# Plant Distribution and Diversity Across an Ozark Landscape

Jiquan Chen[1], Cynthia D. Huebner[2], Sari C. Saunders[3], and Bo Song[4]

Abstract.—The distribution, abundance, and diversity of plant species in a landscape are related to factors such as disturbance history, landform, and climate. In examining the potential effects of landscape structure on the distribution of plant species of the southeast Missouri Ozarks, we sampled a 10,000-m transect in a south-north direction. In September 1997, two 1 x 1 m plots were placed every 10 m along the transect to tally canopy cover, overstory type, coverage of all understory species, and micro-topographic features. We calculated Shannon and Simpson's diversity and species richness for all plots and used correlation and wavelet analyses to examine changes in these variables with elevation across different scales. Of the 332 species recorded along the transect, 104 species occurred only once. *Desmodium nudiflorum* and *Parthenocissus quinquefolia* were the two most frequent species (48.8 percent and 37.0 percent of plots, respectively), while 323 of the 332 species occurred within < 10 percent of the plots. Seventy-one plots contained no species and another 71 plots had only one species. Most plots contained one to seven species. Over 95 percent of the total species were found in < 10 percent of the quadrats. Species richness, Shannon diversity, and Simpson's diversity all correlated negatively with elevation. Distribution of plant species in the landscape was significantly related to position in the landscape, measured by relative elevation ($R^2 = 0.78$). Plots near riparian areas contained more species (> 30 species/plot) than any other plots along the transect. The patterns of patches of elevation and species diversity were most visible at the 1,800-m scale, but the spatial relationship between these patterns was best revealed at scales between 1,340 and 1,400 m. Changes in wavelet variance suggested that multiple scales should be examined when exploring potential influences of landscape structure on plant species.

Understanding organisms and their distributions within ecosystems or landscapes is the first step in any applied or basic ecological research. Such information is critical not only for explaining the processes (e.g., extinction and invasion) and dynamics of the system, but also for developing strategic plans to preserve biological diversity within the scope of natural resource management objectives (Vogt *et al.* 1996). Because the current crisis in loss of global biodiversity is mostly related to human activities, one of the greatest challenges is to adjust current management practices so that human impacts on species are minimized (Frankel *et al.* 1995). The Missouri Ozark Forest Ecosystem Project (MOFEP), initiated in 1991 by the Missouri Department of Conservation, was a landscape-scale experiment undertaken with such an ecosystem management or sustainable management philosophy (Larsen *et al.* 1997). As one of >20 research projects associated with MOFEP, this study has focused on plant distributions across the Ozark landscape.

The MOFEP sites are located in the Ozark Highlands Section and dominated by deciduous

[1] Department of Earth, Ecological and Environmental Sciences (EEES), University of Toledo, Toledo, OH 43606; e-mail: jchen4@utnet.utoledo.edu.

[2] Disturbance Ecology & Management of Oak-Dominated Forests, USDA Forest Service, Northeastern Research Station, Morgantown, WV 26505.

[3] School of Forest and Wood Products, Michigan Technological University, Houghton, MI 49931.

[4] Belle W. Baruch Institute of Coastal Ecology & Forest Science, Clemson University, Georgetown, SC 29442.

forests. Although the soils in the Ozarks are extremely heterogeneous (Hammer 1997), the overall landscape structure characterized by current vegetation is simple, with 73 percent of the landscape defined by the overstory as oak-hickory upland forests (Xu *et al.* 1997). The original forests were cleared in the 1800s to meet the demand for timber. As timber and pulp and paper industries declined early in the 20th century, the vegetation developed into a relatively homogeneous, mixed oak-hickory forest. Suppression of fires in the latter half of the 20th century may have also contributed to the homogeneity of forest patterns across this landscape (Guyette and Dey 1997). Other minor elements of the landscape include dense streams (density ≈ 971 $m.km^{-2}$, Chen *et al.* 1999a,b) and roads (density ≈ 1950 $m.km^{-2}$), bottomland forests and wetland (5%), and shrub or young forests (9%). About 87 percent of the land has slopes <25 percent; and 91.9 percent of the land area is between 150 and 300 m in elevation (Xu *et al.* 1997). With these landscape characteristics, it seemed logical that plant distribution may be strongly influenced by physiographical features such as elevation and slope.

