Chapter 7

Understory Vegetation

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Abstract

This chapter documents patterns of species composition and diversity within the understory vegetation layer and provides a species list for the four study areas in southern Ohio. Within each of 108 plots, we recorded the frequency of all vascular plant species in sixteen 2-m^2 quadrats. We recorded 297 species, including 187 forbs (176 perennials, 9 annuals, 2 biennials), 44 graminoids, 34 shrubs and woody vines, and 32 trees. Only seven species were nonnatives and none of these were abundant. We also documented 12 state-listed species. Detrended correspondence analysis indicated that variation in species composition was primarily along a soil moisture-fertility gradient described by the Integrated Moisture Index. Additional variation in composition among the study areas was correlated with differences in soil texture. Species richness per plot (32-m^2 sampled) ranged from 23 to 106 and averaged 65.2; richness per quadrat averaged 16.7. All measures of species diversity were significantly higher on mesic than on xeric plots, primarily because forb richness was higher on mesic plots.

Introduction

In forested ecosystems, overstory trees largely control primary productivity as well as the cycling of water, nutrients, and gases. Yet the understory vegetation layer, composed of forbs, graminoids, shrubs, vines, and seedlings of tree species, accounts for most of the vascular plant diversity.

The composition of understory communities varies both spatially and temporally in response to resource gradients. Spatially, species are distributed across gradients of soil moisture and nutrient availability that result from variations in elevation, topography, soils, and disturbance history (Bray and Curtis 1957; Beals and Cope 1964; Siccama et al. 1970; Pregitzer and Barnes 1982). Temporally, plant species composition changes over long periods during secondary succession (Oosting 1942; Vankat 1991). Over shorter periods, the cover and abundance of herbaceous species vary annually in response to weather conditions (Rogers 1983) and throughout the growing season as different species emerge and reach maximum biomass at different times (Bratton 1976; Mahall and Bormann 1978; Goebel et al. 1999).

Within the Unglaciated Allegheny Plateau of southern Ohio are numerous "definitive" species that are found only in this region of the state (Silberhorn 1970). These species have centers of distribution in the Appalachian and Cumberland Mountains to the south and east (Thompson 1939; Silberhorn 1970). Across the region, plant distributions are related to differences in bedrock geology (Cusick and Silberhorn 1977).

At a more local scale, the dissected topography of the region produces microclimatic gradients of solar radiation, humidity, and soil moisture (Hutchins et al. 1976) that are strongly related to the distributional patterns of tree species (Muller 1982) and understory vegetation (Olivero and Hix 1998). The Integrated Moisture Index (IMI) used in our study predicts relative soil moisture across the landscape and stratifies vegetation plots into classes likely to be similar in species composition and ecological functioning (Chapter 3).

In this chapter we describe general characteristics of the flora found in the study areas and quantify vegetation-environment relationships. Specifically, we sought to determine how patterns of species composition and diversity vary among the three IMI classes (xeric, intermediate, and mesic). Also, as a component of the ecosystem management study, the results will provide baseline data for examining the long-term effects of prescribed fire on understory vegetation.

Methods

Study Areas and Experimental Design

The study areas and experimental design are described in detail in Chapter 1. Here a brief overview is provided. The four 75-90 ha study areas are located in Vinton County (Arch Rock and Watch Rock) and Lawrence County (Young's Branch and Bluegrass Ridge). The study areas are within in the Southern Unglaciated Allegheny Plateau, which is characterized by high hills, sharp ridges, and narrow valleys. Sandstones and shales are principle bedrocks. Forests are oak-dominated and the current overstory originated in the late-1800s, after the cessation of clearcutting for the charcoal iron industry.

In each study area, three prescribed fire treatments were established, a control unit (CONT), an infrequent burn unit (INFR), and a frequent burn unit (FREQ). To account for variation in soil moisture and vegetation, a GIS-derived integrated moisture index (IMI) was applied across the dissected landscapes of the study areas (Chapter 3). From the calculated IMI scores, each 30 x 30 m pixel was assigned to one of three soil moisture classes: xeric, intermediate, or mesic. Thus to examine the effects of prescribed fire and account for environmental heterogeneity, a split-plot experimental design was established. The four study areas are replicate blocks, fire treatment units are whole plots, and IMI classes are subplots. The 50 x 25 m vegetation plots (N= 108 total) were established as pseudoreplicates in each IMI class within each fire treatment unit (Chapter 1).

Vegetation sampling

To account for varying phenologies of herbaceous species, the understory vegetation was sampled in the spring (April 26 to June 14) and again in late summer (August 22 to September 14) of 1995. We used stratified random sampling on a 25- by 25-m portion of each vegetation plot. Four cross-slope transect lines were established at 5, 10, 15, and 20 m. Three 1- by 2-m quadrats were located randomly along each of the four transect lines using whole numbers (0-24) and placed above or below the line based on a random positive or negative designation. The quadrat locations were the same for spring and late summer. We also sampled an additional permanent quadrat at the midpoint of each line for a total of sixteen 1- by 2-m quadrats per plot.

To accommodate analyses of common and less frequent species, the 1- by 2-m quadrats were nested into three sections of 0.25, 1.0, and 2.0-m^2. For each species, its presence was recorded as first occurring in one of these sections. Here we report data only from the entire 2-m^2 quadrats. For tree species, presence was recorded in four size classes: less than 30 cm tall, 30 cm tall to 2.99 cm in diameter at breast height (d.b.h.), 3.0 to 9.9 cm d.b.h., and 10 or more cm d.b.h.

In addition to the quadrat sampling, species that were listed as threatened and endangered (T&E) in Ohio by the Ohio Department of Natural Resources were noted in the plots. Also, in 1994 and 1995, rare plant surveys were conducted by walking through each study area. The locations of T&E species were submitted to the Ohio Natural Heritage Database (Ohio Department of Natural Resources, Division of Natural Areas and Preserves, Columbus, OH).

Data analysis

For each species, the total frequency per plot was determined as the maximum frequency recorded in either the spring or late summer sampling period. For tree species, the data presented include all four size classes but more than 85 percent of the trees tallied were in the smallest (< 30 cm) class.

Species richness was calculated for each plot by summing the total number of unique species in the 16 quadrats. Life form richness was then calculated for each plot by summing the total number of unique species in each life form category. Average species richness per quadrat was calculated from the cumulative frequency of each species divided by 16 quadrats. We used PC-ORD, ver. 3.0 for Windows, (McCune and Mefford 1997) to calculate species diversity (Shannon Index) and evenness for each plot.

To test for significant pretreatment effects of IMI and treatment units on richness and diversity, a mixed-model analysis of variance (SAS 6.12 for Windows; PROC MIXED, ML option) with maximum likelihood estimation was used (Littell et al. 1996). Study areas were treated as random effects and IMI and treatment units as fixed effects. We used least-squares means to test for significant differences among the IMI classes and treatment units. See Chapter 1 for a description of the statistical model used in this study.

We used detrended correspondence analysis (DCA) to describe patterns of species compositional change along environmental gradients (PC-ORD). The input data was a matrix of species' frequencies in the 108 plots. We used Pearson correlation analysis to quantify the relationship between DCA plot scores and environmental data from each plot. For detailed information on the environmental variables used in the analysis, see Chapters 3 (IMI), 5 (soils), 6 (light availability), and 9 (overstory).

Table 1.--Mean frequency for each common species per IMI class (XER = Xeric; INT = Intermediate; MES = Mesic). Common species are defined as occurring at >10% frequency in one or more IMI classes. N = 33 xeric, 37 intermediate, and 38 mesic plots. Nomenclature is from Gleason and Cronquist (1991).

