TEMPORAL CHANGES IN SPRING GROUND-FLORA COMMUNITIES ACROSS RIPARIAN AREAS IN A NORTH-CENTRAL OHIO OLD-GROWTH FOREST

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ABSTRACT.—Spring ground-flora composition and structure were sampled along riparian areas in Johnson Woods State Nature Preserve, an old-growth oak-maple-beech forest in north-central Ohio. Seven transects that bisected the stream valley were surveyed during early and late spring. Ground-flora communities differed between early and late spring and on landforms during each survey. Early spring floodplains were dominated by *Floerkea proserpinacoides* and *Ranunculus septentrionalis*, while late spring floodplains were dominated by *Geum vernum* and *Leersia virginica*. Early spring uplands were dominated by *Anemone quinquefolia* and *Cardamine concatenate*, while late spring uplands were dominated by *Parthenocissus quinquefolia* and *Podophyllum peltatum*. Principal components analysis showed a complex environmental gradient from stream channel edge into the surrounding uplands strongly related to soil characteristics and landform. The variability observed between early and late spring surveys suggests the need for multiple surveys in both spring and summer in order to gain a complete record of ground-flora communities.

Riparian areas are complex ecotones between aquatic and terrestrial ecosystems creating unique gradients that influence the structure and composition of plant communities. Riparian areas fulfill several important functions including regulating nutrient and energy flow between the terrestrial and aquatic systems (Gregory et al. 1991), providing unique habitat with high species richness and diversity (Goebel et al. 2003c), offering corridors for wildlife movement (Hodges and Krementz 1996), and creating aesthetic appeal (Kline et al. 2000). In many locations these unique systems have been destroyed and their functions disrupted. As a result, ecological, as well as economical, problems have arisen including poor water quality, stream bank erosion, and a decline in populations of flora and fauna.

Where these problems are especially severe, restoration of the riparian area is often selected as a solution. Existing methods that describe riparian restoration are vague and generic (Lee et al. 2000) leaving those who wish to restore riparian areas at a loss for specific guidance. In order to generate better information for restorationists, a reference ecosystem on which to base objectives and goals of a restoration is needed (Pickett and Parker 1994; Aronson et al. 1995). Reference ecosystems provide information on structure, composition, and underlying dynamics that drive sustainable ecosystem functions.

In Ohio, many of the riparian areas have undergone some form of disturbance from agriculture, logging, or urbanization. Therefore, locating undisturbed ecosystems to study for reference conditions is difficult. While scarce, isolated tracts of old-growth forest exist that reflect minimal anthropogenic disturbance. Many of these old-growth forests have small streams or rivers running through them with intact native riparian areas that may be studied as reference ecosystems. The limited number of riparian reference areas that have been identified and studied in Ohio focus mainly on overstory composition, while largely ignoring ground-flora composition and structure (Goebel et al. 2003b, McCarthy 2003). Studies that address ground-flora tend to focus on one survey, usually in mid-summer when spring ephemerals have disappeared. As flora is variable throughout a growing season, it is important to have a complete floristic record of a reference ecosystem (McCarthy 2003).

The objectives of this study were (1) to compare and contrast composition and structure of early and late spring ground-flora in riparian areas of an old-growth forest and (2) characterize a spring ground-flora reference condition for riparian restoration in north central Ohio.

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Study Area

This study was conducted at Johnson Woods State Nature Preserve (JWSNP), an 83 hectare old-growth forest in Wayne County, Ohio. The study area has a humid continental climate with a mean summer temperature of 20.6°C, and a mean winter temperature of -2.8°C (Bureau et al. 1984). Mean annual total precipitation is 90 cm, with sixty percent occurring between April and September, and mean snowfall amount is 91.4 cm (Bureau et al. 1984).

Johnson Woods is located on the western glaciated Alleghany Plateau in an area characterized by gently rolling ground moraine with broad flat-bottomed valleys (White 1967). Headwater streams tend to have small floodplains that rise shallowly into surrounding uplands, often lacking defined terrace or slope landforms. Soils were formed in silty lacustrine deposits resulting from Wisconsian glacial lakebeds (Bureau et al. 1984). A Fitchville silt loam (fine-silty, mixed, mesic Aeric Ochraqualf) composes the small headwater stream valley located at JWSNP, while the uplands are composed of Sebring silt loam (fine-silty, mixed, mesic Typic Ochraqualf) and Glenford silt loam (fine-silty, mixed, mesic Aquic Hapludalf) (Bureau et al. 1984). These soils are classified as moderate to poorly drained, and both the Sebring and Fitchville soils have a seasonally high water table that allows surface ponding (Bureau et al. 1984).