Ecologists have long asserted that species distributions are tightly related to their habitats (e.g., Brown and Lomolino 1998). While new studies continue to find examples of unexpected relationships between structure (i.e., habitat) and species distribution, current management and conservation efforts are often made based on local or fine-scale habitat attributes instead of broad-scale landscape perspectives (Franklin 1993). The northern spotted owl (*Strix occidentalis caurina*) provides an example of this mismatch between conservation initiatives and habitat requirements in the Pacific Northwest (PNW). Although the northern spotted owl has traditionally been considered an old-growth species (Bart and Forsman 1992, Carey *et al.* 1992), it can also be found in young plantations. Thus, both environmental groups and industries have tended to use this species to advance opposing protocols for management of old-growth forests in the PNW. The real issue is not the dependency of the species on the old-growth forest but, more importantly, its need for multiple habitats, including old-growth forest in a landscape context, i.e., landscape complementation (Burnett *et al.* 1998, Dunning *et al.* 1992). This example highlights some of the strengths of MOFEP, but also the difficulties associated with data interpretation. All nine experimental sites in the MOFEP study had a similar overstory structure, allowing examination of the effects of silvicultural treatments on various ecological properties, including distributions of flora and fauna, within a somewhat controlled field setting. This similarity in overstory structure, however, may confound the results, and the data may not reflect the overall dynamics of the species across the landscape. To address this issue, one of the initial goals of our study was to provide baseline information for exploring the differences between data collected within (Grabner *et al.* 1997) and outside of the MOFEP experimental units.

A number of studies have suggested that spatial distribution and temporal dynamics of species in a landscape are scale dependent (Rosenzweig 1995, Wiens 1989). For example, Brosofske *et al.* (1999) found that, across the homogeneous pine-barrens in northern Wisconsin, plant species clustered differently depending on scales used in analysis. A habitat patch can be species-poor at smaller scales, but this patch may be nested within a species-rich landscape at broader scales. Many avian species perceive not only the local-scale structure as traditionally studied (e.g., MacArthur and MacArthur 1961) but also the landscape-level structure of their environment (e.g., Hansen and Urban 1992, McGarigal and McComb 1995, Storch 1997); persistence of avian populations is often dependent not only on habitat structure within focal patches, but also on resources within patches in the surrounding landscape (Whitcomb *et al.* 1977). The communities of neotropical migrants parasitized by brown-headed cowbirds (*Molothus ater*) in the Midwest U.S. change regionally (Hahn and Hatfield 1995), and, consequently, reproductive success and population stability of these species depend on habitat characteristics at the landscape scale (Donovan *et al.* 1995, Robinson *et al.* 1995). Similarly, the foraging behavior of ungulates has been shown to depend on factors such as forage quality, plant species composition, and position in the landscape that will vary in scale from meters to thousands of hectares (Turner *et al.* 1997). Previous simulation studies have also demonstrated the importance of landscape composition and arrangement at multiple scales in determining the dispersal patterns of organisms (Gustafson and Gardner 1996). Thus, landscape-level examinations of habitat-species relationships can link traditional, local microscale studies with information on regional distributions (Dunning *et al.* 1992).

The objective of this study was to explore the spatial relationships between plant species distribution and diversity with position in the landscape (e.g., high or low elevation) at multiple spatial scales in the southeastern Missouri Ozarks. Specifically, we aimed to: (1) explore the changes in understory vegetation with physiography of the landscape using relative elevation as a proxy measurement; (2) examine the importance of scale in quantifying community composition; and (3) discuss research needs for understanding species distributions in the Ozark landscape and priorities for adaptive landscape management. A central hypothesis of this study was that landscape structure, defined by both biotic and abiotic variables, determines the spatial distribution of plant species and, therefore, the species diversity and abundance can be predicted from various, multi-scale measurements of landscape structure. In the southeastern Missouri Ozarks, mature, homogeneous oak-hickory and oak-pine forests cover the majority of the landscape. Physiographical features (e.g., elevation, slope, and aspect) are the dominant structural features affecting species distribution, in addition to characteristics induced by human disturbances.

## METHODS

Our study area is located in the southeast Missouri Ozarks (36°15'N and 90°33') where nine sites had been identified for a large, comprehensive scientific study known as the Missouri Ozark Forest Ecosystem Project (MOFEP) (Brookshire and Shifley 1997). The area is characterized by a humid continental climate, with hot, humid summers and cool winters. Average annual precipitation is 112 cm with the majority of rain falling in spring and summer (Chen *et al.* 1999b). Dolomitic limestone embedded with large quantities of chert dominate the watershed. The soil is clay to clay loams, with extremely variable depths and content across the landscape (Hammer 1997). Due to the clearing of almost all the forest in the 1800s, the landscape is covered by mature, relatively unfragmented southern hardwoods (Guyette and Dey 1997).

