Comparison of Groundlayer and Shrublayer Communities in Full Canopy and Light Gap Areas of Hoot Woods, Owen County, Indiana

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Introduction

Hoot Woods is a 64-acre (25.9-ha) old-growth beech-maple dominated forest located in Owen County, Indiana, about 3 miles northwest of the village of Freedom. The tract occupies a gentle east-facing slope which closely approximates the average environment for that region. Predominate soils are residual Wellston and Muskingum silt loams (35-70% slopes) and Zanesville silt loam (12-18% slope) derived in sandstone and shale (Owen County Soil Survey Report). National Natural Landmark designation was awarded the stand several years ago in recognition of its overall high quality and lack of disturbance.

Forest composition and stand dynamics of Hoot Woods have been the focus of several studies (Petty and Lindsey, 1961; Jackson and Allen, 1967; Donselman, 1973; Levenson, 1973; Williamson, 1975; Abrell and Jackson, 1977; and Jackson and Abrell, 1977).

A 10.87-acre (4.40-ha) area within the best section of the stand was fully censused for forest trees and all stems > 4.0 inches (10 cm) dbh mapped at a 1:33 scale during the summer of 1965 (Jackson and Allen, 1967). An additional 5.43-acre (2.20-ha) adjoining area was mapped during the decade interval follow-up study by Abrell and Jackson (1977) bringing the total area under consideration to 16.30 acres (6.60-ha).

During August 1979, the high-canopied stand (ca. 120 ft. or 37 m) was extensively damaged by tornadic force winds. Three major storm tracts were opened west-east across the mapped portion of the woods. In extensive areas all trees were uprooted, twisted off or seriously damaged. The stand also suffered a number of single or multiple tree falls, plus extensive damage to sections of the woods not the subject of intensive study.

Creation of light gaps by windthrow and other natural processes such as insect damage, disease and tree mortality due to age is a mechanism for retaining successional species within the stand, and for producing compositional mosaics even in older growth forests. The subject of this paper is the comparison of groundlayer and shrublayer communities in the full-canopied and light gap areas of the stand following six growth seasons after disturbance.

Methods

The 16.30-acre (6.60-ha) area was divided into 96 plots each 86 ft. (26.2 m) square. Thirty-two of these plots were selected as groundlayer community sample sites, with the shrublayer community sampled at these 32 locations, plus an additional 8 plots. Density, frequency and cover values were taken for groundlayer species within 1 × 1 m plots centered at the midpoint of the large tree plots. Shrub species were likewise sampled in 3 × 3 m plots at the same locations. Plot centers were permanently marked with sections of ¾-inch diameter electrical conduit. An effort was made to have one-half of each group of samples located in plots covered by full canopy and in plots within light gap areas.

Groundlayer plants were considered to be any vascular species (both herbaceous and woody) less than ½ m tall. Densities of above-ground stems, frequency percentages and subjective vegetation cover determinations were taken for all species present during Spring and Late Summer (late August) for groundlayer species. Shrublayer communities included all woody plants > ½ m < 3 m tall. Similar data were taken for shrubs in Mid-Summer (July) of the 1986 growth season. Percentage of groundlayer plants flowering was also recorded.

Chi-square values were calculated to determine differences in species densities between canopied and light gap areas in each of the sampled communities.

Species importance percentages were determined by averaging relative density, relative cover and relative frequency values for each species.

Results

Groundlayer Community Composition

Species attributes for the Spring and Late Summer sampling periods are listed in Tables 1 and 2, respectively. Considering the apparent ecological differences between the full canopy and light gap areas, and the time elapsed since disturbance (6 growth seasons) the Spring Communities are remarkably similar (Table 1). Each community contained 27 species, with a total of 33 species represented in the two communities combined. Only *Dicentra cucullaria* of the top 18 species was not common to both communities. Eleven species were woody, only two were ferns, plus one each grass and sedge species.

TABLE 1. Comparison of species attributes for the Groundlayer Communites during the Spring sample (based on 17 plots each 1 × 1 m in canopy community, and 15 plots in light gap community).