The Western Glaciated Allegheny Plateau Ecoregion is characterized by beech-maple, mixed-mesophytic, and northern hardwood forests (McNab and Avers 1994). E. Lucy Braun (1950) first characterized the forest communities of Johnson Woods (formerly called Graber Woods). Wet depressions were composed of red maple-American elm communities, while flats with an increased humus layer were dominated by red maple and white oak mixed with red oak, ash, and beech. Low swells had white oak in the canopy with a beech and sugar maple understory (Braun 1950). Currently, well-drained areas are comprised of mixed-oaks and hickory in the overstory, with an increasingly shade-tolerant beech-maple understory. Low-lying areas typically have vernal pools and are comprised of mesic and wet-mesic species including red maple, buttonbush, and green ash.

Methods

Data Collection

In the spring of 2003, the spring ground-flora was sampled along the first-order headwater stream running through Johnson Woods. Two surveys were conducted, the first in early April, and the second in late May. Each time, seven transects bisecting the entire stream valley were sampled. The location of the first transect was determined randomly and each subsequent transect was spaced randomly at least 20 but no more than 40 m apart. Along each transect, the first 1 m^2 quadrat was located in the center of the stream channel with additional quadrats spaced 5 m apart moving perpendicular from the channel into the upland. Each half of a transect ranged in length from 25 to 40 m depending on valley width. A total of 116 quadrats were sampled during each survey.

Soil cores were taken from each quadrat location with a Giddings® probe to a depth of 30 cm. Before the core was disturbed, thickness of the A horizon (cm) was measured in the field. Soil samples were then transported to the laboratory for the remaining analyses. Soil particle fractions for sand (particle size > 0.1 mm), silt (particle size 0.1 – 0.001 mm), and clay (particle size < 0.001) were determined after air drying using the hydrometer method. Percent soil organic matter (% OM) was determined by loss on ignition and pH was measured using an electrode (Sparks et al. 1996).

At each quadrat, the landform was determined to be either floodplain or upland. Floodplain landforms were defined in this study to be a low-lying area adjacent the stream channel that floods regularly. Standard surveying methods and a clinometer were used to determine the distance of the quadrat from the center of the stream channel and its elevation above bankfull channel. All vascular species <1m tall rooted inside the quadrat were identified, and percent cover of the species was visually estimated and designated one of the following cover class codes: <1 percent (1); 1-5 percent (2); 6-10 percent (3); 11-20 percent (4); 21-40 percent (5); 41-70 percent (6); 71-100 percent (7). Species were sorted into

Table 1.—Mean values of environmental variables (±1 SE) for landforms along first order stream at Johnson Woods State Nature Preserve, OH (*P-value<0.001).

Variable	Floodplain	Upland
Distance from Stream (DFS) (m)	8.65 (1.12)	*26.44 (1.28)
Elevation above Stream (ELEV) (m)	0.35 (0.06)	*2.66 (0.21)
pH	*5.11 (0.07)	4.59 (0.04)
Organic Matter (OM) (%)	*4.96 (0.30)	3.38 (0.10)
A Horizon Thickness (ATHICK) (cm)	10.25 (0.59)	9.22 (0.42)
Sand (%)	*26.70 (0.70)	22.93 (0.48)
Silt (%)	39.86 (1.29)	*51.35 (0.53)
Clay (%)	*33.45 (1.24)	25.73 (0.50)

functional lifeform guilds (forb, graminoid, pteridophyte, woody seedling, woody shrub, or woody vine). Nomenclature follows National PLANTS Database (USDA 2002).

Data Analysis

Mean values of the environmental data (soils, distance from stream, and elevation above stream) were determined for each landform. Mann-Whitney tests were conducted to determine differences in each factor between landforms. Principle components analysis (PCA) was implemented to analyze patterns in the environmental data distribution using CANOCO software (ter Braak and Smilauer 1997). Prior to analysis of environmental data by PCA, percent data (organic matter, sand, silt, and clay) were square root arcsine transformed to normalize variances. Pearson correlation coefficients were calculated between PCA axis scores and environmental data to correlate the PCA distribution with specific environmental variables.

