the sink bottoms. Elm, wild cherry and sassafras were probably favored to a lesser extent by the earlier cutting. Six species of oak and hickory represent only 1.17% of the stand importance value. The absence of these species on this well-drained site is a matter of conjecture, since there is no record of recent cutting of either oak or hickory. Apparently, even the moderately tolerant white oak is unable to successfully compete in mature upland stands in this area. Canopy opening would not have favored oak and hickory, because of their slower growth rate as compared to tulip-poplar. Large chinquapin oak (*Quercus muehlenbergii*) is rather common along the drier bluffs and slopes, where, as Reynolds and Potzger (14) pointed out, it even surpasses white oak in abundance. On the uplands it is an inconsequential species, however.

Although there are no trees greater than 40 inches dbh, there are 128 stems in the 28-inch or greater size classes for an average of nearly

TABLE. 1. *Stand Attributes for Jackson Woods, based on trees 4" dbh and greater. 17.46 acres—full tally.*

SPECIES	D_2	D_3	B_2	B_3	V_3	BA/Tree
Fagus grandifolia	14.32	13.13	57.66	51.63	32.38	4.03
Acer saccharum	42.33	38.82	12.67	11.34	25.08	.30
Liriodendron tulipifera	11.68	10.71	19.53	17.49	14.10	1.67
Cornus florida	13.23	11.08	2.18	1.95	6.52	.16
Ulmus rubra	8.30	7.61	2.67	2.39	5.00	.32
Juglans nigra	3.78	3.47	6.46	5.78	4.63	1.71
Fraxinus americana	3.95	3.62	2.63	2.35	2.99	.67
Prunus serotina	3.38	3.10	1.19	1.07	2.09	.35
Nyssa sylvatica	1.72	1.58	1.61	1.44	1.51	.94
Ulmus americana	1.37	1.26	1.26	1.13	1.20	.92
Sassafras albidum	1.55	1.42	.79	.71	1.07	.51
Celtis occidentalis	.86	.79	.67	.60	.70	.80
Quercus alba	.23	.21	.52	.47	.34	2.26
Quercus rubra	.17	.16	.57	.51	.34	3.35
Ostrya virginiana	.57	.52	.11	.10	.31	.19
Carya glabra	.23	.21	.44	.39	.30	1.91
Vitis spp.	.34	.31	.04	.04	.18	.12
Juglans cinerea	.17	.16	.14	.13	.15	.82
Acer negundo	.11	.10	.16	.14	.12	1.45
Fraxinus quadrangulata	.06	.06	.10	.09	.08	1.67
Tilia americana	.11	.10	.03	.03	.07	.27
Carya ovata	.06	.06	.09	.08	.07	1.50
Robinia pseudoacacia	.06	.06	.09	.08	.07	1.50
Carpinus caroliniana	.11	.10	.02	.02	.06	.18
Quercus muehlenbergii	.11	.10	.02	.02	.06	.18
Carya cordiformis	.11	.10	.02	.02	.06	.18
Asimina triloba	.06	.06	.01	.01	.04	.17
Aesculus glabra	.06	.06	.01	.01	.04	.17
Total	109.03		111.69			

8 large trees per acre. All but 15 (88.3%) of these large trees are beech which contributes to the impression that this stand is almost entirely beech. Potzger and Chandler (10) recorded only 17 trees greater than 30 inches (based on a total sample of about 5 acres) in the entire ten stands that they studied. The largest individuals of noteworthy species in the immediate vicinity of this old-growth stand include: beech 39.7, chinquapin oak 39.1, tulip-poplar 36.7, red oak (*Quercus rubra*) 35.2, blue ash (*Fraxinus quadrangulata*) 29.8, black gum (*Nyssa sylvatica*) 29.7, walnut 26.7, pignut hickory (*Carya glabra*) 24.0, Kentucky coffeetree (*Gymnocladus dioica*) 24.0, box-elder (*Acer negundo*) 20.4, butternut (*Juglans cinerea*) 17.1, ironwood (*Ostrya virginiana*) 13.9, and dogwood 9.0. Many of the larger forest-grown tulip trees, beech, walnut