In 1995, we used a digital compass to lay out 3,940 m of transect southward and 6,060 m of transect northward (total 10,000 m) from a permanent climatic station installed in the center of site 1 (Chen *et al.* 1997). A global positioning system (GPS) unit was used to precisely measure the geographic location of the transect, including elevation, every 10 m (Xu *et al.* 2000). With differential correction, GPS locations could be determined within 1.3 m in the horizontal plane and within 28 m in elevation. Vegetation was sampled every 10 m in a 1 x 1 m quadrat on each side of the transect, resulting in a rectangular sample area of 2 $m^2$ within 1,001 plots along the 10,000 m transect. To avoid biases that may be caused by seasonal dynamics of vegetation, we collected vegetation data between September 2 and September 20, 1997. The Shannon-Wiener diversity index (H') (natural log), Simpson's diversity index (D) (natural log), and species richness (N) (Magurran 1988) were calculated. For each species, growth form (e.g., forbs vs. grass), longevity (annual, biennial, and perennial), seed dispersal mechanism (e.g., wind vs. animal), nitrogen fixation capability (actinomycetes vs. *Rhizobium*), and origin (i.e., native vs. exotic) were identified from existing literature and databases (Gleason and Cronquist 1991, Grabner *et al.* 1997, Wherry 1995). The frequency of species occurring along the transect, species richness by plot, and average cover of each species by plot were also calculated. The cumulative number of species was used to generate a species-area curve starting at the southern end of the transect and incorporating new species encountered moving northward.

Our initial analysis indicated a gradual increasing trend in elevation along the transect (fig. 1a). Since our primary interest was to examine how position in the landscape affects plant distribution, we calculated the relative elevation (RE) by subtracting the linear trend of elevation changes (based on a linear regression model) from the actual elevation and scaling its minimum value to be sure to avoid possible computation problems (e.g., log-transformation) later in the analysis. The following equation was used to calculate RE:

$$\text{Relative Elevation (RE)} = -0.3*(188.72+0.01007*\text{Distance-Elevation}) + 20$$

The RE removed the trend while keeping the information on the relative position of each point in the landscape (fig. 1b). The average, minimum, and maximum values for RE along the transect were 19.9, 2, and 35.4 m, respectively (table 1).

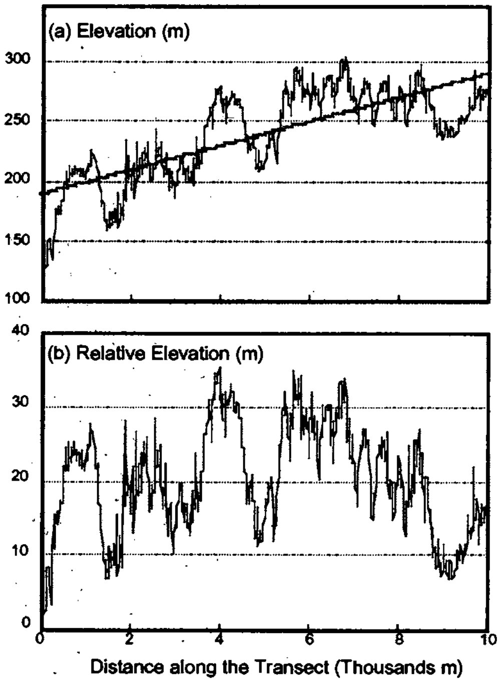


Figure 1.—*The trend of increasing elevation (m) along the 10-km transect (a) was measured using a sub-meter global positioning system (GPS). A linear model (see text) was subtracted and scaled to generate the relative elevation (m; b) for analyzing the importance of elevation in controlling species distribution.*