Prior to analysis, each cover class code was replaced with the midpoint value of that cover class. Mean percent cover of all species and functional lifeform guilds were determined for each landform (floodplain or upland) for each survey (early or late). Richness (S=number of species), diversity (Shannon Wiener index= H'), and evenness (E=H'/ ln(S)) were calculated for each quadrat. Indicator Analysis (Dufrene and Legendre, 1997) was used to 1) determine if individual species cover was significantly different between floodplain or upland landforms for each survey, and 2) to indicate species typically found on each landform for each survey. Indicator Analysis is a technique that utilizes Monte-Carlo permutations and combines information on the relative abundance of a species in a particular group (i.e. landform class) and the likelihood of the species to be present in that group. Mann-Whitney tests were conducted to determine differences in mean percent cover of functional lifeform guilds between landforms for each survey, and to determine differences in mean diversity measures between landforms for each survey.

Results

Environmental characteristics

Of the 116 total quadrats sampled during each survey, 37 quadrats were classified as floodplain and 73 quadrats were classified as upland. Significant differences ($P<0.05$) between floodplain and upland landforms were found in all measured environmental variables except thickness of the A horizon (table 1). In comparison, floodplains had higher pH than uplands (5.11 ± 0.07 and 4.59 ± 0.04, respectively) and higher percent organic matter (4.96 ± 0.30 and 3.38 ± 0.10, respectively). While floodplains had higher percentages of sand and clay particles, uplands exhibited higher percent silt (table 1).

Environmental distribution

PCA demonstrated clear differences in environmental characteristics between floodplain and upland landforms. The first PCA axis explained 51.8 percent of the variation among quadrats and the second PCA axis explained an additional 14.9 percent (figure 1). Floodplain quadrats were positively associated with higher clay, sand, and organic matter content, as well as higher pH and thicker A

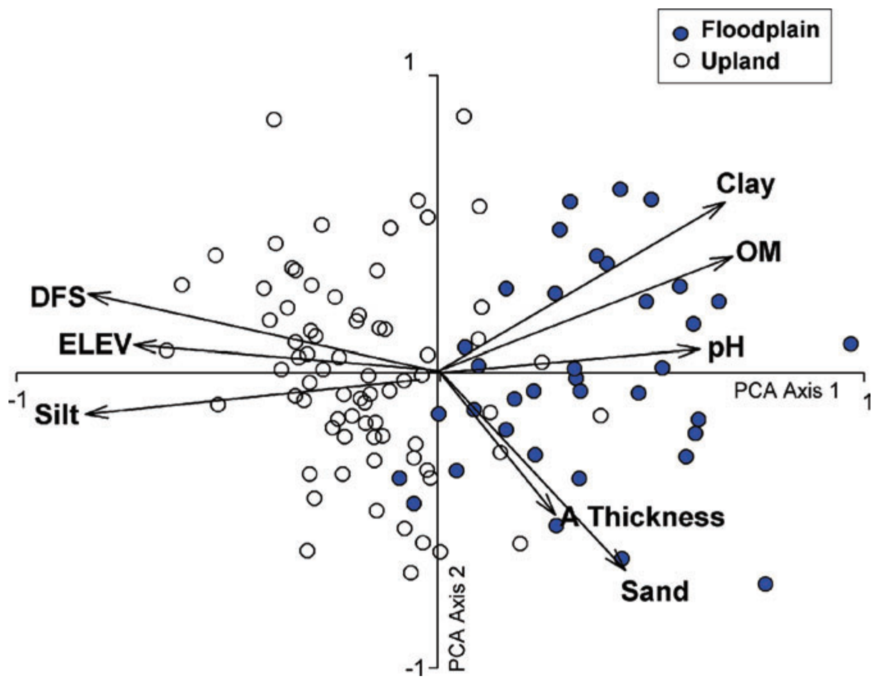

Figure 1.—Principal components analysis (PCA) showing biplot scaling of environmental data and spring 2003 ground flora sample quadrats from Johnson Woods State Nature Preserve, OH. See Table 1 for environmental variable acronyms.