SPECIES	ABB.	XER	INT	MES	SPECIES	ABB.	XER	INT	MES
Acer rubrum	Acru	76.3	66.4	57.8	*Lindera benzoin*	Libe	1.7	15.6	28.3
Acer saccharum	Acsa	4.8	22.5	30.7	*Liriodendron tulipifera*	Litu	14.3	30.9	33.3
Adiantum pedatum	Adpe	0.0	1.6	10.6	*Monarda fistulosa*	Mofi	0.7	2.0	10.1
Amelanchier arborea	Amar	23.3	6.6	7.3	*Nyssa sylvatica*	Nysy	21.5	13.8	20.0
Amphicarpaea bracteata	Ambr	18.8	21.4	17.2	*Osmorhiza spp.*	Ossp	1.5	7.1	17.9
Anemonella thalictroides	Anth	2.9	15.0	55.4	*Ostrya virginiana*	Osvi	11.6	8.2	3.0
Arisaema triphyllum	Artr	1.5	16.8	32.8	*Panicum boscii*	Pabo	20.2	15.5	3.1
Aristolochia serpentaria	Arse	7.0	11.8	11.1	*Panicum dichotomum*	Padi	11.9	3.5	0.9
Asarum canadense	Asca	0.0	5.4	32.1	*Parthenocissus quinquifolius*	Parqu	23.9	49.8	43.2
Aster divaricatus	Asdi	1.7	10.0	24.0	*Pilea pumila*	Pipu	0.2	6.1	12.8
Botrychium virginianum	Bovi	1.7	13.7	11.3	*Polystichum acrosticoides*	Poac	1.5	20.2	37.0
Brachyelytrum erectum	Brer	6.4	20.6	22.2	*Polygonatum biflorum*	Pobi	23.2	15.6	6.1
Carex digitalis	Cadi	5.3	9.9	9.5	*Potentilla canadensis*	Poca	16.4	18.4	9.7
Carex gracilescens	Cagrc	4.0	11.8	15.5	*Poa cuspidata*	Pocu	13.4	15.3	17.0
Carex wildenovii	Cawi	26.3	11.0	1.9	*Podophyllum peltatum*	Podpe	2.9	10.9	14.4
Carpinus caroliniana	Caca	0.4	4.9	12.3	*Prunus serotina*	Prse	11.4	12.2	7.1
Carya cordiformis	Carco	3.1	7.2	10.8	*Quercus alba*	Qual	36.8	22.9	15.8
Carya glabra	Cargl	19.3	14.8	11.6	*Quercus coccinea*	Quco	11.2	3.9	0.7
Cercis canadensis	Ceca	14.9	24.3	9.0	*Quercus prinus*	Qupr	28.7	8.4	3.3
Chimaphila maculata	Chma	9.9	3.8	1.2	*Quercus rubra*	Quru	11.2	11.2	10.4
Cimicifuga racemosa	Cira	0.2	12.2	30.7	*Quercus velutina*	Quve	25.4	11.7	4.7
Circaea lutetiana	Ciqu	1.5	7.1	17.9	*Rosa carolina*	Roca	23.5	11.7	5.7
Claytonia virginiana	Clavi	0.7	4.6	10.8	*Rubus spp.*	Rusp	20.2	26.5	15.1
Cornus florida	Cofl	44.1	37.3	29.3	*Sassafras albidum*	Saal	66.7	30.3	13.2
Crataegus spp.	Crsp	13.4	10.2	9.4	*Sanguinaria canadensis*	Saca	0.0	2.3	13.4
Cunila oreganoides	Cuor	12.1	1.2	0.0	*Sanicula spp.*	Sasp	8.5	17.6	14.2
Danthonia spicata	Dasp	10.8	1.0	0.0	*Scutellaria spp.*	Scsp	2.6	8.7	23.1
Dentaria laciniata	Dela	2.6	19.7	20.0	*Smilacinia racemosa*	Smra	19.5	40.1	34.5
Desmodium glutinosum	Degl	4.4	15.1	14.1	*Smilax glauca*	Smgl	40.6	31.7	16.8
Desmodium nudiflorum	Denu	41.0	53.3	37.5	*Smilax rotundifolia*	Smro	59.4	36.5	27.3
Dioscorea quaternata	Diqu	2.8	12.0	21.9	*Solidago caesia*	Soca	9.6	15.1	10.6
Eupatorium rugosum	Euru	3.9	14.3	20.8	*Thelypteris hexagonoptera*	Thhe	0.2	2.5	11.8
Fagus grandifolia	Fagr	10.1	10.2	17.4	*Tiarella cordifolia*	Tico	0.0	2.3	34.7
Fraxinus americana	Fram	22.6	45.7	34.9	*Toxicodendron radicans*	Tora	10.3	16.9	15.1
Galium aparine	Gaap	3.1	11.8	16.3	*Trillium grandiflorum*	Trgr	0.0	7.9	45.1
Galium circazans	Gaci	17.5	27.1	29.5	*Ulmus rubra*	Ulru	5.7	27.6	25.9
Galium concinnum	Gaco	0.0	5.8	11.3	*Uvularia perfoliata*	Uvpe	11.2	50.3	52.1
Galium triflorum	Gatr	8.5	35.4	36.3	*Vaccinium palidum*	Vapa	51.7	10.2	1.2
Geranium maculatum	Gema	4.4	36.3	62.3	*Vaccinium stamineum*	Vast	13.4	5.3	0.7
Hamamelis virginiana	Hamvi	2.0	6.1	11.5	*Viburnum acerifolium*	Viac	10.1	29.8	34.4
Helianthus divaricatus	Hedi	10.8	4.6	0.7	*Viola spp.*	Viosp	15.8	34.4	37.7

Results

We recorded 297 species distributed in 83 families and 198 genera (Appendix). The most species-rich families were Asteraceae (29 species), Cyperaceae (23), and Poaceae (17); the most species-rich genera were *Carex* (21 species) and *Aster* (10). The species were distributed as 187 forbs (176 perennials, 9 annuals, 2 biennials), 42 graminoids, 34 shrubs and woody vines, and 32 trees. Only seven nonnative species were recorded; the most frequent was *Rosa multiflora*, which was found in less than 1 percent of the quadrats.

Most species were relatively uncommon, with an average frequency of less than 10 percent for all three IMI classes (Appendix). There were 86 common species, defined as having an average frequency of 10 percent or more in at least one IMI class (Table 1). The most frequent species (averaging more than 40 percent) on xeric plots were woody and included *Acer rubrum*, *Sassafras albidum*, *Smilax rotundifolia*, *Vaccinium palidum*, *Cornus florida*, and *Smilax glauca*; *Desmodium nudiflorum*, a forb, was also very frequent. On mesic plots, the most frequent species included four forbs, *Geranium maculatum*, *Uvularia perfoliata*, *Anemonella thalictroides*, and *Trillium grandiflorum*, and two