TABLE 2. *Size Class Table for Jackson Woods. 17.46 Acres—Full Tally.*

Species	Size Class Midpoints 2-4"	6"	10"	14"	18"	22"	26"	30"	34"	38"	Total >4"	Total >2"
Acer saccharum	976	547	152	30	8	2					739	1715
Fagus grandifolia	18	5	3	9	13	47	60	72	28	13	250	268
Cornus florida	79	228	3								231	310
Liriodendron tulipifera	26	36	37	34	36	26	23	8	3	1	204	230
Ulmus rubra	149	103	33	4	2	3					145	294
Fraxinus americana	59	36	15	9	5	2	1	1			69	128
Juglans nigra	2	4	7	15	20	14	6				66	68
Prunus serotina	41	40	13	5		1					59	100
Nyssa sylvatica	7	17	3	3	2	2	2	1			30	37
Sassafras albidum	19	17	5	3	1		1				27	46
Ulmus americana	6	10	5	4	1	3	1				24	30
Celtis occidentalis	18	7	3	3		2					15	33
Ostrya virginiana	12	10									10	22
Vitis spp.	77	6									6	83
Quercus alba					3	1					4	4
Carya glabra			1	1		1	1				4	4
Juglans cinerea		1	1		1						3	3
Quercus rubra	1	1				1			1		3	4
Carpinus caroliniana	26	2									2	28
Tilia americana	4	1	1								2	6
Quercus muehlenbergii	2	2									2	4

Carya cordiformis	2	2									2	4
Acer negundo	2		1			1					2	4
Asimina triloba	34	1									1	35
Carya ovata	1				1						1	2
Fraxinus quadrangulata					1						1	1
Robinia pseudoacacia					1						1	1
Aesculus glabra		1									1	1
Rhus radicans	3											3
Parthenocissus quinquefolia	2											2
Morus rubra	1											1
Cercis canadensis	1											1
Ulmus thomasi	1											1
Total	1569	1077	283	120	95	106	95	82	32	14	1904	3473

and ash have clear boles of 30 to 60 ft with very little taper. The general canopy height averages about 115 to 120 ft in the upland stand, with tulip-poplars reaching the greatest overall height.

The tree reproduction data are summarized in Table 2, so stratum rank values are not listed for small trees. In all, 27 species contribute 1,569 stems in the 2.0 to 4.0 inch dbh size class.

The shrub and vine stratum is dominated by *Lindera Benzoin* (stratum rank 8), particularly in the larger sinks and other very mesic situations. *Asimina triloba* is stratum rank 5; *Rhus radicans* and *Smilax rotundifolia*, 4; *Parthenocissus quinquefolia* and *Ribes cynosbati*, 3; *Sambucus canadensis* and *Viburnum acerifolium* are minor shrubs.

Twenty-two species of summer herbs were stratum-ranked as follows: *Galium concinnum* and *Podophyllum peltatum*, 7; *Arisaema triphyllum* and *Galium circaezans*, 5; *Actaea alba, Boehmeria cylindrica, Circaea latifolia, Viola* sp., 4; *Impatiens pallida, Polygonatum pubescens*, and *Sanguinaria canadensis*, 3; *Cimicifuga racemosa, Dryopteris hexagonoptera, Hydrastis canadensis, Jeffersonia diphylla, Menispermum canadense, Panax quinquefolius, Phytolacca americana, Trillium gleasoni*, 2; *Osmorhiza claytoni* and *Hydrophyllum appendiculatum*, 1. The only herbs present with marked affinities to southern forests are *Cimicifuga* and *Jeffersonia*. The fern flora is very depauperate for a rich, mesic woods.

Sinkhole Comparison. The upland stand has Karst topography that typically develops as a result of surface collapse into solution chambers in the underlying limestone. There are about two dozen sinks of various sizes in the 17½-acre stand. Most range from 8 to 15 feet deep, and vary in bottom configuration and subsurface drainage. They may be grouped into three broad categories as defined in the Methods Section. Some of the larger sinks have almost impenetrable tangles of grapevine, Virginia creeper and spice bush thoroughly interlaced with a rank growth of jewel weed that commonly grows shoulder high.

The total area tallied in the six sinks was 1½ acres or about 8% of the entire stand. The importance values for species present in the three types of sinks are summarized in Table 3. The six species present in the small sinks subject to ponding were confined to the rims above the level of flooding, except for an occasional large beech in the bottom. It is of interest that tulip-poplar, walnut and slippery elm (*Ulmus rubra*) are absent from the small, ponding sinks, although they represent nearly ¼ of the importance value of the total stand (Table 1). The periodic ponding may prevent seed germination near the sink bottoms, particularly the largely gravity dispersed walnut. Collective importance values for beech and sugar maple are reduced along the sinkhole gradient from 79.0% to 68.8% to 58.5% (Table 3), although they are clearly the dominant species in all three cases. This decrease is compensated for by an increase in walnut, slippery elm, American elm (*Ulmus americana*) and tulip-poplar. The fertile soil and mesic conditions of the large sink bottoms provide a situation similar to high floodplains, where these species typically reach their best development. Tree reproduction, shrub and herb strata are well represented in all of the non-ponding sinks, but are almost totally excluded from the ponded sections. Consideration of sinkhole microenvironments is important because they add variety to an otherwise uniform area, and correspondingly enrich the plant communities present.

