FOREST VEGETATION OF THE CLIFTY CANYON NATURE PRESERVE AT CLIFTY FALLS STATE PARK, JEFFERSON COUNTY, INDIANA

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ABSTRACT: Clifty Falls State Park (CFSP), Jefferson County, Indiana, was established in 1920, and a portion of the gorge was designated as the Clifty Canyon Nature Preserve in 1980. Previous descriptions of the forests in southeastern Indiana, including Jefferson County, referred to them as beech-oak and beech-oak-maple-hickory forests. Braun (1950) sampled 80 canopy trees in CFSP and described the forest there as mixed mesophytic. The purpose of this study was to sample the forest vegetation of CFSP, especially the Clifty Canyon Nature Preserve, to determine its structure and composition. The sample totaled 1154 trees (dbh > 10 cm), representing 30 species. The most important species were *Acer saccharum, Quercus rubra, Q. muehlenbergii, Franxinus americana,* and *Tilia heterophylla.* There were 306 trees/ha with a mean basal area of 26 m/ha. Since Braun (1950) reported on canopy trees only, a subset of trees greater than 30 cm dbh was selected from the current sample for comparison with her sample. The similarity coefficient between the two samples was 61%. The CFSP forest is a mixed mesophytic forest as Braun (1950) suggested, but two significant differences exist between the two studies: Braun's (1950) diversity index (H) was 2.47, while it was 3.72 in the current study; Braun listed 10 canopy species, whereas 22 were found in the current study. Braun's sample may have been too small to accurately characterize the species diversity of the CFSP forest.

KEYWORDS: *Acer saccharum, Aesculus octandra,* Clifty Canyon Nature Preserve, Clifty Falls State Park, forest structure and composition, Jefferson County, Indiana, mixed mesophytic forest, *Quercus muehlenbergii,* species diversity, *Tilia heterophylla.*

INTRODUCTION

Clifty Falls State Park (CFSP) was established in 1920, but little is known about the specific structure and composition of its forest. Scott (1926) referred to the dominant vegetation type at CFSP as beech-oak, which fits with Gordon's (1936) mapping of southeastern Indiana as an oak-beech region. Based on General

Land Office surveys, Lindsey, *et al.* (1965) reported that *Fagus-Quercus-Acer-Carya,* or western mesophytic forest, was the primary pre-settlement vegetation type for southeastern Indiana. The only known quantitative survey of the forest vegetation at CFSP was that of Braun (1950). Based on a sample of 80 canopy trees, she characterized the forest as mixed mesophytic. Her data are generally cited (e.g., Petty and Jackson, 1966) as representative of the CFSP vegetation.

Lindsey, *et al.* (1969) made little mention of CFSP in their survey of potential natural areas in Indiana. Yet, in 1980, the gorge area of the park was designated as the Clifty Canyon State Nature Preserve.

The purpose of this study was to intensively sample the forest vegetation of CFSP, especially within the Clifty Canyon Nature Preserve, to determine its structure and composition. These findings were compared with Braun's (1950) data and her description of the vegetation.

DESCRIPTION OF CLIFTY CANYON NATURE PRESERVE

Clifty Falls State Park is located in Jefferson County, southeastern Indiana. The park totals 550.6 ha; the Clifty Canyon Nature Preserve, which is located within the Park, totals 72.1 ha. The gorge was formed by the cutting action of glacial melt waters. The bedrock is Ordovician to Silurian shale and limestone. Soils on the slopes are predominantly Eden-Caneyville and Grayford (Nickell, 1985). Slopes range from 12% to 60% grade, and many rock facings and cliffs outcrop throughout the gorge.

The climate in the area is temperate and humid. Mean rainfall is 107 cm, and the average temperature is 1.7° C in the winter and 24° C in the summer. The climate is uniform throughout Jefferson County, although its effect is modified locally by runoff, direction of slope, steepness of slope, and proximity to the Ohio River (Nickell, 1985).