Species	Density/m²		Relative Cover		% Importance		Deviations in % Importance
	Full Canopy	Light Gaps	Full Canopy	Light Gaps	Full Canopy	Light Gaps	
Dicentra canadensis (Goldie) Walp.	45.71	48.80	26.33	34.69	19.74	26.54	+6.80
Erythronium americanum Nutt.	48.65	43.87	13.91	13.55	17.23	17.57	+0.34
Podophyllum peltatum L.	3.35	4.27	17.19	16.50	8.11	8.02	−0.09
Acer saccharum Marsh.	5.65	3.20	8.65	7.39	7.44	6.26	−1.18
Dentaria laciniata Muhl.	12.48	3.80	1.81	1.24	5.74	3.85	−1.89
Claytonia virginica L.	8.12	5.80	1.31	1.25	4.78	4.83	+0.05
Impatiens spp. L.	5.41	6.47	3.65	7.02	4.41	6.14	+1.73
Cystopteris fragilis (L.) Bernh.	12.18	4.00	4.08	1.88	4.01	2.07	−1.94
Brachyelytrum erectum (Schreb.) Beauv.	12.06	0.60	4.57	0.45	3.94	0.80	−3.14
Viola papilionacea Pursh.	6.12	5.40	1.33	1.27	3.54	3.47	−0.07
Dicentra Cucullaria (L.) Bernh.	4.41	—	4.88	—	3.53	—	−3.53
Arisaema triphyllum (L.) Schott.	5.48	2.00	0.80	1.53	2.36	2.24	−0.12
Galium asprellum Michx.	1.24	3.27	2.43	3.48	2.36	3.70	+1.34
Laportea canadensis (L.) Wedd.	3.12	3.73	2.88	3.17	2.19	2.44	+0.25
Erigenia bulbosa (Michx.) Nutt.	1.35	0.80	0.08	0.03	1.82	0.71	−1.11
Parthenocissus quinquefolia (L.) Planch.	1.24	1.33	1.15	1.02	1.71	2.43	+0.72
Rubus allegheniensis Porter.	0.18	1.00	0.36	3.17	0.37	2.05	+1.68
Viola eriocarpa Schw.	0.12	0.93	0.19	0.53	0.52	1.16	+0.64
[1]Other species	6.46	3.27	4.37	1.89	6.17	5.72	−0.45
Total	183.33	142.54	99.97	100.04	99.97	100.00	

[1] Other species in descending order of importance: Ulmus rubra Muhl., Phytolacca americana L., Polystichum acrostichoides (Michx.) Schott., Galium sp. L., Carex sp. L., Lindera Benzoin (L.) Blume., Cornus florida L., Ulmus americana L., Fagus grandifolia Ehrh., Prunus serotina Ehrh., Fraxinus sp. L., Solidago sp. L., Asimina triloba (L.) Dunal., Trillium sp. L., Isopyrum biternatum (Raf.) T. & G.

Chi Square value for density comparison for top 7 species is 8.901, 6df; not significant at 0.05 level.

Total mean density per square meter was significantly higher in the Spring full canopy samples than in the light gaps at 183.33 versus 142.54 (Chi-square 1.08, ldf) (Table 1). *Dicentra canadensis* and *Erythronium americanum* were codominant in both Full Canopy and Light Gap communities at combined importances of 37% and 44%, respectively. The top four species were the same order in both communities, with only minor shifts in order among the top eight species. The top eight species had very closely similar combined importances of 71.5 and 75.3%, respectively, in the two communities (Table 1).

Total mean density per square meter values for the Late Summer Community were only 9 and 15% of the Spring Community totals at 16.84 and 21.87, respectively (Table 2). The Full Canopy and Light Gap Communities contained only 18 and 13 species, respectively. *Acer saccharum* seedlings and *Pilea pumila* were dominant in both cases at a combined importance of 60 and 67%, in the Full Canopy and Light Gap Communities, respectively. The most dramatic change between communities was the nearly double increase in importance for *Pilea pumila* in the Light Gap Community (from 28.70 to 53.41%) (Table 2). Woody species comprised a much larger portion of the fall sample at 47.2 and 22.9% in the Full Canopy and Light Gaps, respectively.

TABLE 2. Comparison of species attributes for the Groundlayer Communities during the Late Summer sample (based on 17 plots each 1 × 1 m in canopy community, and 15 plots in light cap community).