Table 2.—Pearson correlation coefficients between PCA ordination axes and environmental variables (p-value<0.001; * p-value<0.01) for Johnson Woods State Nature Preserve, OH.**

	PCA1	PCA2
Eigenvalue	0.50	0.15
Cumulative variance explained (%)	50.10	65.00
Correlation Coefficient		
% Organic Matter	**0.735	*0.318
% Sand	**0.468	**-0.688
% Silt	**-0.918	-0.066
% Clay	**0.775	**0.546
Distance From Stream	**-0.800	0.155
Elevation Above Stream	**-0.769	0.081
pH	**0.655	-0.012
A Horizon Thickness	**0.378	**-0.534

horizon. Pearson correlation coefficients (table 2) indicated significant correlations ($P<0.001$) for all variables along the first axis. The second axis was positively correlated with clay content and negatively correlated with thickness of the A horizon, sand, and organic matter content.

Ground flora composition

Indicator Analysis revealed significant differences ($P<0.10$) in species composition between the floodplain and upland ground-flora communities for each survey (table 3). Early spring floodplains were characterized by *Floerkea proserpinacoides*,*Glechoma hederacea*, *Leersia virginica*, and *Ranunculus septentrionalis*, while the late spring floodplains were characterized by *Floerkea proserpinacoides*, *Geum vernum*, *Glechoma hederacea*, *Laportea canadensis*, *Leersia virginica*, *Lilium canadense*, *Poa alsodes*, and *Viburnum acerifolium*. Early spring uplands were characterized by *Anemone quinquefolia*, *Cardamine concatenate*, and *Podophyllum peltatum*, while late spring uplands were characterized by *Fagus grandifolia*, *Fraxinus pennsylvanica*, *Parthenocissus quinquefolia*, *Podophyllym peltatum*, *Polygonatum pubescens*, and *Prunus serotina*.

Table 3.—Mean percent cover of ground flora species on landforms for each survey at Johnson Woods State Nature Preserve (*significant (P<0.10) for landform during survey).

	Early Spring		Late Spring	
Species	Floodplain	Upland	Floodplain	Upland
Acer rubrum	0.00	0.04	0.08	0.06
Acer saccharum	0.00	0.30	0.42	1.70
Aesculus sp.	0.00	0.00	0.00	0.10
Amphicarpa bracteata	0.00	0.00	0.00	0.04
Anemone quinquefolia	1.16	*3.08	1.64	1.42
Arisaema triphyllum	0.08	0.00	2.03	1.21
Aster sp.	0.08	0.08	0.08	0.10
Botrychium dissectum	0.00	0.14	0.00	0.14
Cardamine concatenata	1.00	*2.30	0.00	0.19
Carex albursina	0.00	0.00	0.00	0.04
Carex rosea	0.00	0.00	0.00	0.04
Carya ovata	0.00	0.04	0.00	0.24
Cinna arundinacea	1.46	0.18	1.05	0.41
Circaea quadrisulata	0.00	0.00	1.45	2.04
Claytonia virginica	5.64	7.78	0.18	0.83
Dryopteris carthusiana	0.00	0.23	0.00	0.50
Dryopteris sp.	0.00	0.10	0.00	0.00
Erythronium americanum	3.69	5.38	0.09	0.15
Euonymus obovata	0.42	0.10	0.42	0.04
Fagus grandifolia	0.00	0.53	0.00	*1.75
Floerkea proserpinacoides	*5.89	0.30	*4.77	0.39
Fraxinus pennsylvanica	0.08	0.04	0.60	*1.60
Galium aparine	1.01	1.37	1.82	1.66
Geum canadense	0.00	0.00	0.11	0.10
Geum vernum	1.15	0.33	*1.96	0.33
Glechoma hederacea	*0.55	0.20	*0.60	0.04
Impatiens capensis	1.23	1.27	8.11	6.92
Laportea canadensis	0.00	0.00	*5.42	1.36
Leersia virginica	*1.54	0.04	*4.03	0.14
Lilium canadense	0.08	0.04	*1.12	0.15
Lindera benzoin	0.00	0.00	0.65	0.68
Lobelia cardinalis	0.42	0.00	0.22	0.00
Lycopodium flabelliforme	0.00	0.00	0.00	0.04
Mimulus ringens	0.00	0.00	0.00	0.08
Mitchella repens	0.00	0.04	0.00	0.00
Osmorhiza claytonii	0.00	0.08	0.01	0.23
Osmorhiza sp.	0.00	0.04	0.00	0.00
Ostrya virginiana	0.00	0.08	0.00	0.00
Parthenocissus quinquefolia	0.00	0.14	1.01	*4.87
Poa alsodes	1.87	1.39	*3.42	1.61
Podophyllum peltatum	0.00	*0.25	0.00	*8.91
Polygonatum pubescens	0.00	0.11	0.32	*2.08
Polygonum caespitosum	0.00	0.00	0.85	0.41
Polygonum persicaria	0.08	0.04	0.38	1.20
Polygonum sp.	0.00	0.00	0.00	0.08
Populus grandidentata	0.00	0.00	0.00	0.04
Prenanthes sp.	0.00	0.01	0.22	0.51
Prunus serotina	0.00	0.36	0.16	*1.20
Quercus alba	0.00	0.00	0.00	0.11
Quercus rubra	0.00	0.00	0.00	0.18
Ranunculus abortivus	0.16	0.04	0.08	0.14
Ranunculus septentrionalis	*0.38	0.00	0.64	0.10
Ribes cynosbati	0.00	0.23	0.00	0.10
Rosa multiflora	0.42	0.23	0.42	0.42