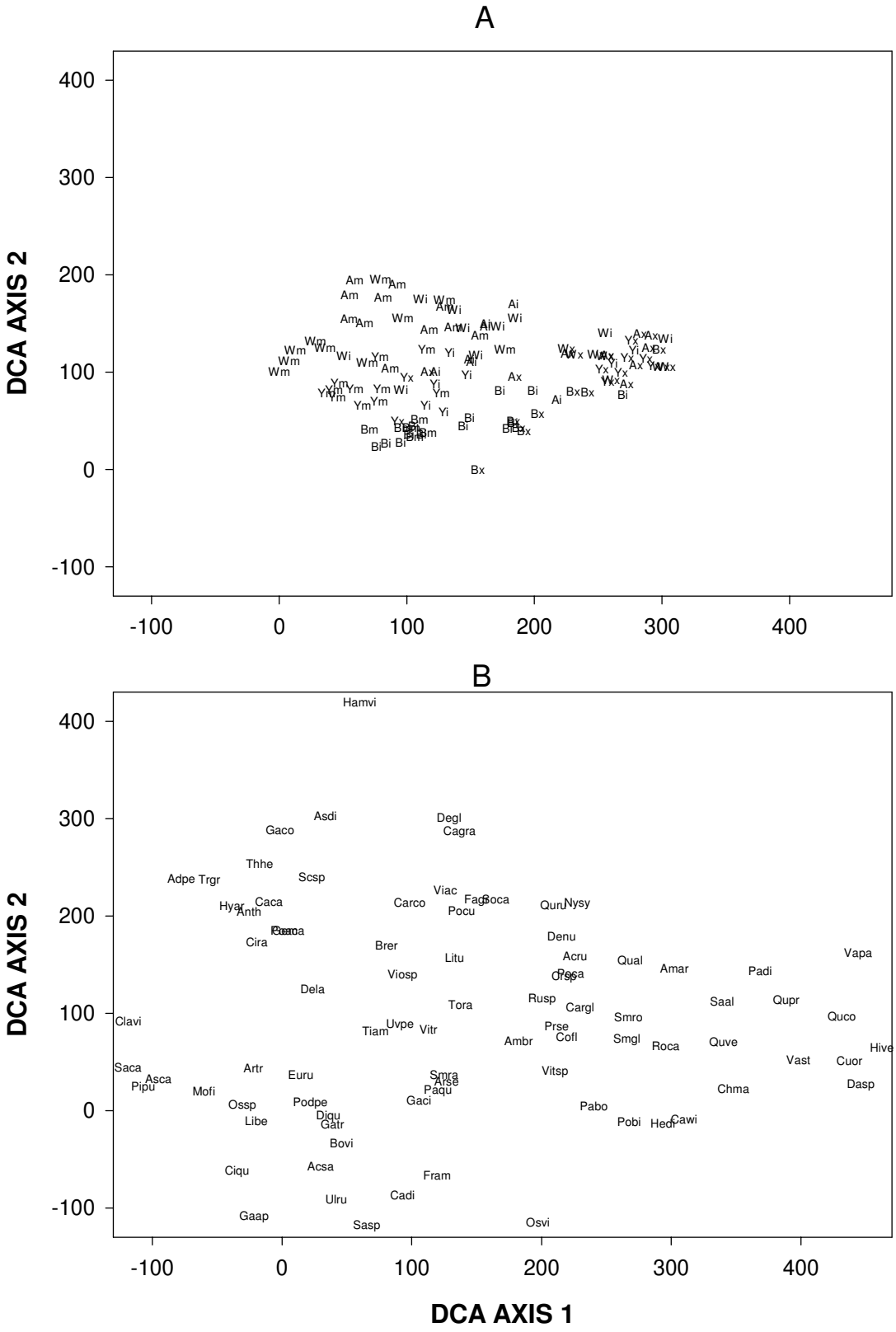

Figure 1.—Detrended correspondence analysis of the 108 vegetation plots. The input data for each plot was the frequency of each species recorded in 16 2 m^2 quadrats within a 25 X 25 m area. A. Each vegetation plot is represented by two letters denoting the study area (A = Arch Rock, B = Bluegrass Ridge, W = Watch Rock, and Y = Young's Branch) and IMI class (x = xeric, I = intermediate, and m = mesic). B. Each common species, defined as averaging >10% frequency at least one IMI class, is represented by a unique 4 or 5 letter code, based on the genus and species. The species codes are listed in Table 1.

Table 2.—Eigenvalues for the DCA axes and correlation coefficients (Pearson) for the environmental variables and the plot scores calculated in DCA. Only correlations significant at p<0.05 are listed.

Variable	Axis 1	Axis 2	Axis 3
IMI	-0.754	0.304	ns
NO_3	-0.694	ns	ns
pH	-0.626	-0.385	ns
NH_4	-0.587	ns	0.267
PO_4	-0.329	-0.448	-0.244
Light	0.194	ns	ns
Tree basal area	ns	ns	ns
Stand age	ns	ns	ns
Clay (%)	ns	-0.486	ns
Sand (%)	ns	-0.630	ns
Silt (%)	ns	0.606	ns
Eigenvalue	0.374	0.151	0.084

woody species, *Acer rubrum* and *Parthenocissus quinquifolius*. The most frequent species on intermediate plots were *Acer rubrum*, *Desmodium nudiflorum*, *Uvularia perfoliata*, *Parhtenocissus quinquifolius*, *Fraxinus americana*, and *Smilacina racemosa* (Table 1).

Detrended correspondence analysis

DCA indicated that plots were separated primarily along the moisture gradient predicted by the IMI classes. Mesic plots generally had low axis 1 scores and xeric plots had high axis 1 scores (Fig. 1a). The eigenvalues for axis 1 and 2 were 0.374 and 0.151, respectively (Table 2). Axis 1 plot scores were most strongly correlated with IMI (-0.754), NO_3^- (-0.694), pH (-0.626), and NH_4^+ (-0.587), indicating a compositional gradient also related to decreasing nutrient availability along axis 1 (Table 2).

Common species associated with the xeric sites included six woody species, *Vaccinium palidum*, *V. stamineum*, *Quercus coccinea*, *Q. prinus*, *Q. velutina*, *Sassafras albidum*, three forbs, *Hieraceum venosum*, *Cunila oreganoides*, *Chimaphilia maculata*, and two grasses, *Danthonia spicata* and *Panicum dichotomum* (Fig. 1b). Except for *Acer saccharum*, all of the species associated with the mesic plots were forbs, and included *Sanguinaria canadendsis, Claytonia virginiana, Pilea pumila, Adiantum pedatum, Monarda fistulosa*, and *Trillium grandiflorum*.

Many of the most frequent species were common in all IMI classes, and had intermediate axis 1 scores. Among these were *Rubus spp., Desmodium nudiflorum, Acer rubrum, Cornus florida*, and *Vitis spp*., which were found toward the xeric portion of axis 1, while *Viburnum acerifolium, Uvularia perfoliata, Smilacina racemosa, Parthenocissus quinquifolius, Galium circazans*, and *Fraxinus americana* were found toward the mesic portion of axis 1 (Fig. 1b).

Axis 2 indicated additional compositional variation among the four study areas (Fig. 1a). Although plots were not strongly separated by study area, BR plots had low axis 2 scores, WR and AR plots had high axis 2 scores, and YB plots were intermediate. For axis 2, the compositional variation among the study areas was primarily in the intermediate and mesic plots. Axis 2 plot scores were most strongly correlated to percent sand (-0.630), percent silt (0.606), and percent clay (-0.486) (Table 2).

Species associated with the AR and WR mesic plots included *Hammamelis virginiana, Aster divaricatus, Desmodium glutinosum, Galium concinnum,* and *Carex gracilescens*. Species associated with the mesic plots at BR included *Ostrya virginiana, Sanicula spp., Galium aparine, Ulmus rubra, Carex digitalis, Fraxinus americana, Circaea quadrisulcata*, and *Acer saccharum*.

Species richness and diversity

Species richness per plot ranged from 23 to 106 and averaged 65.2. Mean richness per quadrat (2-m^2) ranged from 6 to 30 and averaged 16.7. For 13 different measures of richness and diversity, there were no significant pretreatment differences among the fire treatment units (Tables 3-4). Also, there were no significant IMI x treatment interaction effects for any richness or diversity measure.

By contrast, all measures of total richness and diversity were significantly different among the IMI classes. Species richness was significantly greater on intermediate and mesic plots than on xeric plots, both at the scale of plot ($F = 10.34$, $p = 0.001$) and quadrat ($F = 11.32$, $p = 0.002$) (Table 3). Species evenness on mesic plots was significantly greater than on xeric plots ($F = 5.04$, $p = 0.02$). Species diversity also was significantly higher on intermediate and mesic than on xeric plots ($F = 9.59$, $p = 0.002$).

Among the four major life forms, forbs had the highest species richness, averaging 31.9 species per plot and 8.1 species per quadrat. There were significant differences in forb richness among IMI classes, both at the plot ($F = 23.21$, $p = 0.0001$) and quadrat ($F = 26.94$, $p = 0.0001$) scale of measurement; forb richness was significantly greater on mesic than on intermediate plots, which were significantly more rich than the xeric plots (Table 4). There were no significant IMI effects on the richness of tree species, graminoids, shrubs, or woody vines (Table 4).

Threatened and endangered (T&E) species survey

Twelve state-listed T&E species were identified in the four study areas (Table 5). Arch Rock had the most species

Table 3.—Mean values for measures of total species richness per plot from ANOVA testing for effects of IMI and treatment unit; no significant IMI*unit interactions; significant differences among least squares means represented by different letters for treatment units (a,b,c) and IMI classes (d,e,f).

	Treatment unit			
IMI class	Control	Infrequent	Frequent	Mean
	Species richness/plot			
Xeric	51.0	54.4	61.6	55.7_{d}
Intermediate	58.7	72.2	69.4	66.8_{e}
Mesic	71.4	74.8	69.2	71.8_{e}
Mean	60.4_{a}	67.1_{a}	66.7_{a}	
	Species richness/quadrat			
Xeric	11.8	12.7	16.3	13.6_{d}
Intermediate.	14.9	17.8	17.8	16.8_{e}
Mesic	19.1	20.0	17.9	19.0_{e}
Mean	15.3_{a}	16.8_{a}	17.4_{a}	
	Evenness/plot			
Xeric	0.90	0.912	0.909	0.910_{d}
Intermediate.	0.916	0.916	0.919	0.917_{de}
Mesic	0.926	0.922	0.925	0.924_{e}
Mean	0.917_{a}	0.917_{a}	0.917_{a}	
	Species diversity/plot			
Xeric	3.56	3.63	3.69	3.63_{d}
Intermediate.	3.70	3.91	3.88	3.83_{e}
Mesic	3.95	3.97	3.92	3.95_{e}
Mean	3.74_{a}	3.84_{a}	3.83_{a}	

(eight) and YB the fewest (two). Two species, *Calamagrostis porteri* subsp. *insperata,* and *Gentiana villosa* were listed as endangered, the highest conservation category in Ohio. Both were found in relatively xeric areas, i.e., on ridgetops, or south- or west-facing slopes.