To examine the effects of scale on plant distribution, plant diversity, and position in the landscape, we used wavelet analysis as the primary statistical tool to explore the spatial changes of RE, richness, and diversity indices along the transect at scales between 10 and 3,500 m (see Bradshaw and Spies 1992, Brosofske *et al.* 1999, Gao and Li 1993, and Saunders *et al.* 1998 for methodology, application details, and interpretations). Wavelet analysis quantifies the pattern within a data series as a function of scale and location along a transect and indicates the dominant scales of pattern in a data set (Bradshaw 1991, Graps 1995). We calculated wavelet transforms for RE, H', D, and N along the transects as:

$$W(a,b) = \frac{1}{a}\sum f(x) * g\left(\frac{x-b}{a}\right)$$

where the shape (i.e., the dimension of the window of analysis) of the analyzing wavelet, $g(x)$, changes with scale, $a$, and the analyzing wavelet moves along the data series, $f(x)$, centered at each point, $b$, along the transect (Bradshaw and Spies 1992, Li and Loehle 1995). The wavelet transform was calculated across scales of $a$ = 10, 20..., 3500 in $a \le b \le n-a$. We used the wavelet variance, $V(a)$:

$$V(a) = \frac{1}{n}\sum W^2(a,b)$$

Table 1.—*Summary statistics of plant species richness and diversity, and of elevation along a 10-km transect in the southeast Missouri Ozarks*

| | Average | Minimum | Maximum |
|---|---|---|---|
| Total number of species | 332 | | |
| Accurately identified | 302 | | |
| Elevation (m) | 239 | 129.3 | 303.1 |
| Relative elevation (m) | 19.9 | 2 | 35.4 |
| No. species/plot | 6.54 | 0 | 43 |
| Shannon H' | 0.88 | 0 | 2.13 |
| Simpson's D | 0.77 | 0 | 2.93 |

to capture the dominant scales of patch patterns. Use of this technique ensured that our analysis of patterns and relationships across the landscape need not be restricted to data sets with stationary statistical properties (i.e., properties such as mean and variance that are similar regardless of location along the transect) as with related techniques such as Fourier analysis (Bradshaw 1991). Because information on location along the transect is retained for the wavelet transform, we were able to examine our data *post hoc* for features in the landscape that might have influenced patterns in species distribution. A program developed by Li and Loehle (1995) was used to calculate both Mexican hat wavelet transform and wavelet variance. The Pearson correlation coefficient (r) was used to examine the relationship between wavelet transforms of relative elevation and species diversity and thus to identify the most prominent scales for species "hot spots" in the landscape.

## RESULTS

We encountered 332 plant species (302 were identified to the species level) in the 1,001 plots along the 10-km transect, with average, minimum, and maximum richness of 6.5, 0, and 43 species per plot, respectively (table 1). Because many plots had fewer than two species, the Shannon H' and Simpson's D indices varied from 0 to 0.88 and 0.77, respectively (table 1). All 332 of 332 species occurred within <10 percent of the plots, and 72 species were encountered only once along the transect. *Desmodium nudiflorum* and *Parthenocissus quinquefolia* were the two most frequently encountered species (48.8 and 37.0 percent of plots, respectively). Only two plots had no species, and 197 and 114 plots had one and two species, respectively. Two-thirds of the plots (67.8%) contained < seven species (fig. 2).

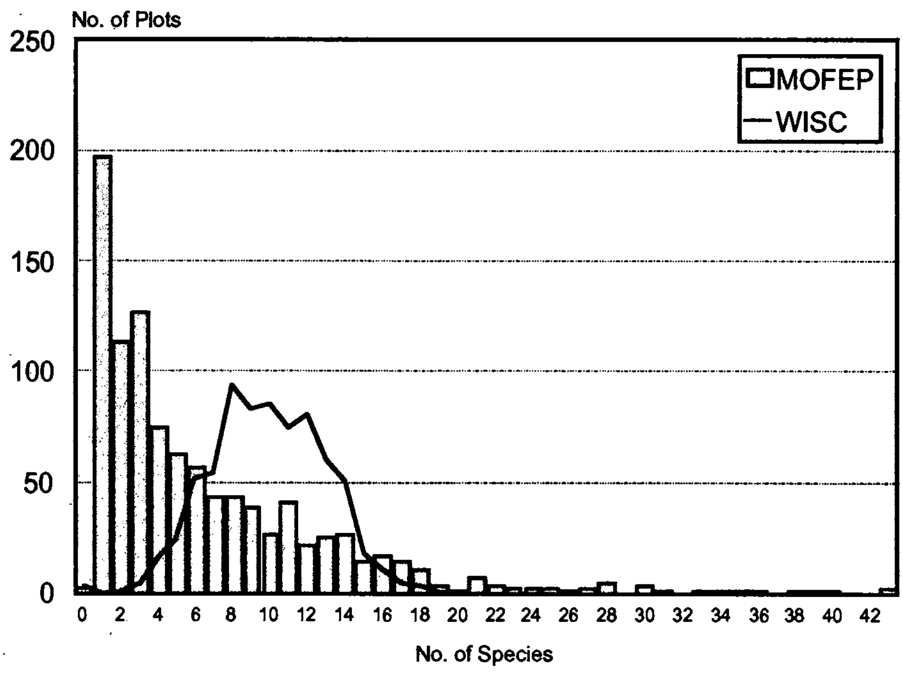


Figure 2.—*Frequency distribution of sampling plots by the number of species per plot along the 10-km transect oriented south-north in the Missouri Ozarks. Most plots contained fewer than six species.*