	Density/m²		Relative Cover		% Importance		
Species	Full Canopy	Light Gaps	Full Canopy	Light Gaps	Full Canopy	Light Gaps	Deviations in % Importance
Acer saccharum Marsh.	5.65	1.40	31.04	16.37	31.12	13.44	−17.68
Pilea pumila (L.) Gray.	5.23	14.33	32.87	55.85	28.70	53.41	+24.71
Polystichum acrostichoides (Michx.) Schott.	2.12	—	8.88	—	7.88	—	− 7.88
Laportea canadensis (L.) Wedd.	1.76	1.20	7.01	23.50	7.30	12.13	+ 4.83
Carya cordiformis (Wang.) K. Koch.	0.12	—	5.61	—	3.58	—	− 3.58
Galium sp. L.	0.41	0.93	0.14	0.13	3.08	4.99	+ 1.91
Asimina triloba (L.) Dunal.	0.06	—	5.61	—	2.73	—	− 2.73
Fraxinus sp. L.	0.18	—	0.14	—	2.62	—	− 2.62
Cornus florida L.	0.24	—	2.81	—	2.14	—	− 2.14
Lindera Benzoin (L.) Blume.	0.12	—	2.81	—	1.91	—	− 1.91
Sassafras albidum (Nutt.) Nees.	0.12	—	1.40	—	1.44	—	− 1.44
Viola papilionacea Pursh.	0.29	0.20	0.05	0.04	1.34	1.47	+ 0.13
Fagus grandifolia Ehrh.	0.06	—	1.40	—	1.32	—	− 1.32
Cystopteris fragilis (L.) Bernh.	0.18	0.67	0.05	0.04	1.10	1.24	+ 0.14
Ulmus americana L.	0.12	0.13	0.05	2.52	0.99	2.18	+ 1.19
Prunus serotina Ehrh.	0.06	—	0.05	—	0.87	—	− 0.87
Epifagus virginiana (L.) Bart.	0.06	—	0.05	—	0.87	—	− 0.87
Parthenocissus quinquefolia (L.)	0.06	0.67	0.05	0.04	0.87	1.24	+ 0.37
Acer rubra L. Planch.	—	0.40	—	0.08	—	2.94	+ 2.94
Circaea quadrisulcata (maxim) Franch. & Sav.	—	0.20	—	0.08	—	2.60	+ 2.60
Smilax hispida Muhl.	—	0.67	—	1.26	—	1.65	+ 1.65
Rubus flagellaris L.	—	0.20	—	0.04	—	1.47	+ 1.47
Phytolacca americana L.	—	0.67	—	0.04	—	1.24	+ 1.24
Totals	16.84	21.87	99.97	99.99	99.86	100.00	

Groundlayer Flowering Rates

The percentage of above ground stems which flowered were computed for each the Spring and Late Summer groundlayer communities (Table 3). Most species had very low flowering rates with 10 of 14 species in the Spring Full Canopy Community and 7 of

TABLE 3. Comparison of flowering data for herbaceous groundlayer species during the Spring and Late Summer sample periods.

Species	Full Canopy		Light Gaps	
	No. Flowering	% Flowering	No. Flowering	% Flowering
Spring Community				
Dicentra canadensis	2/777	0.26	7/732	0.96
Erythronium americanum	3/827	0.36	1/658	0.15
Podophyllum peltatum	1/57	1.75	1/64	1.56
Impatiens spp.	0/92	0	0/97	0
Dentaria laciniata	1/212	0.47	9/57	15.78
Claytonia virginica	98/138	71.01	24/87	27.59
Brachyelytrum erectum	4/205	1.95	—	—
Viola papilionacea	0/104	0	1/81	1.23
Galium asprellum	19/21	90.48	12/49	24.49
Dicentra cucullaria	0/75	0	—	—
Arisaema triphyllum	0/93	0	0/30	0
Laportea canadensis	0/53	0	0/56	0
Erigenia bulbosa	7/23	30.43	—	—
Viola eriocarpa	1/1	100.00	6/14	42.86
Late Summer Community				
Pilea pumila	62/89	69.66	138/215	64.19
Laportea canadensis	4/30	13.33	4/18	22.22
Galium sp.	1/7	14.28	1/14	7.14
Circea quadrisulcata	—	—	0/3	0
Viola papilionacea	0/5	0	0/3	0
Phytolacca americana	—	—	0/1	0
Epifagus virginiana	0/1	0	—	—

11 species in the Spring Light Gaps Community registering less than 2% of above ground stems which flowered (Table 3). In eight of these cases, there wsa no flowering for species represented by 30 or more individuals. Only *Claytonia virginica* and *Galium asprellum* of higher density species had flowering rates above 50%. In general, flowering rates for the Light Gaps Community were low also, with *Claytonia* and *Galium* showing marked reductions. Only *Dentaria laciniata* experienced a marked increase in flowering in the Light Gaps.