TABLE 3. *Comparison of Average Importance Values for Woody Species Located in Three Contrasting Types of Sinkholes.*

Species	Small Temporarily-Ponding Sinks	Small Non-Ponding Sinks	Large Non-Ponding Sinks
Ostrya virginiana	3.4	---	---
Prunus serotina	3.8	1.7	---
Cornus florida	6.5	3.0	1.7
Fraxinus americana	7.4	6.6	2.2
Acer saccharum	24.4	17.0	9.6
Fagus grandifolia	54.6	51.8	37.0
Juglans nigra	---	8.4	21.5
Ulmus rubra	---	11.6	12.0
Ulmus americana	---	---	12.0
Liriodendron tulipifera	---	---	2.1
Celtis occidentalis	---	---	1.7

Slope Forests. The west, northwest and northeast-facing slope aspects represent 600 feet or 0.6 acre each of the 2,600-foot belt transect, and the north and east-facing slope aspects represent 400 feet or 0.4 acre each. No south slope was present in that immediate area. Data for basal area per acre and importance values are summarized in Table 4. The slope both lengthens (vertically) and steepens from the west side around to the east. The richness of the woody flora decreases and soil moisture increases from west to east. The soil pH remains moderately acid until the steeper northeast and east-facing slopes with numerous limestone outcroppings are encountered, then it becomes slightly basic. On the latter slopes, there are abundant mid-slope seepage outlets from the internally-drained upland sinks. Since soil moisture readings were taken in July following a long dry period, none of the areas had high moisture values.

Species shifts follow, in general, the drouth susceptibility of the slopes (Table 4). Trees more typical of more xeric slopes, such as black locust (*Robinia pseudoacacia*) (probably an escape), Eastern red cedar (*Juniperus virginiana*), blue beech (*Carpinus caroliniana*), redbud (*Cercis canadensis*) and dogwood are restricted to the west and northwest-facing slopes. Oaks, hickories and beech are absent from the mesic northeast and east-facing slopes, except for one bitternut hickory (*Carya*

TABLE 4. *Comparison of basal area per acre and importance values for forests of contrasting slope aspects along a mid-slope horizontal transect.*

Species	West-Facing		NW-Facing		North-Facing		NE-Facing		East-Facing	
	B_2	V_3	B_2	V_3	B_2	V_3	B_2	V_3	B_2	V_3
Cornus florida	0.3	0.9	--	--	--	--	--	--	--	--
Robinia pseudoacacia	0.9	2.2	--	--	--	--	--	--	--	--
Cercis canadensis	1.1	3.5	--	--	--	--	--	--	--	--
Quercus muehlenbergii	2.6	4.6	--	--	--	--	--	--	--	--
Juniperus virginiana	2.3	5.3	--	--	--	--	--	--	--	--
Fraxinus quadrangulata	1.0	1.3	2.3	1.6	--	--	--	--	--	--
Carpinus caroliniana	0.4	1.8	2.6	7.7	--	--	--	--	--	--
Aesculus glabra	1.1	1.8	--	--	1.0	2.2	--	--	--	--
Liriodendron tulipifera	3.0	2.7	--	--	6.3	5.8	--	--	--	--
Carya ovata	2.9	3.4	--	--	2.8	2.2	--	--	--	--
Quercus alba	7.4	5.7	--	--	4.2	2.8	--	--	--	--
Quercus rubra	0.8	1.9	0.4	1.0	9.4	6.2	--	--	--	--
Ostrya virginiana	2.9	11.0	8.7	14.7	1.7	5.5	--	--	--	--
Fagus grandifolia	9.0	12.9	13.3	11.4	19.0	22.2	--	--	--	--
Carya cordiformis	6.2	8.3	2.1	2.6	3.5	2.5	1.0	0.9	--	--
Ulmus rubra	0.2	0.9	5.4	6.2	--	--	18.3	13.1	11.0	9.0
Tilia americana	0.6	1.9	3.5	2.7	4.2	4.5	14.9	9.9	10.2	9.3
Acer saccharum	23.5	29.8	45.0	42.4	30.6	41.4	39.9	51.4	20.8	38.3
Juglans nigra	--	--	5.4	4.0	6.3	4.7	18.2	10.5	28.5	24.3
Fraxinus americana	--	--	7.6	5.9	--	--	2.1	1.8	0.7	2.1
Ulmus americana	--	--	--	--	--	--	3.9	5.5	12.3	12.3
Celtis occidentalis	--	--	--	--	--	--	8.7	7.0	--	--
Fraxinus pennsylvanica	--	--	--	--	--	--	--	--	3.4	3.7
Acer negundo	--	--	--	--	--	--	--	--	0.4	1.1
Total Basal Area Per Acre	66.2		96.3		89.0		107.0		87.3	
Percent Slope	40		40		58		75		81	
Soil—Percent Dry Weight	25.0		27.7		27.3		29.9		33.3	
Soil pH	6.0		6.5		5.9		7.3		7.4	
Number of Species	18		11		11		8		8	