Discussion

The 297 species recorded in this study represent approximately 15 percent of the more than 2,000 species known from southeastern Ohio (Cusick and Silberhorn 1977). A flora of the Vinton Furnace Experimental Forest (VFEF) documented 536 species for the 485-ha area (Hall 1958). Even though our sampling at AR and WR (in and adjacent to the VFEF) was confined to upland closed-canopy forests and covered less than 0.03 percent (0.173 ha) of the area surveyed by Hall, we recorded 260 species at these sites.

Surprisingly, we recorded only seven exotic species, and none of these were abundant. Ecosystems that experience relatively mild and/or infrequent anthropogenic disturbance generally are less susceptible to invasion by exotic species (Rejmanek 1989). In the 1800s, our study areas were disturbed by clearcutting and likely by fire and grazing, while selective harvesting likely occurred in the 1900s (Chapter 2). Although Hall (1958) recorded 45 exotic species in his survey of the VFEF, nearly all were restricted to disturbed areas such as roadsides, lawns associated with buildings, open bottomlands, and recently harvested stands. Our results indicate that despite a presumably large pool of exotic species in the area, few can establish or persist in upland mature forests.

Relatively few T&E species were recorded in the sampling and surveying, probably because our study areas are fairly typical of large portions of southeastern Ohio. The Pennsylvanian sandstone underlying the study areas is the most common bedrock type in the Unglaciated Allegheny Plateau of southern Ohio (Cusick and Silberhorn 1977). By contrast, the uncommon outcrops of Silurian limestones and dolomites located south and west of the study areas in Adams County contain numerous T&E species (Cusick and Silberhorn 1977).

In landscapes with significant topographic variation, plant species composition often is most strongly related to gradients of aspect (Lieffers and Larkin-Lieffers 1987; Olivero and Hix 1998), slope position (Bridge and Johnson 2000), or an integration of both (Allen and Peet 1990), that result in variation in microclimate and soil moisture. Similarly, we found that understory composition was most strongly related to the IMI, which incorporates aspect (hillshade index, 40 percent), slope position (cumulative flow of water downslope, 30 percent), soil water-holding capacity (20 percent) and curvature (10 percent) (Chapter 3). Species composition also was strongly related to soil NO_3^-, pH, and NH_4^+, which varied directly with the IMI (Chapter 5). Moisture-fertility gradients control patterns of species composition in many ecosystems (e.g., Neave et al. 1995; Smith 1995; Bridge and Johnson 2000).

More than half of the common species associated with the xeric plots were woody, and included several species of *Quercus*, *Vaccinium*, and *Smilax* (Fig. 1b). *Quercus spp*. and *Vaccinium spp*. have morphological and physiological traits that infer a degree of resistance to drought (Parker and Pallardy 1988; Matlack et al. 1993; Pallardy and Rhoads 1993). Despite the greater overall richness of forbs in the regional species pool, relatively few forb species establish and persist on xeric, nutrient-poor slopes. In sharp contrast, more than 75 percent of the common species associated with the mesic plots were forbs (Fig. 1b). Similar patterns of life form distribution have been quantified by Mabry et al. (2000),

Table 4.—Mean values for species richness of life forms from ANOVA testing for the effects of IMI and treatment unit; significant differences among least squares means are represented by different letters for treatment units (a,b,c) and IMI classes (d,e,f).

	Treatment Unit			
IMI class	Control	Infrequent	Frequent	Mean
		Forb richness		
Xeric	17.7	20.8	26.9	21.8_{d}
Intermediate	25.7	37.1	34.8	32.6_{e}
Mesic	40.7	41.9	37.0	40.0_{f}
Mean	28.0_{a}	33.3_{a}	32.9_{a}	
		Forb richness/Quadrat		
Xeric	3.3	3.8	6.0	4.4_{d}*
Intermediate	5.9	8.6	8.7	7.7_{e}
Mesic	11.8	12.3	10.1	11.4_{f}
Mean	7.0_{a}	8.2_{a}	8.3_{a}	
		Graminoid richness/Plot		
Xeric	6.6	7.3	9.0	7.6_{d}
Intermediate	6.8	8.4	8.4	7.9_{d}
Mesic	5.2	7.3	5.9	6.1_{d}
Mean	6.2_{a}	7.7_{a}	7.8_{a}	
		Graminoid richness/Quadrat		
Xeric	1.0	1.3	1.8	1.4_{d}
Intermediate	1.3	1.9	1.7	1.5_{d}
Mesic	1.0	1.4	1.2	1.2_{d}
Mean	1.1_{a}	1.5_{a}	1.6_{a}	
		Shrub and vine richness/Plot		
Xeric	9.6	10.5	9.7	9.9_{d}
Intermediate	9.7	11.5	10.9	10.7_{d}
Mesic	11.1	10.7	11.1	10.9_{d}
Mean	10.1_{a}	10.9_{a}	10.5_{a}	
		Shrub and vine richness/Quadrat		
Xeric	2.7	3.0	3.2	3.0_{d}
Intermediate	2.9	2.9	2.9	2.9_{d}
Mesic	2.8	2.6	2.5	2.7_{d}
Mean	2.8_{a}	2.9_{a}	2.9_{a}	
		Tree richness/Plot		
Xeric	17.1	15.9	16.1	16.3_{d}
Intermediate	16.7	15.1	15.2	15.7_{d}
Mesic	14.5	14.9	14.9	14.8_{d}
Mean	16.1_{a}	15.3_{a}	15.4_{a}	
		Tree richness/Quadrat		
Xeric	4.6	4.6	5.2	4.8_{d}
Intermediate	4.7	4.3	4.6	4.5_{d}
Mesic	3.9	3.8	4.1	3.9_{d}
Mean	4.4_{a}	4.6_{a}	4.2_{a}	

*Overall F test significant.

who reported traits associated with xeric habitat include woody roots and the ability to sprout while traits associated with mesic areas included low capacities for vegetative spread and root storage.

Species composition also varied among the four study areas, though most of that variation occurred among the intermediate and mesic plots (Fig. 1a). Boerner et al. (Chapter 5) also found that the xeric plots were relatively similar among the study areas. However, the mesic plots at BR had more Ca and Mg and had higher percentages of clay and sand than the AR and WR mesic plots. These results suggest that regional differences in bedrock geology caused additional variation in species composition, particularly the interbedded limestone associated with the lower slopes at BR.

Despite some variation in overstory composition, tree basal area and light availability generally were similar across the landscape (Chapters 6 and 9). Overstory structure variables were not strong correlates with plant composition probably because of the spatial homogeneity of light availability. In ecosystems with spatially heterogeneous structure (e.g., oak savannas), the distribution of species is strongly related to light availability (Leach and Givnish 1999).

Plant species diversity often is greatest in habitats with intermediate resource levels (Tilman 1982). By contrast, we found that diversity was greatest in mesic plots, which also had the greatest nutrient availability. Findings similar to ours have been reported for upland forests (Glenn-Lewin 1975; Huebner and Randolph 1995; Jenkins and Parker 1999). However, we did not sample the entire resource gradient for these study areas, because plots were not located in ravines and bottomlands. In a regional analysis in Illinois, tree species diversity was higher in upland mesic sites than in lowland wet-mesic sites (Adams and Anderson 1980).

For large-scale, long-term ecosystem studies, it is critical to quantify initial landscape patterns of structure, composition, and function (Stohlgren et al. 1995). The IMI was designed to map potential moisture conditions across a complex landscape. The IMI was positively correlated with soil nitrogen and pH, and thus also captured some of the variation in soil fertility. For studies of understory vegetation, our results indicate that the IMI is a useful tool.

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Table 5.—State-listed threatened and endangered plant species recorded in 1994 and 1995 on surveys of each study area (P=potentially state threatened, T=state threatened, E=state endangered).

Species	Ohio Status	Study area	Regional habitat description[a]
Asclepias amplexicaulis	P	AR	Dry fields, prairies and open woods
Calamagrostis insperata	E	AR,WR	Dry rocky woods
Carex abscondita	P	BR	Moist to wet woods
Carex juniperorum	T	BR	Open woodlands with limestone bedrock
Cirsium carolinianum	T	AR	Dry woods
Clitoria mariana	P	AR,WR	Dry upland woods and barrens
Cyprepedium calceoulus var. pubescens	P	AR,WR,YB	Mesic woods and ravines
Desmodium pauciflorum	P	YB,BR	Moist woods
Gentiana villosa	E	BR	Dry woods and prairies
Malaxis unifolia	P	AR	Oak woods
Rhododendron periclymenoides	T	YB	Moist or dry woods and bogs
Scutellaria serrata	P	AR	Mesic woods and ravines

[a]From Cusick and Silberhorn (1977), Gleason and Cronquist (1991), and Catling et al. (1993).