The Late Summer Community had too few individuals for several species for meaningful comparison. The dominant species, *Pilea pumila* had about ⅔ of the stems flowering, with *Laportea canadensis* ranging from 13 to 22% flowering (Table 3). No major differences were noted between Full Canopy and Light Gap areas.

Shrub Community Composition

Species attributes for shrub species for both the Fall Canopy and Light Gaps Communities are summarized in Table 4. Slightly more species comprised the Full Canopy (20 *versus* 17); whereas the Light Gaps Community had a higher total density (263 *versus* 195). *Asimina triloba* dominated both communities similarly at 33.6 and 36.9 percent importance, respectively (Table 4). The most notable difference between the two communities is the addition of *Rubus allegheniensis* at 14.6 percent importance in the Light Gap community, reflecting the invasion potential of blackberry into the high-light openings. Other than the difference in *Rubus*, the top four species had combined importance percentages in the two communities of 75.5 and 62.6, respectively (Table 4).

Tree seedlings comprised a very similar combined importance of 41.7 and 39.3 percent, respectively, with the very tolerant *Acer saccharum* and *Fagus grandifolia* both being well represented in both communities, but at reduced density and cover values in

TABLE 4. Comparison of species attributes for the Shrub Community during Midsummer sample (based on 20 3 × 3 m plots in each community).

Species	Density/20 plots		Relative Cover		% Importance		Deviations in % Importance
	Full Canopy	Light Gaps	Full Canopy	Light Gaps	Full Canopy	Light Gaps	
Asimina triloba (L.) Dunal.	66	84	51.93	59.18	33.55	36.85	+ 3.30
Acer saccharum Marsh.	39	30	16.56	9.64	18.04	12.57	− 5.47
Rubus allegheniensis Porter.	—	78	—	7.24	—	14.61	+ 14.61
Lindera Benzoin (L.) Blume	26	7	13.53	5.54	13.46	5.05	− 8.41
Fagus grandifolia Ehrh.	18	18	8.50	5.11	10.41	8.15	− 2.26
Cornus florida L.	8	3	5.42	2.01	5.43	1.98	− 3.45
Fraxinus Spp. L.	11	7	1.37	1.63	5.04	2.82	− 2.22
Ulmus rubra Muhl.	7	18	0.29	5.73	2.64	8.82	+ 6.18
Carya cordiformis (Wang.) K. Koch.	5	6	0.34	0.97	2.32	2.94	+ 0.62
Quercus Muehlenbergii Michx.	2	—	0.20	—	1.31	—	− 1.31
Carya ovata (Mill.) K. Koch	2	—	0.98	—	1.12	—	− 1.12
Sassafras albidum (Nutt.) Nees	2	3	0.05	2.01	0.81	1.98	+ 1.17
Liriodendron tulipifera L.	—	3	—	0.66	—	1.99	+ 1.99
[1]Other species	9	6	0.83	0.28	5.89	2.24	− 3.65
Total	195	263	100.00	100.00	100.02	100.00	

[1] Other species in descending order of importance in *Full Canopy*: Sambucus canadensis L., Morus rubra L., Ostrya virginiana (Mill.) K. Koch., Vitis sp. L., Prunus serotina Ehrh., Smilax hispida Muhl., Quercus alba L., Quercus rubra L., Cercis canadensis L.; Species richness: 20

Other species in descending order of importance in *Light Gap*: Prunus serotina Ehrh., Vitis sp. L. Smilax hispida Muhl., Sambucus canadensis L., Parthenocissus quinquefolia L. Planch., Rubus occidentalis L. Species richness: 17

Chi-square for species in common = 45.267, 8 df.

the Light Gaps (Table 4). Riemenschneider and Blodgett (1984) also found little change in tree regeneration due to windthrow disturbance in Bendix Woods. *Cornus florida* was present in both communities, but again at lower incidence in the Light Gaps. Wind dispersed and intolerant *Liriodendron tulipifera* seedlings were present only in Light Gaps samples. *Ulmus rubra*, also wind dispersed and frequently aggressively invading in disturbance sites was present in the Light Gaps at three times its importance in the Full Canopy Community (Table 4). Chi-square values for densities of the 9 species in common to both communities showed significant differences (Chi-square = 45.27, 8df).