Most species (193 of 302, 63.9%) were forbs, excluding 23 legume species (table 2). Regarding lifespan, 251 (83.1%) of the species were perennial and only 5 species were biennial. Eighteen of 302 species were nitrogen fixers. When we examined the seed dispersal mechanisms of these plants from existing publications, most (246 of 302, 81.4%) had mixed dispersal mechanisms such as by both wind and animal. No plant was found to be solely dependent on wind or water for its seed dispersal. Twenty-three species were identified as being solely dispersed by animals. Ten exotic species were encountered (appendix 1).

Table 2.—*Distribution of plant species within different functional groups. This table includes only plants that were identified to species.*

| Category | Species |
|---|---|
| | *Number* |
| **Plant Form** | |
| Forbs (1) | 193 |
| Shrub (2) | 30 |
| Grass (3) | 27 |
| Sedge (4) | 16 |
| Fern (5) | 8 |
| Legume (6) | 23 |
| Tree (7) | 5 |
| **Longevity** | |
| Annual (1) | 39 |
| Biennial (2) | 11 |
| Perennial (3) | 252 |
| **Seed Dispersal** | |
| Wind (1) | 0 |
| Animal (2) | 23 |
| Water (3) | 0 |
| Mix (4) | 244 |
| Wind/Water (5) | 35 |
| **N-fixation** | |
| N-Fixation (1) | 18 |
| No. N-fixation (2) | 284 |
| **Origin** | |
| Native (1) | 292 |
| Exotic (2) | 10 |
| **Total** | 302 |

The cumulative number of species we encountered moving away from a point along the transect (i.e., β-diversity) suggested that new species added to the total pool tended to occur when RE changed (fig. 3). This suggested that heterogeneity of landform in the landscape was a key determinant of the overall, regional diversity (i.e., γ -diversity). Along the transect, we detected several jumps in β-diversity at 900-1,000 m, 4,800-5,000, and 8,900-9,100 m. It was clear that many sampling plots within a wide range of the landscape were needed to obtain a thorough species list for the Ozarks (fig. 3). With 600 1 x 1 m plots at 3,000 m from the south end of the transect, we encountered only 278 of 332 species (83.7%). Excluding the 30 new species added to the pool where a north-facing slope dropped to a bottomland at about 9,000 m near the north end of the transect, we collected 92.1 percent of the total species encountered within the first 3,000 m of the transect. The plots at around 5,000 and 9,200 m on the transect were near small streams and contained more species (>30/plot) than any other plots along the transect. Overall, uplands (3,800 to 10,000 m), generally had 5 species/plot while plots in the Current River Valley (i.e., 0 to 3,800 m) contained 10-15 species (see fig. 3). Small differences existed between lowlands and uplands in the Current River Valley (<3,800 m) where species diversity was similar to that of low elevation areas in the uplands. It was apparent that three quantitative measurements (i.e., H', D, and N) provided different information on the effects of landforms on plant distributions.

Changes in species abundances were strongly associated with RE, as evident from the two most frequent species (fig. 4). Generally, north-facing slopes and the bottomlands appeared to be preferred habitats for new species. The lowland areas at 1,500, 5,000, and 9,000-10,000 m along the transect were obviously the "hot spots" for both species richness and abundance. However, the relationship varied among species, and the correlation between species abundance and elevation was dependent on location. For example, both *Desmodium nudiflorum* and *Parthenocissus quinquefolia* were abundant at a bottomland between 4,200 and 5,600 m along the transect, but not at other bottomlands (fig. 4). In general, measures of species richness correlated negatively with relative elevation, although there were very weak correlations between diversity measurements and relative elevation (fig. 5).