TABLE 5. *Comparison of changes in basal area per acre and importance values from upland to floodplain in 100-linear-foot increments along a vertical transect.*

	Upland				Slope							
	1		2		3		4		5		6	
Species	B_2	V_3	B_2	V_3	B_2	V_3	B_2	V_3	B_2	V_3	B_2	V_3
Nyssa sylvatica	4.2	5.0	---	---	---	---	---	---	---	---	---	---
Fraxinus americana	2.0	6.0	---	---	---	---	---	---	---	---	---	---
Cornus florida	1.1	5.4	1.5	2.6	---	---	---	---	---	---	---	---
Liriodendron tulipifera	3.9	7.1	26.2	27.8	---	---	---	---	---	---	---	---
Fagus grandifolia	54.2	40.2	107.3	49.1	11.6	7.3	---	---	---	---	---	---
Acer saccharum	15.0	32.9	12.2	18.7	23.7	35.0	23.6	47.1	18.0	27.2	9.8	16.7
Celtis occidentalis	1.9	3.6	---	---	---	---	---	---	---	---	1.4	2.6
Ulmus rubra	---	---	1.9	2.8	5.4	7.6	5.6	6.7	16.4	10.4	0.5	2.1
Tilia americana	---	---	---	---	17.9	12.1	20.3	19.2	---	---	9.0	10.7
Fraxinus quadrangulata	---	---	---	---	14.3	8.7	---	---	---	---	---	---
Carya cordiformis	---	---	---	---	8.2	9.0	---	---	---	---	---	---
Quercus rubra	---	---	---	---	5.0	4.1	---	---	---	---	---	---
Carya ovata	---	---	---	---	0.9	2.1	---	---	---	---	---	---
Ulmus americana	---	---	---	---	15.4	14.2	3.0	5.0	21.6	19.0	---	---
Juglans nigra	---	---	---	---	---	---	24.8	22.1	32.2	26.5	47.1	43.4
Fraxinus pennsylvanica	---	---	---	---	---	---	---	---	8.0	12.2	8.9	8.8
Acer negundo	---	---	---	---	---	---	---	---	0.9	2.5	---	---
Prunus serotina	---	---	---	---	---	---	---	---	---	---	1.7	4.7
Platanus occidentalis	---	---	---	---	---	---	---	---	---	---	5.4	4.9
Gleditsia triacanthos	---	---	---	---	---	---	---	---	---	---	4.4	6.2
Total Basal Area Per Acre	82.3		149.1		102.4		77.3		97.1		88.2	
Soil—Percent Dry Weight	18.8		18.5		18.3		33.4		42.6		48.4	
Soil pH	6.2		5.9		6.9		7.3		7.4		7.4	
Number of Species	7		4		9		5		7		9	

cordiformis). Both basswood (*Tilia americana*) and walnut increase progressively from drier to mesic slopes. Sugar maple is well represented on all slopes although fluctuating widely in both basal area per acre and importance value. Also of interest is the addition of species more typical of floodplains (American elm, hackberry (*Celtis occidentalis*), green ash (*Fraxinus pennsylvanica*) and box-elder) as the mesic slopes with subsurface seeps were reached. Kentucky coffeetree, sycamore (*Platanus occidentalis*) and honey locust (*Gleditsia triacanthos*) were present on the east slope, although they did not fall within the transect.

The species-substrate relationships described above serve to illustrate quantitatively how community types of the Laughery Valley change progressively with the compass in this diverse topography. The richest flora occurs on the west slope community, which, according to Braun (1), is more typically mixed mesophytic than is either the upland or the moist east and northeast-facing slopes. The latter are undoubtedly late seral stages, rather than mature stands, held there in this case by physiographic instability and excess subsurface moisture.

The results from two vertical belt transects down the east slope from the upland to the beginning of the Laughery floodplain are combined and summarized in Table 5. The linear 100-foot increments represent horizontal distances since slope corrections were made. The combined transect represents 0.2 acre per 100 feet increment. Sections 1 and 2 are on the relatively level upland; section 3 represents the abrupt break at the bluff; sections 4 and 5 the steep (75-80°) mid-portion of the slope, and section 6 the less steep beginning of the floodplain. (Slope percentages are given for only sections 4 and 5 because the slope percentages change continually in the other sections.)