Continued.

Table 3.—Continued.

Species	Early Spring Floodplain	Early Spring Upland	Late Spring Floodplain	Late Spring Upland
Rubus idaeus	0.00	0.00	0.00	0.10
Rubus occidentalis	0.00	0.04	0.00	0.10
Sambucus canadensis	0.16	0.22	0.30	0.70
Senecio aureus	0.16	0.10	0.43	0.10
Smilacina recemosa	0.00	0.00	0.00	0.04
Smilax rotundifolia	0.00	0.00	0.00	0.04
Solidago sp.	0.00	0.00	0.08	0.00
Toxicodendron radicans	0.00	0.10	3.01	3.22
Trillium grandiflorum	0.00	0.04	0.22	0.20
Trillium sp.	0.08	0.08	0.08	0.35
Ulmus americana	0.00	0.00	0.00	0.43
Urtica dioica	0.00	0.00	*0.50	0.22
Viburnum acerifolium	0.00	0.00	0.00	0.20
Viola blanda	0.00	0.04	0.00	0.00
Viola pubescens	0.46	0.29	0.00	0.14
Viola sp.	0.34	0.65	1.99	1.92

Table 4.—Diversity measures of ground flora for each survey by landform at Johnson Woods State Nature Preserve, OH. S=number of species, H'=Shannon-Wiener index, E=H'/ ln (S).

	Early Spring Floodplain	Early Spring Upland	Late Spring Floodplain	Late Spring Upland
Richness (S)	4.0270	4.1520	5.7840	6.4810
Evenness (E)	0.8022	0.8227	0.8074	0.8672
Diversity (H')	0.9970	1.0856	1.2350	1.4642

Ground flora structure

Richness, evenness, and diversity did not differ (P>0.10) among landforms within the early spring or late spring survey (table 4). The late spring survey had higher richness and diversity values for both floodplains and uplands than the early spring survey (table 4). Mean percent cover of forbs differed between floodplain and upland landforms (P<0.10) for both the early and late spring surveys, while other functional lifeform guilds did not differ significantly (P>0.10) in mean percent cover between landforms for either survey (figure 2).

Discussion

Spring ground-flora communities at Johnson Woods differed both spatially and temporally. While the structure of ground-flora communities did not differ significantly between landforms, except by mean forb cover, indicator analysis showed that composition differed between landforms. Temporally, species richness was higher during the late spring survey. While some species present during the early spring survey were still present during the late spring survey, additional species emerged, changing the overall composition and structure of the ground-flora communities of each landform during the spring. Higher species richness in the late spring survey corresponded to others studies where the highest species richness during one growing season occurred in early June (Tremblay and Larocque 2001, Small and McCarthy 2001).