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Appendix. Mean frequencies/plot for vascular plant species recorded in 1995 (F=forb, G=graminoid, SV=shrub/woody vine, T = tree).

SPECIES	Life Form	IMI class			Study Area			
		Xeric	Intermediate	Mesic	Watch Rock	Arch Rock	Young's Branch	Bluegrass Ridge
		Percent			Percent			
Division Polypodiopyta (Ferns)								
Ophioglossaceae								
Botrychium dissectum	F	0.0	0.5	0.0	0.0	0.0	0.0	0.7
Botrychium virginianum	F	3.6	10.3	12.7	5.8	3.2	12.5	14.8
Osmundaceae								
Osmunda cinnamomea	F	0.0	0.0	2.0	0.0	2.8	0.0	0.0
Osmunda claytonia	F	0.0	2.2	6.3	4.6	5.1	0.9	1.2
Adiantaceae								
Adiantum pedatum	F	0.0	0.5	11.2	4.9	4.9	6.7	0.0
Aspleniaceae								
Asplenium platyneuron	F	0.4	1.2	0.5	0.5	0.9	0.2	1.2
Athyrium filix-femina	F	0.0	0.7	2.0	1.4	1.9	0.5	0.0
Athyrium thelpterioides	F	0.0	0.0	1.6	2.1	0.2	0.0	0.0
Cystopteris protrusa	F	0.0	0.0	0.2	0.2	0.0	0.0	0.0
Cystopteris spp.	F	0.0	0.0	1.5	2.1	0.0	0.0	0.0
Dryopteris spinulosa	F	0.0	0.2	0.0	0.2	0.0	0.0	0.0
Polystichum acrosticoides	F	3.6	18.2	35.7	23.6	23.6	20.4	12.0
Thelypteris hexagonoptera	F	0.2	2.0	11.7	6.5	6.0	6.7	0.2
Thelypteris noveboracensis	F	0.0	0.7	9.4	3.5	9.5	1.2	0.0
Onoclea sensibilis	F	0.0	0.0	1.8	2.3	0.2	0.0	0.0
Division Pinophyta (Gymnosperms)								
Pinaceae								
Pinus spp.	T	0.2	0.3	0.0	0.0	0.0	0.5	0.2
Division Magnoliophyta (Flowering Plants)								
Magnoliaceae								
Liriodendron tulipifera	T	13.3	30.2	34.4	31.3	22	30.6	22.2
Lauraceae								
Lindera benzoin	SV	6.4	10.0	28.6	8.8	9.7	31.3	12.0
Sassafras albidum	T	63.1	35.8	12.8	27.5	40.7	38.0	38.0
Aristolociaceae								
Aristolochia serpentaria	F	7.4	11.8	10.7	10.0	8.1	6.5	15.7
Asarum canadense	F	2.1	2.0	32.1	15.3	4.6	30.6	0.0
Ranunculaceae								
Anemonella thalictroides	F	4.7	12.0	54.3	27.8	31.5	30.8	8.6
Cimicifuga racemosa	F	2.7	9.3	30.1	18.3	14.4	20.8	4.9
Clematis virginiana	SV	0.2	0.3	0.0	0.0	0.2	0.0	0.5
Delphinium tricorne	F	0.0	0.2	0.0	0.0	0.0	0.0	0.2
Hepatica americana	F	0.4	1.4	8.7	4.9	9.3	0.0	0.5
Hydrastis canadensis	F	0.0	3.5	3.1	1.4	0.7	0.7	6.5
Ranunculus allegheniensis	F	0.6	0.2	1.8	2.8	0.7	0.0	0.0
Ranunculus hispida	F	0.6	1.9	0.2	0.5	1.4	0.0	1.6
Ranunculus recurvatus	F	0.6	2.9	2.3	0.0	0.2	1.9	5.8
Thalictrum dioicum	F	0.0	0.3	0.0	0.2	0.2	0.0	0.0
Thalictrum revolutum	F	0.0	0.2	0.0	0.0	0.0	0.0	0.2
Berberidaceae								
Caulophyllum thalictroides	F	0.0	0.7	2.3	1.4	0.2	2.5	0.0
Jeffersonia diphylla	F	0.0	1.7	0.0	0.0	0.0	0.0	2.3
Podophyllum peltatum	F	4.0	9.5	14.5	10.9	5.6	11.3	10.4

Appendix cont.

SPECIES	Life Form	IMI class			Study Area			
		Xeric	Intermediate	Mesic	Watch Rock	Arch Rock	Young's Branch	Bluegrass Ridge
		Percent			Percent			
Menispermaceae								
Menispermum canadense	SV	0.4	0.3	0.5	0.5	0.7	0.5	0.0
Papaveraceae								
Sanguinaria canadensis	F	0.0	1.4	13.7	8.6	3.0	9.5	0.0
Papaveraceae								
Sanguinaria canadensis	F	0.0	1.4	13.7	8.6	3.0	9.5	0.0
Fumariaceae								
Dicentra cucullaria	F	0.0	0.0	1.8	2.5	0.0	0.0	0.0
Hamamelidaceae								
Hamamelis virginiana	SV	2.1	6.3	10.9	13.2	10.9	2.3	0.0
Ulmaceae								
Celtis occidentalis	T	0.0	0.2	0.3	0.0	0.0	0.2	0.5
Ulmus rubra	T	9.1	23.5	26.5	4.9	10.4	25.0	40.3
Moraceae								
Morus rubra	T	0.0	0.5	0.0	0.2	0.2	0.0	0.2
Urticaceae								
Boehmeria cylindrica	F	0.0	0.2	3.1	0.0	0.0	4.2	0.5
Laportea canadensis	F	0.0	0.0	0.2	0.0	0.0	0.2	0.0
Pilea pumila	F	0.4	5.4	12.8	12.5	5.3	3.7	4.4
Urtica dioica	F	0.6	0.0	0.3	0.0	0.0	1.2	0.0
Juglandaceae								
Carya cordiformis	T	3.2	7.3	10.4	9.5	8.8	5.3	4.9
Carya glabra	T	18.4	16.6	11.0	9.0	22.0	16.7	13.0
Carya ovata	T	1.7	1.5	1.2	1.4	3.7	0.2	0.5
Carya tomentosa	T	4.9	8.1	2.6	9.5	5.1	0.7	5.6
Juglans nigra	T	0.0	0.0	0.3	0.0	0.0	0.2	0.2
Fagaceae								
Fagus grandifolia	T	9.5	10.8	16.9	14.8	12.5	17.6	5.3
Quercus alba	T	35.2	25.7	15.1	24.1	36.6	18.3	20.6
Quercus coccinea	T	10.6	4.9	0.7	6.7	1.4	6.3	6.3
Quercus prinus	T	26.5	11.1	3.3	11.8	13.4	19.4	7.6
Quercus rubra	T	11.2	11.8	9.9	14.8	14.4	8.1	6.5
Quercus velutina	T	25.0	12.8	4.6	17.1	16.2	9.0	12.3
Betulaceae								
Carpinus caroliniana	T	0.4	5.1	11.7	7.9	7.2	3.2	5.6
Corylus americana	SV	2.5	6.6	4.9	9.3	8.1	0.9	0.7
Ostrya virginiana	T	11.9	8.4	2.8	2.5	0.0	0.0	27.5
Phytolaccaceae								
Phytolacca americana	F	0.0	0.2	0.0	0.0	0.0	0.0	0.2
Portulaceae								
Claytonia virginiana	F	0.8	4.7	10.2	19.4	0.0	0.0	2.3
Caryophyllaceae								
Paronychia canadensis[b]	F	0.0	0.2	0.0	0.0	0.2	0.0	0.0
Silene stellata	F	1.3	2.9	0.5	4.4	1.6	0.2	0.0
Silene virginica	F	0.4	0.2	0	0.2	0.5	0.0	0.0
Stellaria pubera	F	0.0	0.3	5.1	7.6	0.0	0.0	0.0
Polygonaceae								
Polygonum persicaria[a]	F	0.0	0.7	0.0	0.0	0.0	0.0	0.9
Polygonum scandens	F	0.0	1.0	0.0	0.0	1.4	0.0	0.0
Polygonum virginianum	F	0.2	5.2	9.0	9.0	4.2	1.2	5.8

Appendix cont.