The stand attributes of the upland sections were not appreciably different from those of the upland stand in general (Table 1), except that the relatively small transect sample missed many of the rarer species of the upland stand. Sugar maple was represented in all slope sections, although the basal area and importance values fluctuated rather widely. Beech stopped at the bluff; whereas, oak, hickory and blue ash were restricted to the bluff edge and dropped out as the mesic lower slopes were reached. The vertical distribution of these species is similar to the horizontal distribution shown in Table 4, with respect to moisture conditions. Basswood, walnut and slippery elm increased in response to increasing mesic conditions as they did in the slope aspect comparison. Species typical of wet sites, such as box-elder, sycamore and honey-locust were encountered as the floodplain was neared.

Potzger Woods

Stand Description. Species attributes are listed in Table 6 for the 24 species greater than 4 inches dbh. Both the stand density of 121.43 stems per acre and the stand basal area of 116.58 square feet per acre are slightly higher than the corresponding values for the preceding stand. This stand is heavily dominated by sugar maple and beech with the two species accounting for nearly 70% of stand importance. Also of interest

TABLE 6. *Stand Attributes for Potzger Woods, based on trees 4" dbh and greater. 6.44 acres—full tally.*

SPECIES	D_2	D_3	B_2	B_3	V_3	BA/Tree
Acer saccharum	68.63	56.52	23.93	20.53	38.53	.35
Fagus grandifolia	14.29	11.77	57.84	49.61	30.69	4.05
Juglans nigra	4.50	3.71	7.44	6.38	5.05	1.65
Fraxinus americana	6.52	5.37	4.51	3.87	4.62	.69
Nyssa sylvatica	2.64	2.17	5.24	4.49	3.33	1.98
Ulmus rubra	3.88	3.20	3.12	2.68	2.94	.80
Liriodendron tulipifera	2.48	2.04	4.13	3.54	2.79	1.66
Prunus serotina	3.57	2.94	2.44	2.09	2.52	.68
Cornus florida	3.11	2.56	.42	.36	1.46	.14
Ostrya virginiana	2.48	2.04	.45	.39	1.22	.18
Ulmus americana	1.55	1.28	1.00	.86	1.07	.65
Tilia americana	1.24	1.02	.90	.77	.90	.73
Celtis occidentalis	.78	.64	.98	.84	.74	1.26
Carya cordiformis	.93	.77	.74	.63	.70	.80
Quercus rubra	.93	.77	.60	.51	.64	.65
Fraxinus pennsylvanica	.78	.64	.66	.57	.61	.85
Fraxinus quadrangulata	.93	.77	.19	.16	.47	.20
Quercus alba	.62	.51	.40	.34	.43	.65
Sassafras albidum	.16	.13	.71	.61	.37	4.43
Aesculus glabra	.62	.51	.24	.21	.36	.39
Carya ovata	.31	.26	.36	.31	.29	1.16
Carya glabra	.16	.13	.19	.16	.15	1.19
Quercus muehlenbergii	.16	.13	.05	.04	.09	.31
Acer rubrum	.16	.13	.04	.03	.08	.25
Total	121.43		116.58			

is the 5.05% importance value for walnut, which represents one of the highest upland stand values for that species in the state.

When the size-class data are examined (Table 7) the preponderance of small sugar maple is immediately apparent. Again, ratios were calculated for the proportion of sugar maple and beech below and above 12 inches. For sugar maple greater than 2 inches the ratio of small to large trees is 1002/26 or 38.54, and the corresponding figure for greater than 4 inches is 416/26 or 16.00. The ratios for beech are 10/84 or 0.12 and 8/84 or 0.10, respectively. A comparison with previous studies of Potzger Woods indicates that sugar maple is gaining in stand importance, possibly at the expense of beech. This is discussed in more detail in the section comparing the two stands.

There are 52 stems greater than 28 inches, or an average of 8 large trees per acre. Forty-four (84.4%) of the large trees are beech. The largest individuals of species in the full tally plot include: beech 45.8, tulip-poplar 35.2, sugar maple 32.4, sassafras 29.0 (44 feet clear bole),