Based on the PCA, environmental variables appeared to explain a large portion of the variability observed in ground flora communities. One environmental variable not sampled directly, but noteworthy, is the degree of flooding on floodplain landforms during the sample periods. Many floodplain quadrats were inundated during each survey, therefore not supporting ground flora species during the

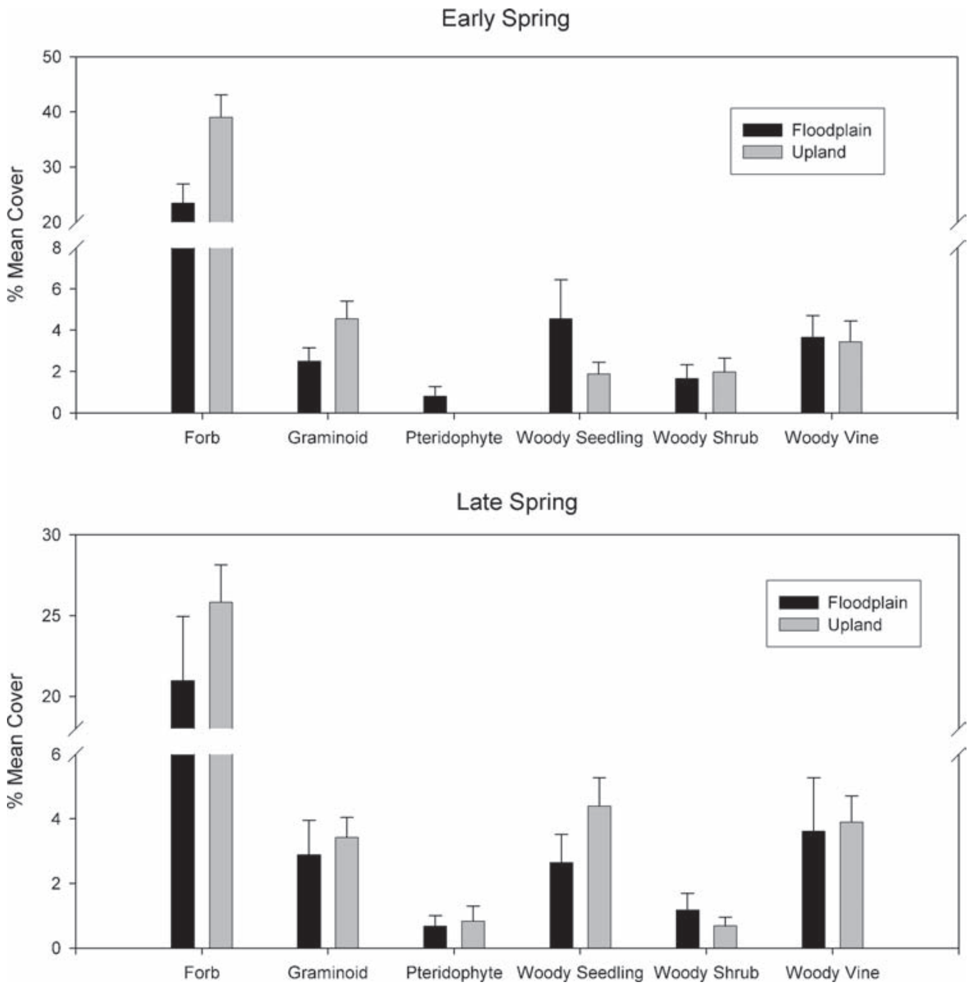

Figure 2.—Mean (± 1 SE) percent cover of plant functional guilds for each survey by landform at Johnson Woods State Nature Preserve, OH.

early and late spring. This may explain the lack of research comparing spring ground-flora communities on floodplains. Spring flooding may also explain the higher mean cover of forbs on upland quadrats than floodplains, contradicting summer structure at Johnson Woods where mean forb cover is higher on floodplains than uplands(Goebel et al. 2003a).

The need for multiple ground-flora surveys throughout a growing season has been expressed by McCarthy (2003) in order to capture a complete floristic record for an area. While McCarthy (2003) suggested a spring, mid summer, and late summer survey to achieve a complete record, this study showed the variability and temporal nature of ground flora communities within just a few weeks of a growing season. Multiple surveys in spring and summer may be required in order to gain a complete account of communities.

By quantifying the variability and underlying dynamics operating in these communities, better suites of reference conditions can be developed and used to guide riparian restoration efforts. Specifically, the variability as expressed in the ground-flora communities at Johnson Woods, as well as other relatively undisturbed forests, should be emulated in disturbed headwater riparian areas of north-central Ohio. From this study, it is apparent that additional research is needed to better understand the vegetation dynamics that characterize our reference ecosystems before actual restoration efforts can be judged successful.

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