Discussion

The Spring groundlayer community composition showed much less variation between Full Canopy and Light gaps samples than suspected *a priori*. With 17 of the top 18 species common to both samplings (many at virtually identical importances, Table 1), plus a community coefficient value for the two communities of 85.8% similarity, could hardly be expected if the *same* community were sampled twice, with successive samples at different locations. When a coefficient of community was calculated between the Summer groundlayer community of this study and the one taken by Levenson (1973), a value of only 51.1% was obtained. The wider difference was in part due to the almost total absence of Levenson's top dominant species (*Parthenocissus quinquefolia*) from our sample, plus the much greater diversity obtained in Levenson's much larger sample size (0.01 ha).

As was pointed out by Moore and Vankat (1986), many of the Spring groundlayer species have life cycles that are geared to completing flowering and much of their photosynthetic activity prior to canopy closure as the trees reach full leaf. In that sense, the creation of light gaps due to canopy disturbances is not expected to affect spring wildflower patterns appreciably. With the soil profile and leaf litter intact, the biotope of spring wildflowers is probably little changed from full canopied conditions prior to disturbance. In fact some forest wildflower species such as *Claytonia* and *Erythronium* persist for many years in parks and lawns after the original forest canopy is essentially gone, with the soil and leaf litter changed accordingly. Rogers (1982) speculated that death or removal of overstory trees may significantly reduce root competition in the groundlayer, but such effects would be hard to document.

That six growth seasons have elapsed since the light gaps were created have permitted ingrowth and size increases of subcanopy trees which have doubtless partially masked differences in the light regime that occurred immediately following disturbance. Such rapid recovery would favor those groundlayer species (woody and herbaceous) which may be present in a spring sample, yet persist and photosynthesize through more of the growth season.

Late summer groundlayer species exhibited much greater differences between Full Canopy and Light Gaps areas (Table 2). Of the 23 species present in the two communities collectively, only 8 were common to both. During mid-to-late summer the differences in light regime between the two communities is very obvious from a simple woods walk. Moisture relations are likewise modified, though less drastically. These environmental changes plus aggressive invasion by such species as clearweed (*Pilea pumila*) and blackberry (*Rubus allegheniensis*) present serious challenges to regeneration of woody seedlings, especially. Moore and Vankat (1986) found the cover percentages of tree seedlings to decline in older gaps in Heuston Woods in Ohio.

The relatively low diversity of herbaceous species (33 in spring and 23 in summer samplings) may be representative of climax forests as they mature. Brewer's (1980) analysis of the groundlayer species over a 50-year period in Warren Woods in Michigan, pointed to the herbaceous flora becoming progressively more restricted. If this is the case for other beech-maple stands, disturbances such as the damage experienced at Hoot Woods should counteract this downtrend in diversity. We observed a few examples of species increases or invasions into light-gap areas in this study. More long-term studies are sorely needed.

Thompson (1980) examined colonization patterns and diversity differences among herbs in old-growth forests in Illinois in terms of landscape heterogenity created by tip-up mounds and pits following tree falls of varying ages. Our study did not focus on this aspect, as few of our plots centered on those altered landforms. Hoot Woods has relatively uniform topography (being on a gentle east-facing slope with shallow ravines) which would further tend to restrict species diversity.

The low incidence of flowering among groundlayer species (Table 3) may be more of a characteristic of the woods, than of the species. One of the authors (MTJ) has walked this woods during most springs of the past 20 years and has repeatedly commented on the depauperate spring wildflower display. Members of the Hoot family have likewise reminisced about the wildflowers being far fewer now than during their girlhood. The only possible explanation that comes to mind is that the woods was lightly grazed by sheep for a short time during the 1950s. Perhaps the wildflower populations are still recovering from that disturbance and are slowly building vigor necessary before flowering. The botanical literature has a notable paucity of such data as the frequency or consistency of flowering among wildflower populations.

The overwhelming invading woody species into the shrub community in the Light Gaps is blackberry (*Rubus allegheniensis*). In the larger openings it forms near-impenetrable thickets of brambles. Its presence marks the predominant change in the Shrub Community composition (Table 4). Intolerant tree seedlings such as tulip tree and sassafras had minor increases; but composition was similar between the two communities (Table 4). When coefficient of community values were run between this study and that of Donselman (1973), a similarity of 67.4% was obtained. In both studies 20 species contributed to the shrub layer with 14 species in common.

It will be interesting to follow the changes in the shrub layer during the next decade as subcanopy tree ingrowths and size changes create the shade necessary to exclude the blackberry and favor the more typical beech-maple forest shrubs. Data on tree dynamics in Hoot Woods during the past 20 years is being reported elsewhere by Jackson and Abrell, (In Preparation).

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