SPECIES	Life Form	IMI class			Study Area			
		Xeric	Intermediate	Mesic	Watch Rock	Arch Rock	Young's Branch	Bluegrass Ridge
		Percent			Percent			
Clusiaceae								
Hypericum spp.	F	0.0	0.8	0.2	0.5	0.9	0.0	0.0
Tiliaceae								
Tilia americana	T	0.4	0.3	1.0	0.7	0.2	1.4	0.0
Violaceae								
Hybanthus concolor	F	0.0	0.3	0.0	0.5	0.0	0.0	0.0
Viola affinis	F	1.3	0.0	0.0	1.6	0.0	0.0	0.0
Viola blanda	F	0.0	0.0	1.0	0.0	1.4	0.0	0.0
Viola canadensis	F	0.0	0.3	2.3	3.2	0.5	0.0	0.0
Viola pensylvanica	F	0.0	0.2	2.1	2.1	0.0	0.0	1.2
Viola sororia	F	0.0	1.7	3.1	4.4	0.2	0.0	2.1
Viola spp.	F	18.0	32.8	36.7	36.1	33.1	22.7	26.6
Viola striata	F	0.0	0.0	0.2	0.2	0.0	0.0	0.0
Viola triloba	F	17.6	24.5	24.7	16.9	31.7	16.0	25.2
Passifloraceae								
Passiflora lutea	F	0.4	1.4	1.5	0.0	0	1.2	3.2
Brassicaceae								
Cardamine douglassii	F	0.0	1.0	2.5	4.9	0.0	0.0	0.0
Cardamine hirsuta[ab]	F	0.0	0.3	0.2	0.0	0.7	0.0	0.0
Dentaria laciniata	F	3.6	19.4	18.9	19.9	10.6	23.4	3.7
Dentaria heterophylla	F	1.3	5.1	9.2	7.4	1.4	3.5	9.3
Ericaceae								
Chimaphila maculata	F	8.3	5.6	1.2	2.5	2.8	5.6	8.6
Gaultheria procumbens	F	0.2	0.0	0.0	0.0	0.2	0.0	0.0
Gaylussacia baccata	SV	0.2	0.0	0.0	0.0	0.0	0.2	0.0
Oxydendrum arborea	T	5.9	4.1	1.6	6.3	3.7	4.2	0.9
Vaccinium angustifolium	SV	0.9	0.0	0.0	0.0	0.0	1.2	0.0
Vaccinium palidum	SV	47.9	15.2	1.2	21.1	22.0	27.8	10.2
Vaccinium stamineum	SV	12.7	6.4	0.7	6.0	3.9	8.1	7.2
Pyrolaceae								
Pyrola rotundifolia	F	0.0	0.2	1.8	2.5	0.2	0.0	0.0
Monotropaceae								
Monotropa hypopithys	F	0.2	0.0	0.2	0.2	0.2	0.0	0.0
Monotropa uniflora	F	3.4	2.7	1.6	4.2	3.5	2.1	0.5
Primulaceae								
Lysimachia quadriflora	F	3.0	9.8	4.8	9.3	6.7	6.0	1.9
Hydrangeaceae								
Hydrangea arborescens	SV	0.9	4.7	19.2	8.1	10.4	14.6	1.6
Grossulariaceae								
Ribes spp.	SV	0.2	0.0	0.3	0.5	0.0	0.2	0.0
Crassulaceae								
Sedum ternatum	F	1.7	0.3	4.1	3.7	2.5	0.9	1.2
Saxifragaceae								
Heuchera americana	F	0.6	1.5	1.5	0.7	1.4	0.5	2.3
Tiarella cordifolia	F	0.0	1.4	33.9	22.2	23.4	3.0	0.9
Rosaceae								
Agrimonia spp.	F	4.0	6.9	5.3	1.4	5.3	4.9	10.2
Amelanchier arborea	T	23.3	7.4	6.9	9.7	12.0	16.7	10.0
Crataegus spp.	T	13.6	10.5	9.0	15.5	12.0	5.3	10.9
Geum spp.	F	1.1	2.7	4.1	3.0	3.2	0.5	4.2
Porteranthus stipulatus	F	8.0	1.7	0.0	0.7	5.3	2.5	3.5

Appendix cont.

SPECIES	Life Form	IMI class			Study Area			
		Xeric	Intermediate	Mesic	Watch Rock	Arch Rock	Young's Branch	Bluegrass Ridge
		Percent			Percent			
Potentilla canadensis	F	16.1	19.6	9.2	17.4	19.2	8.6	14.4
Prunus serotina	T	11.4	12.2	7.4	10.2	10.4	8.1	12.3
Prunus spp.	SV	0.9	0.5	0.2	0.0	0.0	0.2	1.9
Pyrus coronaria	T	1.9	0.0	0.0	2.3	0.0	0.0	0.0
Rosa carolina	SV	23.3	12.8	5.4	16.4	16.2	7.2	13.9
Rosa multiflora[a]	SV	0.0	1.5	1.3	1.9	1.4	0.0	0.7
Rosa setigera	SV	0.0	0.2	0.0	0.0	0.0	0.0	0.2
Rosa spp.	SV	2.1	0.7	0.3	0.2	0.5	0.7	2.5
Rubus spp.	SV	21.4	26.7	14.3	22.9	28.9	12.3	18.8
Caesalpiniaceae								
Cercis canadensis	T	18.2	22.0	9.0	1.4	4.2	17.4	42.1
Fabaceae								
Amphicarpaea bracteata[b]	F	19.3	21.8	16.4	10.2	28.2	15.7	22.5
Apios americana	F	0.0	0.0	0.2	0.2	0.0	0.0	0.0
Clitoria mariana	F	0.0	0.2	0.0	0.0	0.2	0.0	0.0
Desmodium glutinosum	F	4.9	15.2	13.3	12.3	26.9	3.7	2.8
Desmodium nudiflorum	F	42.6	53.7	36.2	31.9	55.1	58.3	31.3
Desmodium rotundifolium	F	0.0	0.5	0.0	0.0	0.0	0.0	0.7
Lespedeza hirta	F	0.4	0.0	0.0	0.0	0.2	0.2	0.0
Lespedeza spp.	F	4.2	1.2	0.2	0.7	2.1	1.4	2.8
Vicia caroliniana	F	3.0	3.5	0.7	0.0	0.0	1.2	8.3
Onagraceae								
Circaea lutetiana	F	3.6	5.1	17.3	7.2	6.5	12.5	9.5
Cornaceae								
Cornus alternifolia	SV	0.2	0.7	2.0	0.7	0.2	3.0	0.0
Cornus florida	T	44.1	38.7	28.6	23.1	34.7	43.3	46.1
Nyssa sylvatica	T	20.3	15.0	19.7	20.1	22.7	16.4	13.9
Celastraceae								
Celastrus scandens	SV	2.1	2.9	4.8	3.0	2.8	2.1	5.3
Euonymous atropurpureus	SV	0.0	0.8	0.8	0.7	0.2	0.5	0.9
Euphorbiaceae								
Acalypha virginica[b]	F	1.1	3.0	0.3	0.7	2.8	0.0	2.5
Euphorbia corollata	F	0.4	0.0	0.0	0.0	0.2	0.0	0.2
Rhamnaceae								
Ceanothus americanus	SV	0.4	0.0	0.0	0.0	0.5	0.0	0.0
Vitaceae								
Parthenocissus quinquifolius	SV	26.3	48.1	42.4	21.3	36.3	35.6	64.6
Vitis spp.	SV	20.8	25.0	15.6	15.5	18.8	19.2	28.2
Staphyleaceae								
Staphylea trifolia	SV	0.0	0.3	1.0	1.6	0	0.2	0.0
Hippocastanaceae								
Aesculus flava	T	0.2	0.5	0.7	0.7	0.9	0.2	0.0
Aceraceae								
Acer rubrum	T	75.9	68.9	56.4	63.2	76.4	76.9	50.2
Acer saccharum	T	5.1	21.3	30.8	10.0	8.8	22.9	37.0
Anacardiaceae								
Toxicodendron radicans	SV	10.8	16.9	14.6	16.7	17.4	4.6	18.3
Rutaceae								
Ptelea trifoliata	SV	0.0	0.2	0.2	0.0	0	0.2	0.2
Oxalidaceae								
Oxalis grandis	F	0.0	1.0	0.5	0.0	2.1	0.0	0.0

Appendix cont.