TABLE 7. *Size class table for Potzger Woods. 6.44 acres—full tally.*

Species	Size Class Midpoints												Total	Total
	2-4″	6″	10″	14″	18″	22″	26″	30″	34″	38″	42″	46″	>4″	>2″
Acer saccharum	586	359	57	8	4	5	5	3	1				442	1028
Fagus grandifolia	2	5	3	4	6	20	10	23	13	7		1	92	94
Fraxinus americana	9	20	10	5	4	3							42	51
Juglans nigra		1	1	11	9	5	2						29	29
Ulmus rubra	9	12	7	3		1	2						25	34
Prunus serotina	1	11	4	4	4								23	24
Cornus florida	64	20											20	84
Nyssa sylvatica	2	5	2	2		1	6	1					17	19
Ostrya virginiana	26	14	2										16	42
Liriodendron tulipifera	2	5	4		3	1	1	1	1				16	18
Ulmus americana	1	4	2	4									10	11
Tilia americana	7	5	1	1			1						8	15
Carya cordiformis	3	3	1		2								6	9
Quercus rubra	2	1	4		1								6	8
Fraxinus quadrangulata		6											6	6
Celtis occidentalis	4	1	3					1					5	9
Fraxinus pennsylvanica		3			2								5	5
Aesculus glabra	5	2	1	1									4	9
Quercus alba	1	2		2									4	5
Carya ovata	3		1	1									2	5
Sassafras albidum								1					1	1
Carya glabra				1									1	1
Quercus muehlenbergii		1											1	1
Acer rubrum		1											1	1
Vitis spp.	35													35
Carpinus caroliniana	6													6
Asimina triloba	1										0	1	782	1551
Total	769	481	103	47	35	36	27	30	15	7				1

black gum 28.7, hackberry 28.1, basswood 25.4 and walnut 24.5. The general canopy height of this stand is 110 to 115 feet with a few taller trees reaching 120 feet. Increment cores taken from the outer portion of large tulip-poplar and beech trees (34.8 and 34.1 inches dbh, respectively) indicate that they are still steadily growing: a 3-inch increase in radius in 24 years or 0.25 inch diameter average increase per year for tulip-poplar, and a 3-inch radial increase in 33 years or 0.18 inch average diameter increase per year for beech. A complete coring of a 22.5-inch walnut showed the tree to be 66 years old, or an average annual diameter growth increase of slightly over ⅓ inch.

Stratum rank values for 10 species of shrubs and vines are: *Lindera benzoin* and *Smilax rotundifolia*, 5; *Viburnum acerifolium* and *Vitis* sp., 4; *Parthenocissus quinquefolia* and *Ribes cynosbati*, 3; *Asimina triloba, Rhus radicans, Viburnum rufidulum* and *Sambucus canadensis*, 2.

Twenty-four species of summer herbs and ferns had the following stratum rank values: *Impatiens pallida*, 7; *Galium concinnum* and *Urtica procera*, 6; *Galium circaezans* and *Podophyllum peltatum*, 5; *Adiantum pedatum, Arisaema triphyllum, Athyrium asplenioides, Circaea latifolia, Osmorhiza claytoni*, and *Polygonatum pubescens*, 4; *Cimicifuga racemosa, Dryopteris hexagonoptera, Menispermum canadense, Ranunculus septentrionalis, Smilacina racemosa, Solidago caesia* and *Viola* sp., 3; *Actaea alba, Anemone quinquefolia Boehmeria cylindrica, Polystichum acrostichoides* and *Sanguinaria canadensis*, 2; and *Panax quinquefolius*, 1. The fern flora is much richer than in Jackson Woods.

Comparison with Previous Studies. Potzger Woods is one of the few stands in the state to have four forest ecological studies during a 20-year period. Unfortunately, the exact plot and sample point locations were not permanently marked so that exact comparisons could be made. Potzger (9) plot sampled the woods using 33 ten-meter square quadrats, for a sample totalling about 12.5% of the nearly 6½ acres full tallied in this study. In 1955, Petty (8) full-tallied 5 acres of the least-disturbed part of the stand; however, it is unknown if the present full-tally completely included the earlier 5-acre census. Stearns (15) intensively sampled the area by the random pairs method by establishing 140 points and recording data for 280 trees over 4 inches dbh. His sample would be equivalent to nearly 36% of the 782 trees included in this tally.

A comparison of these studies clearly indicates the value of taking full tallies of forest remnants whenever possible. Although there have undoubtedly been some compositional changes in the stand during the past 18 years, many of the differences in stand attributes obtained in the four studies are due to differences in sampling adequacy and data interpretation.