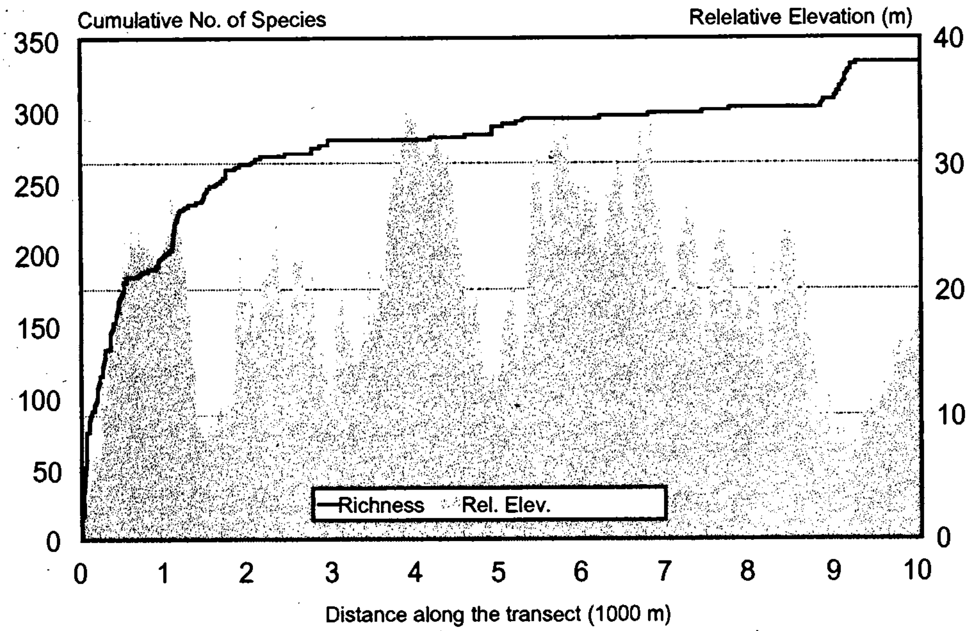


Figure 3.—*Changes in cumulative number of plant species, overlaid on relative elevation, along the 10-km transect in the southeast Missouri Ozarks. It appears that at least 300 1x2 m² plots (i.e., 600 m²) spread across at least 3,000 m are needed to encounter most (278 of 332 species, 83.7%) of the total species in the landscape.*

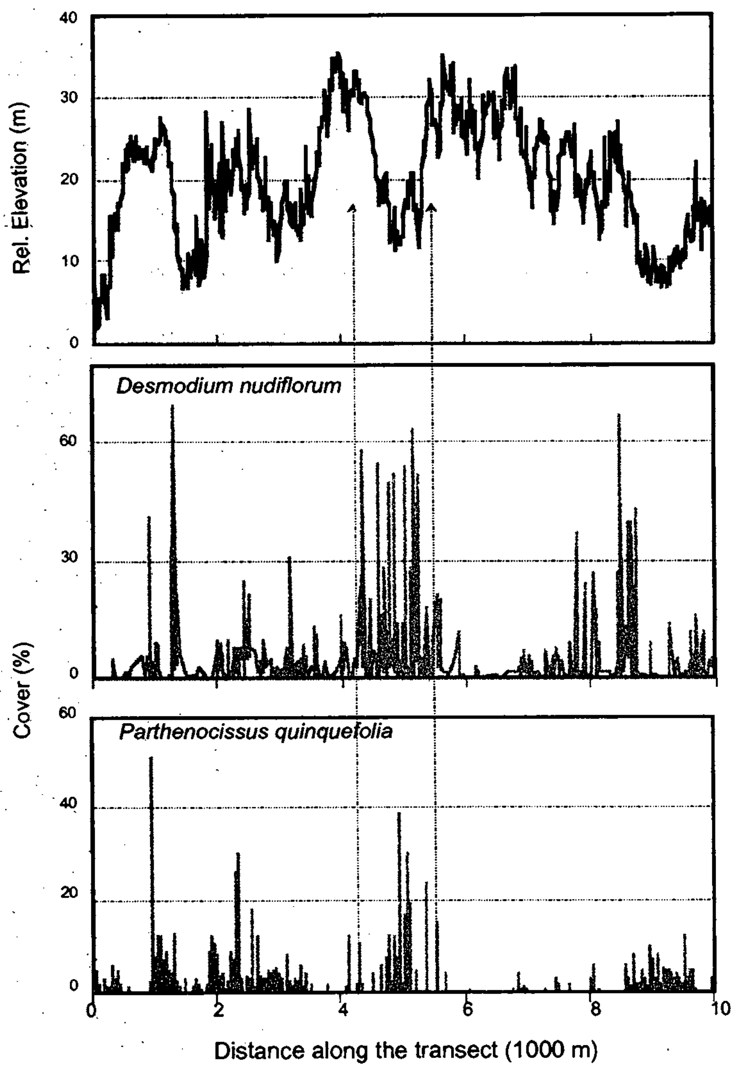


Figure 4.—*Changes with elevation (a) in species cover of the two most frequent species (b and c) along the 10-km transect in the southeast Missouri Ozarks. There is a clear negative correlation with relative elevation, i.e., the two selected species are more abundant in areas with low relative elevation.*