SPECIES	Life Form	IMI class			Study Area			
		Xeric	Intermediate	Mesic	Watch Rock	Arch Rock	Young's Branch	Bluegrass Ridge
		Percent			Percent			
Oxalis stricta	F	0.0	0.2	1.6	2.3	0.0	0.0	0.2
Oxalis violacea	F	5.5	2.7	0.2	3.5	3.9	1.4	1.9
Geraniaceae								
Geranium maculatum	F	8.0	31.9	61.3	43.5	42.8	32.9	20.6
Balsaminaceae								
Impatiens spp.[b]	F	0.0	2.5	0.3	0.0	0.0	0.0	3.9
Araliaceae								
Panax quinquefolius	F	0.8	1.9	4.1	0.5	1.6	4.2	3.0
Apiaceae								
Angelica venenosa	F	0.8	0.2	0.0	0.5	0.7	0.0	0.0
Cryptotaenia canadensis	F	0.0	0.2	0.8	0.2	1.2	0.0	0.0
Erigenia bulbosa	F	0.0	0.2	0.0	0.2	0.0	0.0	0.0
Osmorhiza claytonii	F	3.0	4.1	18.8	8.6	4.4	9.0	13.7
Sanicula spp.	F	10.2	15.9	14.3	3.9	7.4	12.0	31.0
Taenida integerrima	F	0.4	0.0	0.0	0.0	0.0	0.0	0.5
Thaspium trifoliatum	F	1.3	0.7	0.2	0.2	0.2	0.9	1.4
Apocynaceae								
Apocynum cannabinum	F	0.4	0.2	0.0	0.0	0.0	0.0	0.7
Asclepiadaceae								
Asclepias quadrifolia	F	1.5	0.5	0.8	0.2	1.6	0.2	1.6
Convolvulaceae								
Convolvulaceae spp.	F	1.1	1.4	0.5	0.9	2.3	0.2	0.5
Polemoniaceae								
Phlox divaricata	F	1.3	5.1	7.6	2.3	0.2	3.9	12.7
Phlox subulata	F	0.6	0.0	0.0	0.7	0.0	0.0	0.0
Polemonium reptans	F	0.0	0.2	2.1	0.7	2.3	0.0	0.2
Hydrophyllaceae								
Hydrophyllum canadense	F	0.0	0.0	0.2	0.2	0.0	0.0	0.0
Hydrophyllum macrophyllum	F	0.0	1.2	8.9	9.5	1.2	3.2	0.2
Boraginaceae								
Cynoglossum virginianum	F	1.1	0.8	0.3	0.2	0.9	0.0	1.9
Hackelia virginiana[c]	F	0.0	0.5	0.0	0.0	0.5	0.0	0.2
Verbenaceae								
Phryma leptostachya	F	0.9	2.2	0.7	0.0	0.2	0.2	4.6
Verbena urticifolia	F	0.2	0.7	0.3	0.0	1.6	0.0	0.0
Lamiaceae								
Blephilia hirsuta	F	0.0	0.2	0.5	0.0	0.0	0.7	0.2
Collinsonia canadensis	F	0.6	0.7	8.1	0.5	1.4	10.4	0.7
Cunila oreganoides	F	12.5	1.2	0.0	3.0	6.0	5.8	2.1
Glechoma hederacea[a]	F	0.2	0.0	0.3	0.0	0.5	0.2	0.0
Monarda fistulosa	F	0.8	1.9	9.7	6.7	2.1	6.5	1.9
Salvia lyrata	F	0.0	0.7	0.0	0.0	0.0	0.0	0.9
Scutellaria spp.	F	4.2	7.1	22.4	13.2	17.4	8.6	7.2
Oleaceae								
Fraxinus americana	T	24.2	42.4	36.7	11.8	15.0	34.7	77.8
Scrophulariaceae								
Aureolaria flava	F	0.0	0.2	0.0	0.2	0.0	0.0	0.0
Aureolaria laevigata	F	6.4	1.9	0.2	0.2	1.2	6.9	2.3
Aureolarlia virginica	F	1.5	0.0	0.0	0.2	1.6	0.0	0.0
Pedicularis canadensis	F	0.2	0.2	0.0	0.0	0.0	0.2	0.2

Appendix cont.

SPECIES	Life Form	IMI class			Study Area			
		Xeric	Intermediate	Mesic	Watch Rock	Arch Rock	Young's Branch	Bluegrass Ridge
		Percent			Percent			
Orobanchaceae								
Conopholis americana	F	2.1	3.5	4.3	0.9	2.1	2.8	7.6
Epifagus virginiana	F	0.0	0.2	1.8	0.0	2.5	0.2	0.0
Acanthaceae								
Ruellia caroliniense	F	0.6	0.3	0.0	0.0	0.0	0.0	1.2
Campanulaceae								
Campanula americana[c]	F	0.0	0.0	0.2	0.2	0.0	0.0	0.0
Lobelia inflata[b]	F	0.0	0.3	0.3	0.0	0.0	0.0	0.9
Lobelia puberula	F	0.2	0.2	0.0	0.2	0.2	0.0	0.0
Rubiaceae								
Galium aparine	F	3.6	11.5	15.8	12.3	0.9	7.6	21.5
Galium circazans	F	20.5	24.7	28.9	14.4	24.5	23.4	37.3
Galium concinnum	F	0.0	5.9	10.7	17.6	5.3	0.2	0.0
Galium lanceolatum	F	1.1	0.3	3.6	0.0	6.9	0.0	0.0
Galium triflorum	F	11.7	30.6	37.3	19.9	21.1	26.2	41.7
Hedyotis caerulea	F	2.5	1.2	0.0	0.5	0.9	3.0	0.2
Hedyotis longifolia	F	2.1	0.2	0.0	0.9	0.7	0.0	1.2
Mitchellla repens	F	0.4	0.0	0.0	0.2	0.2	0.0	0.0
Caprifoliaceae								
Lonicera japonica[a]	SV	0.4	0.5	0.3	0.0	0.0	0.0	1.6
Sambucus canadensis	SV	0.9	0.2	0.5	0.0	0.0	1.9	0.2
Triosteum aurantiacum	F	0.8	0.7	0.2	0.0	0.0	0.7	1.4
Viburnum acerifolium	SV	12.9	27.2	33.7	24.5	30.3	30.8	14.8
Viburnum dentatum	SV	0.0	0.0	0.8	0.2	0.9	0.0	0.0
Viburnum prunifolium	SV	3.2	5.1	5.6	8.3	4.9	3.2	2.3
Asteraceae								
Antennaria plantaginifolia	F	7.0	1.0	0.0	2.5	4.6	2.5	0.2
Aster divaricatus	F	2.7	9.5	22.7	12.7	23.4	8.6	3.5
Aster infirmus	F	2.5	0.0	0.0	0.0	0.0	0.7	2.3
Aster macrophyllus	F	0.0	0.0	0.5	0.0	0.7	0.0	0.0
Aster patens	F	0.8	0.3	0.0	0.0	0.7	0.0	0.7
Aster prenanthoides	F	0.2	0.0	0.0	0.0	0.2	0.0	0.0
Aster sagittifolius	F	0.0	0.0	0.2	0.0	0.2	0.0	0.0
Aster schreberi	F	0.0	0.8	0.3	0.0	1.6	0.0	0.0
Aster shortii	F	0.0	0.2	0.0	0.0	0.2	0.0	0.0
Aster simplex	F	0.2	0.2	0.2	0.0	0.7	0.0	0.0
Aster spp.	F	8.3	6.8	10.9	14.6	8.6	6.7	4.9
Aster undulatus	F	2.8	0.5	0.5	0.0	0.0	1.9	3.0
Cacalia atriplicifolia	G	0.0	0.7	0.7	0.5	0.5	0.0	0.9
Coreopsis major	F	3.2	1.5	0.0	0.0	0.0	3.5	2.5
Erechtites hieracifolia[b]	F	1.5	5.9	9.2	8.1	8.3	3.2	3.2
Erigeron spp.	F	0.2	0.3	0.0	0.2	0.2	0.0	0.2
Eupatorium rugosum	F	4.9	13.3	20.2	15.0	8.8	13.9	15.0
Eupatorium spp.	F	2.5	0.3	1.6	0.7	0.5	0.2	4.4
Helianthus divaricatus	F	10.4	5.2	0.8	3.9	5.6	3.7	7.9
Helianthus microcephalus	F	1.3	0.3	0.2	0.0	0.0	0.0	2.3
Hieracium spp.	F	0.8	0.0	0.0	0.9	0.0	0.0	0.0
Hieracium venosum	F	11.7	1.0	0.0	3.5	5.6	5.8	0.9
Krigia biflora	F	0.4	0.3	0.0	0.0	0.2	0.2	0.5
Senecio aureas	F	0.4	0.0	0.0	0.0	0.0	0.0	0.5
Senecio spp.	F	0.2	0.3	0.0	0.0	0.0	0.0	0.7

Appendix cont.