MATERIALS AND METHODS

The park naturalist, Richard Davis, identified some of the "most characteristic and least-disturbed" areas within the Preserve, and his observations provided the basis for selecting sampling sites for this study. Six sites were sampled: Hoffman Falls, both the south-facing (19 plots) and north-facing (15 plots) slopes; Tunnel Falls, both the west-facing (15 plots) and east-facing (12 plots) slopes; and two shallow tributary ravines, Little Clifty Creek (16 plots) and Big Clifty Creek (16 plots).

Trees, woody plants greater than 10 cm in diameter at breast height (dbh), were sampled in 0.04 ha circular plots. Plots were spaced at ca. 30 m intervals across the slopes and were positioned at lower, middle, and upper slope levels of the various aspects to insure an adequate sampling of the forest.

Tree data were analyzed to find density (trees/ha) and relative density (RD), basal area (m/ha) and relative dominance (RDo), importance value (IV), and species diversity (*H*). Species diversity was calculated using the Shannon-Wiener function:

$$H = -\sum_{i=1}^{s} (p_i)(\log_2 p_i)$$

where s is the number of species, and p_i is the proportion of the total sample belonging to the ith species (Shannon, 1948). The nomenclature follows Deam (1940).

The coefficient of determination ($100r$) was calculated using the correlation coefficient, r, relating stem counts to their size class based on dbh (Schmelz and Lindsey, 1965). A low coefficient of determination indicates a high level of disturbance. The similarity coefficient (C; Bray and Curtis, 1957) was used to compare the current sample with Braun's (1950). The equation for calculating similarity is:

$$C = (2W)/(a + b)$$

where a equals the sum of the RDs for our sample, b equals the sum of the RDs for Braun's sample, and w is the sum of the lower values for the species that occur in both samples. The equitability (evenness) of the stand (E) was calculated using a method based on the Shannon-Wiener function (H):

$$E = H/H_{max}$$

where H_{max} is the diversity under maximum equitability ($H = \log_2 S$), and S is the number of species in the sample.

RESULTS

The current sample totaled 30 tree species and 1154 individuals. The most important species (Table 1) were *Acer saccharum* (sugar maple, IV = 62.31), *Quercus rubra* (red oak, IV = 24.05), *Q. muehlenbergii* (chinquapin oak, IV = 16.66), *Fraxinus americana* (white ash, IV = 16.46), and *Tilia heterophylla* (white basswood, IV = 10.49). There were 306.5 trees/ha with a mean basal area of 26.12 m/ha. Tree species diversity (H) was 3.36. The forest has been protected from logging and other major disturbances for over 70 years, and this protection was reflected by a coefficient of determination of 94.84.

The similarity coefficient (C) between this total forest sample and Braun's (1950) was 51%. Since Braun (1950) only reported on canopy trees, the current sample was subdivided into canopy and subcanopy species using a minimum dbh of 30 cm as the criterion for being considered a canopy species (*sensu* Abrell and Jackson, 1977). The values of RD, RDo, IV, and H were recalculated for this subsample. Canopy trees accounted for only 37% of the individuals in the current sample but for more than 79% of the basal area. The similarity (C) between the current sample of canopy trees and Braun's (1950) was 61%.

Twenty-two tree species occurred in the canopy. Sugar maple accounted for 42.55% of the trees in the total forest, but only 16.95% in the canopy, where it ranked behind red oak in basal area (RDo) and IV (Table 2). In the subcanopy, sugar maple contributed ca. 57% of the individuals. The next most important species, chinquapin oak, made up ca. 5% of the trees in the subcanopy. Some species, *Cercis canadensis, Cornus florida, Ostrya virginiana,* and *Carpinus caroliniana,* are generally confined to the subcanopy.

Table 1. The number (N), relative density (RD), relative dominance (RDo), and importance value (IV) for all tree species greater than 10 cm dbh at Clifty Canyon Nature Preserve, Clifty Falls State Park, Indiana.