This is particularly apparent when the rarer species are considered. In both full tallies, 24 species were recorded, although only 21 were common to the two studies. Differences in the species lists result largely from the plots not being exactly the same size and in the same location, since only one individual was involved for five of the six species in question. The other case is a question of how consistently white ash (*Fraxinus americana*) and green ash (*F. pennsylvanica*) can be separated in the field. There should, obviously, be no problem in obtaining comparable species lists for a stand when full tallies include the identical stand segment. By comparison, Potzger (9) recorded only 16 of the 24 species listed in this study with his 12.5% sample and Stearns (15) encountered only 15 species in a 36% sample, the latter being a much more intensive forest sample than is usually taken. Coefficients of community, based on relative density, were calculated for the four studies of the single stand. Relative density is used in this comparison since importance values were not determined in the two earlier studies. The coefficients of community ranged from 61.8 to 82.3% similarity with the two full tallies giving the greatest similarity. The similarity between the two full tallies probably would have been even closer except that density for the former study was based on 3-inch and larger trees; whereas, this study was based on trees greater than 4 inches dbh.

Substantial composition changes could also occur in an 18-year period. The main changes in density during the 13-year period between Petty's (8) study and this study include an increase in sugar maple from 42.4% to 56.5% and a decrease in American elm from 5.0% to 1.3%. All other species have remarkably constant values between the two studies. The latter change is largely due to mortality of American elm due to disease. Sugar maple most likely is increasing substantially in density, particularly in the smaller size classes (Table 7). When the present sugar maple density values are compared to Potzger's 1950 study, the change is even greater: 39.9% to 56.5%.

Stearns (15) found beech and sugar maple importance values of 43.8% and 24.5%, respectively, as compared to 30.7% and 38.5%, respectively, in this study. Comparable shifts in relative density and relative basal area are as follows: sugar maple increased from 33.9% to 56.5% density, and from 15.0% to 20.5% for basal area; whereas, beech decreased from 27.5% to 11.8% density and from 60.1% to 49.6% basal area. Some differences would occur due to sampling differences, as mentioned previously, but these data indicate a definite trend toward increased maple importance largely at the expense of beech.

This comparison is not intended to be a criticism of any previous study. Each study was well conceived and properly executed. The problem is one of sampling intensity and adequacy, particularly with respect to low frequency species. Since full tallies can be made for most accessible stands at the rate of about one acre per hour for all field labor, it is hardly justifiable when working with small stands, to compromise the adequate stand data obtained from full tallies for the slight gain in field efficiency obtained by low intensity sampling. Furthermore, it is questionable whether Potzger Woods could have been sampled by taking 140 sets of random pairs of trees in less time than the six hours required in this study to full tally the stand.

Comparison of Stands

There is remarkable vegetational and floristic similarity between the two stands (Tables 1 and 6). Twenty-one of the 24 species of woody plants greater than 4 inches dbh occurring in Potzger Woods are also found in Jackson Woods. Beech has almost identical absolute values for density and basal area in the two stands, but sugar maple represents over 13% greater importance in Potzger Woods by virtue of a very high density per acre of 68.6 and nearly double (23.9 to 12.7) its former basal area value. The only other substantial shifts are decreases in importance value for tulip-poplar from 14.1% to 2.8% and dogwood from 6.5% to 1.5%. The combined importance value for beech and sugar maple is 11.7% greater in Potzger Woods than in Jackson Woods, compensating, in part, for the decreased importance of tulip-poplar in the former stand.

When the two stands were compared by coefficients of community based on tree importance values, the stands were 77.8% similar. This compares well with the highest coefficient found (82.3%) when the four studies of Potzger Woods were compared.

The two stands are also very similar with respect to shrub and herb composition. All nine of the shrub and vine species present in Jackson Woods were present in Potzger Woods. The only additional shrub in Potzger Woods was *Viburnum rufidulum*, the southern black haw. Coefficients of community based on stratum rank values for shrubs and vines yielded a similarity percentage of 80.0. Sixteen of the 22 and 24 herb species found in Jackson and Potzger Woods, respectively, were in common to both woods. The coefficient of community based on herb species was 61.5% similarity.

With such close similarity between the local climates, physiography, drainage and soils of the two sites, lack of vegetation similarity would be anomalous. However, the degree of similarity described here is much closer than for most individual stands within a forest association.

Apparently even the time and amount of past disturbance has been similar. When the density was plotted (on the ordinate) per size class (on the abscissa) on semi-log paper, each of these stands exhibited the same departure from the straight line relationship considered typical of old-growth stands. Both stands have similar pronounced plateaus in the 18- to 30-inch size classes, which indicate substantial disturbance during the same time period. The disturbance largely reflects the moderate cutting about 30 to 40 years ago, as previously mentioned. This selective cutting favored seedling establishment and release of established individuals of relatively intolerant species such as tulip-poplar, walnut, ash, slippery elm, wild cherry and sassafras. These relationships become clear when Tables 2 and 7 are examined.