SPECIES	Life Form	IMI class			Study Area			
		Xeric	Intermediate	Mesic	Watch Rock	Arch Rock	Young's Branch	Bluegrass Ridge
		Percent			Percent			
Solidago caesia	F	9.8	15.5	10.0	12.3	24.3	1.2	9.7
Solidago flexicaulis	F	0.6	1.4	8.9	8.6	6.5	0.0	0.0
Solidago spp.	F	3.2	9.8	4.4	14.8	0.2	4.2	4.4
Solidago ulmifolia	F	2.3	0.5	0.2	0.0	0.0	0.0	3.7
Taraxacum officinale[a]	F	0.4	0.0	0.0	0.5	0.0	0.0	0.0
Verbesina alternifolia	F	0.0	0.7	2.5	3.0	0.2	0.7	0.5
Araceae								
Arisaema triphyllum	F	4.4	11.3	34.4	12.0	16.4	29.9	10.9
Commelinaceae								
Tradescantia virginiana	F	2.8	2.2	1.5	5.8	0.2	0.0	2.5
Juncaceae								
Luzula multiflora	G	1.9	0.7	0.0	0.9	1.6	0.2	0.5
Cyperaceae								
Carex albicans	G	0.4	0.2	0.0	0.7	0.0	0.0	0.0
Carex albursina	G	1.5	1.2	5.6	0.0	3.7	5.6	2.1
Carex amphibola	G	0.0	0.0	0.8	0.0	0.0	0.9	0.2
Carex blanda	G	1.5	6.6	3.3	4.6	7.6	0.0	3.2
Carex communis	G	0.0	0.8	0.0	1.2	0.0	0.0	0.0
Carex complanata	G	1.7	0.7	0.0	0.0	0.0	0.2	2.8
Carex digitalis	G	5.3	10.0	9.4	0.7	4.2	10.9	17.6
Carex flaccosperma	G	0.0	2.4	0.0	3.2	0.0	0.0	0.0
Carex gracilescens	G	4.4	11.8	14.8	15.5	20.8	2.3	3.7
Carex gracillima	G	0.4	0.2	0.0	0.2	0.5	0.0	0.0
Carex jamesii	G	0.0	0.0	0.8	1.2	0.0	0.0	0.0
Carex juniperorum	G	0.6	0.0	0.0	0.0	0.0	0.0	0.7
Carex laxiculmis	G	0.0	1.2	0.7	0.0	2.1	0.2	0.2
Carex laxiflora	G	1.7	6.1	1.3	6.7	2.3	1.9	1.4
Carex nigromarginata	G	2.3	0.3	0.0	2.3	0.2	0.7	0.0
Carex oligocarpa	G	0.6	0.7	0.8	0.0	0.0	0.0	2.8
Carex pennsylvanica	G	8.0	2.7	0.5	3.5	5.6	0.5	4.6
Carex platyplhylla	G	0.0	0.0	0.2	0.2	0.0	0.0	0.0
Carex rosea	G	1.5	5.2	3.8	0.0	7.4	1.6	5.3
Carex spp.	G	4.7	9.6	8.7	16.0	4.6	5.1	5.6
Carex sparganioides	G	0.0	1.7	0.8	0.0	1.2	0.0	2.3
Carex umbellata	G	0.6	0.0	0.0	0.5	0.0	0.2	0.0
Carex wildenovii	G	25.8	12.5	1.8	8.6	12.5	10.9	19.2
Scirpus verecundus	G	0.0	0.3	0.0	0.0	0.5	0.0	0.0
Poaceae								
Agrostis perannans	G	0.2	0.0	0.0	0.2	0.0	0.0	0.0
Brachyelytrum erectum	G	7.4	19.3	22.2	20.8	23.6	7.4	14.8
Bromus pubescens	G	3.0	8.3	6.3	2.5	6.7	3.0	11.6
Danthonia spicata	G	10.8	1.4	0.0	4.9	3.9	3.7	2.5
Diarrhena americana	G	1.3	2.2	4.6	2.3	2.8	2.1	3.9
Elymus hystrix	G	2.5	1.7	0.3	0.2	0.7	0.2	4.6
Festuca obstusa	G	0.4	1.5	0.5	0.0	0.0	0.7	2.5
Muhlenbergia teniflora	G	1.3	3.2	0.5	0.0	6.0	0.2	0.5
Panicum boscii	G	19.9	16.7	3.0	11.3	14.8	8.3	16.9
Panicum commutatum	G	1.3	0.3	0.2	0.2	0.0	0.9	1.2
Panicum dichotomum	G	11.6	4.2	0.8	7.9	5.8	6.5	0.9
Panicum latifolium	G	4.5	3.9	2.0	3.7	10.0	0.0	0.0
Panicum linearifolium	G	0.4	0.0	0.0	0.5	0.0	0.0	0.0

Appendix cont.

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		Xeric	Intermediate	Mesic	Watch Rock	Arch Rock	Young's Branch	Bluegrass Ridge
		Percent			Percent			
Panicum spp.	G	5.5	5.6	1.3	12.0	2.5	1.6	0.0
Poa alsodes	G	0.2	0.0	0.0	0.0	0.2	0.0	0.0
Poa cuspidata	G	13.6	15.9	16.1	18.5	25.9	3.7	13.0
Poa nemoralis[a]	G	0.0	0.0	0.8	0.0	1.2	0.0	0.0
Sphenopholis nitida	G	0.4	0.5	0.2	0.5	0.7	0.0	0.2
Liliaceae								
Allium canadense	F	0.0	0.0	0.2	0.2	0.0	0.0	0.0
Chamaelirium luteum	F	0.0	0.7	0.2	0.9	0.2	0.0	0.0
Erythronium spp.	F	0.0	0.0	3.5	4.6	0.0	0.2	0.0
Lilium canadense	F	0.0	0.7	0.3	1.4	0.0	0.0	0.0
Medeola virginiana	F	0.0	4.6	7.1	3.7	5.1	7.4	0.0
Polygonatum biflorum	F	22.9	15.7	6.9	11.1	5.6	14.8	27.8
Smilacinia racemosa	F	21.2	37.5	35.4	26.6	22.2	32.4	45.8
Trillium grandiflorum	F	1.1	6.4	43.4	25.0	20.8	21.5	3.9
Uvularia perfoliata	F	15.0	44.8	53.1	29.6	30.8	46.5	47.5
Smilacaceae								
Smilax ecirrhata	F	1.1	0.5	1.0	0.0	2.5	0.2	0.7
Smilax glauca	SV	37.9	35.8	16.3	29.4	24.3	28.7	35.9
Smilax hispida	SV	2.8	4.4	8.9	3.7	4.9	8.6	4.9
Smilax rotundifolia	SV	58.5	38.7	27.0	29.4	39.4	59.5	34.3
Dioscoreaceae								
Dioscorea quaternata	F	5.1	9.8	21.2	2.1	0.9	35.6	10.9
Dioscorea villosa	F	0.6	1.2	3.1	3.7	3.0	0.0	0.0
Iridaceae								
Iris cristata	F	0.0	0.5	1.5	0.0	0.0	2.8	0.0
Sisyrinchium angustifolium	F	0.0	0.2	0.0	0.0	0.0	0.0	0.2
Orchidaceae								
Corallorhiza odontorhiza	F	0.2	0.0	0.0	0.0	0.2	0.0	0.0
Cypredium acaule	F	0.9	0.0	0.0	0.0	0.0	1.2	0.0
Cyprepedium calceolus	F	0.0	0.2	0.5	0.5	0.2	0.2	0.0
Goodyera pubescens	F	1.9	2.0	2.6	4.2	2.8	1.9	0.0
Liparis lilifolia	F	0.4	0.7	0.2	0.0	0.0	0.0	1.6
Malaxis unifolia	F	0.2	0.0	0.0	0.0	0.2	0.0	0.0
Orchis spectabilis	F	0.8	1.0	2.6	2.1	0.9	2.1	0.9

[a]Non-native.
[b]Annual.
[c]Biennial.