	N	RD	RDo	IV
Acer saccharum	491	42.55	19.76	62.31
Quercus rubra	86	7.45	16.60	24.05
Quercus muehlenbergii	79	6.85	9.81	16.66
Fraxinus americana	78	6.76	9.70	16.46
Tilia heterophylla	48	4.16	6.33	10.49
Liriodendron tulipifera	34	2.95	6.19	9.14
Fagus grandifolia	32	2.27	5.31	8.08
Quercus alba	28	2.43	5.18	7.61
Fraxinus quadrangulata	31	2.69	3.59	6.28
Juglans nigra	23	1.99	3.62	5.61
Carya cordiformis	34	2.95	2.63	5.58
Aesculus octandra	35	3.03	2.51	5.54
Ulmus rubra	31	2.69	1.33	4.02
Carya ovata	22	1.91	0.93	2.85
Celtis occidentalis	21	1.82	0.51	2.33
Sassafras albidum	14	1.21	0.79	2.00
Prunus serotina	9	0.78	1.13	1.91
Quercus velutina	8	0.69	1.05	1.74
Ostrya virginiana	16	1.39	0.21	1.60
Carya glabra	5	0.43	1.01	1.44
Platanus occidentalis	6	0.52	0.88	1.40
Cornus florida	7	0.61	0.09	0.70
Ulmus americana	4	0.35	0.16	0.51
Carpinus caroliniana	5	0.43	0.06	0.49
Quercus shumardii	1	0.09	0.33	0.42
Quercus coccinea	1	0.09	0.18	0.27
Cercis canadensis	2	0.17	0.03	0.20
Juniperus virginiana	1	0.09	0.05	0.14
Nyssa sylvatica	1	0.09	0.01	0.10
Aesculus glabra	1	0.09	0.01	0.10
Totals	1154	100.03	99.99	200.02

Eight species each contributed more than 5% to the canopy basal area and seven species more than 5% of the density (Table 2). Species diversity (*H*) was 3.72 in the canopy and 2.80 in the subcanopy. Red oak was the canopy dominant based on IV (Table 2), followed by sugar maple, white ash, chinquapin oak, tulip tree (*Liriodendron tulipifera*), white basswood, beech (*Fagus grandifolia*), and

Table 2. The number (N), relative density (RD), relative dominance (RDo), and importance value (IV) for all canopy tree species greater than 30 cm dbh at Clifty Canyon Nature Preserve, Clifty Falls State Park, Indiana.

	N	RD	RDo	IV
Quercus rubra	64	15.50	20.02	35.52
Acer saccharum	70	16.95	11.39	28.34
Fraxinus americana	46	11.14	10.56	21.70
Quercus muehlenbergii	41	9.93	11.01	20.94
Liriodendron tulipifera	30	7.26	7.72	14.98
Tilia heterophylla	29	7.02	7.41	14.43
Fagus grandifolia	23	5.57	6.42	11.99
Quercus alba	18	4.36	9.11	10.47
Juglans nigra	17	4.12	4.17	8.29
Fraxinus quadrangulata	15	3.63	3.24	6.87
Carya cordiformis	15	3.63	2.32	5.95
Aesculus octandra	10	2.42	2.28	4.70
Quercus velutina	7	1.69	1.32	3.01
Ulmus rubra	7	1.69	1.07	2.76
Prunus serotina	5	1.21	1.28	2.49
Platanus occidentalis	4	0.97	0.96	1.93
Carya glabra	3	0.73	1.16	1.89
Sassafras albidum	3	0.73	0.44	1.17
Carya ovata	3	0.73	0.40	1.13
Quercus shumardii	1	0.24	0.41	0.65
Quercus coccinea	1	0.24	0.23	0.47
Celtis occidentalis	1	0.24	0.09	0.33
Totals	413	100.00	100.01	200.01

white oak (*Quercus alba*). The RDs for six of the ten species common to Braun's (1950) sample and the current canopy sample showed significant differences (Table 3).

DISCUSSION

The current study supports Braun's (1950) contention that the Clifty Canyon Nature Preserve of the CFSP forest is a mixed mesophytic community. In southeastern Indiana, mixed mesophytic stands are characteristic of the steeper slopes, especially on cherty limestone soils (Lindsey, *et al.,* 1965) such as at CFSP. The indicator species for the Mixed Mesophytic Forest Region, *Tilia heterophylla* and *Aesculus octandra* (Braun, 1950), were prominent in Braun's and, to a lesser extent, in the current sample (Table 3). However, two differences

Table 3. A comparison of Braun's (1950) canopy percentages with the 1991 canopy percentages for Clifty Canyon Nature Preserve, Clifty Falls State Park, Indiana.