Phytogeographic Position of the Stands

In her discussion of the Area of Illinoian Glaciation in southeastern Indiana and adjacent southwestern Ohio, Braun (1) states: "In transitional bands between the flats and the slopes of the area, where drainage and aeration are better and yet dissection is not apparent, sugar maple appears with the beech. This beech-maple forest is a seral community which is replaced by mixed mesophytic forest whenever dissection becomes more evident." She goes on to add concerning the dissected areas of that region: "In most of the mixed mesophytic forest communities of this section of the Western Mesophytic Forest region, beech forms approximately 50 per cent of the canopy. In the mixed mesophytic communities, tulip tree, sugar maple, basswood, walnut and white ash are almost always present together with some six or eight species of lesser frequency."

The authors feel that the upland stands described in this paper fit Braun's description almost exactly. Both sites are well-drained, but not excessively dissected. Although the importance values (Tables 1 and 6) give the impression that maple is co-dominant with beech, inspection of the basal area columns (the best single attribute for expressing dominance) places sugar maple in more nearly its actual position. In both of these stands, beech represents about 50% of the stand basal area, while 10 and 8 additional species (including all of those Braun mentioned) have about 1% or greater relative basal area in Jackson and Potzger Woods, respectively. Presently, these upland stands should be classified as beech and sugar maple dominated mixed mesophytic forests.

As previously mentioned, many old-growth stands have prodigious sugar maple reproduction and very few young beech, but differential survival rates compensate to keep beech persisting or even increasing as a co-dominant. This will no doubt be the short-term effect as the stands continue to recover during the next 50 years or so from the moderate past disturbance. It would appear, however, that over long periods beech may lose importance as the physiography and stands mature. Should this occur, the stands would be expected to become more mixed in total composition with sugar maple gaining somewhat in importance value. The latter situation is exemplified in the west-facing slope data in Table 4. Excluding black locust (one individual) and Eastern red cedar (which was confined to one small limestone outcrop), 14 species each represent greater than 1% of the west-facing slope importance value, indeed a very mixed stand with no species clearly dominant. The west-facing slope represents mature but not over-dissected topography and a slightly drier than average aspect. It is expected that the upland stand composition will approach that currently occurring on the west-facing slope, as the physiography of the upland matures.

Although these mixed forests are not the true Mixed Mesophytic forests typical of the Cumberland Mountains, they were derived from that type in response to Post-Pleistocene northward migration and the attendant compositional changes as the forest segregated in the complex of habitats in the Laughery Valley (1). Neither yellow buckeye nor white basswood, considered by Braun (1) as indicators of the Mixed Mesophytic type, were found in the vicinity of the study area. Both are reported in Clifty Falls State Park, located about 25 miles south, and Deam (2) reports white basswood for Ripley County, but a persistent search in these stands failed to produce either species.

Future work on the forests of the Laughery Valley should center on long-term changes within the best described old-growth stands and relating these stands to the forest complex of the region as a whole.

Summary

1. Two old-growth upland forests were studied by taking full tallies of all trees over 2.0 inches dbh for segments of 17.46 acres and 6.44 acres, respectively, in Jackson and Potzger Woods.

2. Both stands are beech and sugar maple-dominated mixed mesophytic forests with the two dominant species totaling 57.5% and 69.2% of the importance value, respectively. Ten and eight other species each represent about 1% or greater importance values in the two stands, respectively.

3. Sugar maple dominates the smaller size classes, indicating that it is likely increasing in stand importance, probably in response to limited disturbance about 30 to 40 years ago.

4. Intolerant species such as tulip-poplar, walnut, elm and wild cherry have been favored by past cutting which created rather extensive canopy openings.

5. The forest composition of sinkholes changes in response to ponding or improved internal drainage. Beech and sugar maple decrease in importance, but walnut, elm and tulip-poplar increase with increases in internal drainage and increases in sinkhole size.

6. The effect of slope aspect on forest composition was determined by transect sampling. The west-facing slope is a mixed-mesophytic forest with many species sharing dominance. Oak and hickory species increase in importance value on the excessively-drained northwest and north-facing slopes. The steep northeast and east-facing slopes are very moist due to subsurface seeps; this results in a species composition similar to floodplains. Sugar maple occurs on all slopes, but beech is absent from the northeast and east slopes.

7. A comparison of four studies of Potzger Woods based on different sampling methods indicates that rarer species were encountered only in full tallies. Since 1956, sugar maple has increased in stand importance, possibly at the expense of beech, which has decreased.

8. Changes in stand composition over the next several decades will likely show additional recovery from disturbance and a gain in sugar importance at the expense of the more intolerant species. Beech will likely hold its position as the stand co-dominant.

9. As the physiography matures and becomes more dissected over a great number of years, the stand should become more mixed mesophytic in composition rather than the present beech and maple dominated mixed composition.

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