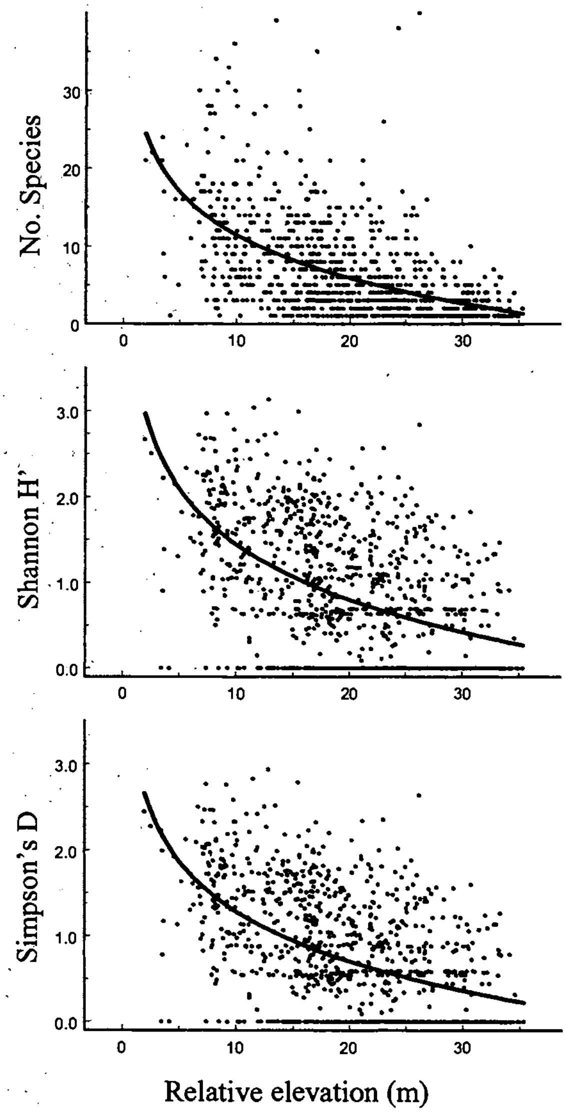


Figure 5.—*Relationships between three measurements of species diversity and relative elevation along the 10-km transect in the southeast Missouri Ozarks. The solid lines are logarithm regression models showing the general trends for each of the three diversity measurements.*

The changes in wavelet transforms of relative elevation, species richness, Shannon diversity, and Simpson diversity suggested that scale had an important effect on underlying patterns in diversity (fig. 6). Patterns were scale-dependent. For example, a low-diversity patch at about 4,000 m on the transect was visible only at scales of 1,800-2,300 m, while another similar patch at 900 m could only be detected at analysis scales of 300-1,700 m. Finally, it seemed that the patch patterns of relative elevation were similar to those of diversity measurements.

The correlation between diversity and relative elevation also showed a strong dependency on scale, with a peak at 1,340 -1,400 m (fig. 7a) for all three diversity measurements. However, the changes in wavelet variance (an indicator of dominant patch size) with scale (fig. 7b) suggested that even broader scales are necessary when diversity measures are independently analyzed. For example, wavelet variance of diversity measures peaked at a scale of 1,720 m, while for relative elevation most of the variation in patterns based on wavelet variance occurred at 1,850 m. This suggests that 1,400 m is the most appropriate scale to use in identifying "diversity patches," but smaller scales between 1,340 and 1,400 m are more appropriate to examine the spatial relationships between diversity measurements and elevation. The above differences in determining the right scales for patch delineation and spatial correlations were likely caused by distance lags (i.e., about 500-m differences) between the elevation patch and diversity patch.