	Braun	1991
Fagus grandifolia	27.50	5.57[*]
Acer saccharum	20.00	16.95
Tilia heterophylla	15.00	7.02[*]
Liriodendron tulipifera	8.80	7.26
Quercus rubra	10.00	15.50[*]
Fraxinus americana	8.80	11.14
Aesculus octandra	6.30	2.42[*]
Juglans nigra	1.20	4.12[*]
Celtis occidentalis	1.20	0.24
Quercus muehlenbergii	1.20	9.93[*]

[*] Significant difference at the 0.01 level (z-test).

were noted between the two samples. First, the high diversity characteristic of all-deciduous mixed mesophytic forests (Monk, 1967; Martin, 1992) was found in both the total sample ($H = 3.36$) and the canopy ($H = 3.72$) in the current study but was considerably lower ($H = 2.47$) for Braun's (1950) sample. Second, 22 of the 30 tree species encountered in this study were recorded in the canopy, but Braun listed only 10 canopy members. The percent differences between the canopy composition of the two samples indicates that Braun's sample was too small (80 trees) to be representative of the broad species diversity as it relates to the underlying topographic diversity at CFSP.

Braun's sample (Table 3) was probably taken from only one area of CFSP, the upland bench and adjacent Little Clifty Creek near the main shelterhouse. This area is the only site known at CFSP having a concentration of canopy-size beech. The other nine species in Braun's table also occur in this area. Scott (1926) also noted that beech was an important species at CFSP. However, beech was of minor importance in the current study except in a few local areas. Some changes in forest structure and composition may occur over the time period between the two samplings but not to the extent found in this study. Bray and Curtis (1957) reported that replicate samples in the same forest typically should have similarity values of ca. 80% to 85%. The similarity values for the two samples at CFSP were 51% and 61% for the total forest and canopy, respectively.

The CFSP forest has been preserved for over 70 years and appears to have a high degree of stability as judged by the coefficient of determination (94.84). Basal area and density values for CFSP are also comparable to those reported for mature mixed mesophytic forests (Martin, 1992). At various sites, basal area exceeds the 30 m/ha suggested for climax mesic forests in the Midwest (Held and Winstead, 1975). Tornados that hit Jefferson County during 1974 (Bailey and MacMillan, 1977; Martin and MacMillan, 1982) did not touch down in Clifty Canyon. Disturbances there are the result of occasional blowdowns, uprootings, and trail work.

Species diversity for both the total forest and the canopy are greater than 3.0, which is characteristic of mixed mesophytic forests (Martin, 1992). The evennness for the entire forest was 0.68 and for the canopy, 0.83. Both values show the contributions of the many species in mixed mesophytic forests (Braun, 1950; Martin, 1992).

Lindsey, *et al.* (1965) found that the pre-settlement forests of southeastern Indiana were dominated by trees in four genera — *Fagus, Quercus, Acer,* and *Carya.* The species in those four genera contributed ca. 60% to both the density and basal area at CFSP (Table 2). By including *Fraxinus,* the contributions were ca. 75% in each. However, the RD and RDo contributions for *Tilia* and *Liriodendron* were greater than for either *Fagus* or *Carya,* suggesting an overemphasis of beech by Braun (1950) and an underestimation of the other species.

Red oak is the leading canopy member in the current sample. Another oak species, chinquapin, is generally a minor associate in the mixed mesophytic complex except in those areas marked by outcrops of Ordovician and Silurian limestone such as are found in CFSP (Reynolds and Potzger, 1950). Chestnut oak (*Quercus prinus*), a disjunct species at CFSP (Deam, 1940), is confined to one or two small areas in the park and did not fall within our sampling plots.

By combining all aspects and slope positions, some of the variation between sites at CFSP was obscured. However, the combined data give a more realistic view of the CFSP forest than has been presented previously.

ACKNOWLEDGMENTS

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