## DISCUSSION

One significant characteristic of the Ozarks landscape is its high plant richness, although the landscape structure (defined as overstory vegetation) along the transect is relatively simple and homogeneous. Associated with the MOFEP treatment sites, Grabner *et al.* (1997) reported that 530 vascular species in 85 families were identified, including 25 exotic species. We encountered 332 species within a 2,000 $m^2$ sampling area; Brosofske *et al.* (1999) found fewer than 150 species in a similar study in northern Wisconsin. This high γ-diversity is not associated with total number of species per plot (α-diversity), but with high species variation among the plots (i.e., the β-diversity). In the

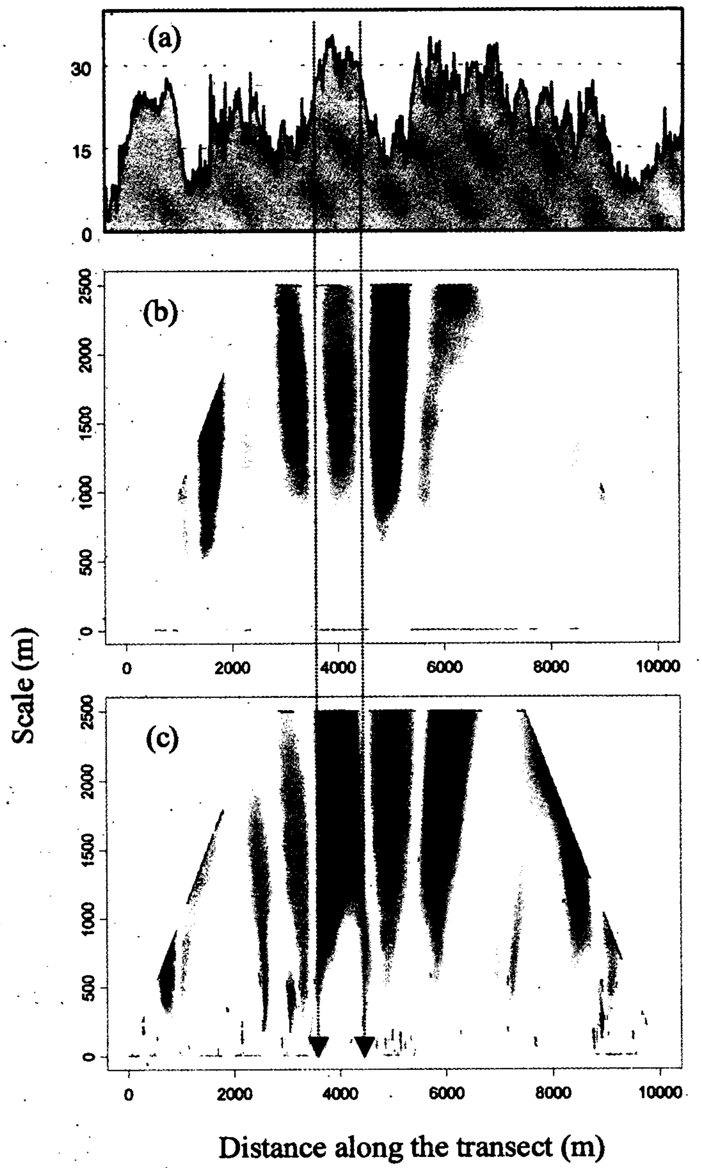


Figure 6.—*Relative elevation (a) and wavelet transforms of relative elevation (b) and the Shannon diversity index (H') (c) along the 10-km transect in the southeast Missouri Ozarks. The negative correlation between relative elevation and plant diversity is clearer with increasing scale. Changes from green to red indicate a decrease in wavelet transform.*

Ozark landscape, there was a J-shaped frequency distribution of plots by category of number of species (fig. 2), but in northern Wisconsin, there was a bell-shaped frequency (Brosofske *et al.* 1999). One possible explanation for the high γ-diversity in the Ozarks is that species contained in each plot differ from each other. The high species turnover among plots in the Ozark landscape contrasts with other regions such as northern Wisconsin. In Wisconsin, where intense and frequent disturbances (e.g., fires and harvesting) have occurred since the 19th century, high average numbers of species per plot were also observed. However, species composition was similar among plots. In the two previous case studies, it is apparent that the warm, humid climate is responsible for the high total number of species (Brown and Lomolino 1998) in Missouri, but it cannot explain the high variation among the plots. Although time since disturbance, initial cutting practices, and post-harvest silvicultural management could lead to high levels of variation in plant diversity at the scale observed in Wisconsin (e.g., see Rubio *et al.* 1999), these factors are unlikely to produce the finer scale variation observed among plots in Missouri. We suggest that the terrain and heterogeneous soils (Hammer 1997) are probably responsible for the high β-diversity in the Ozarks.

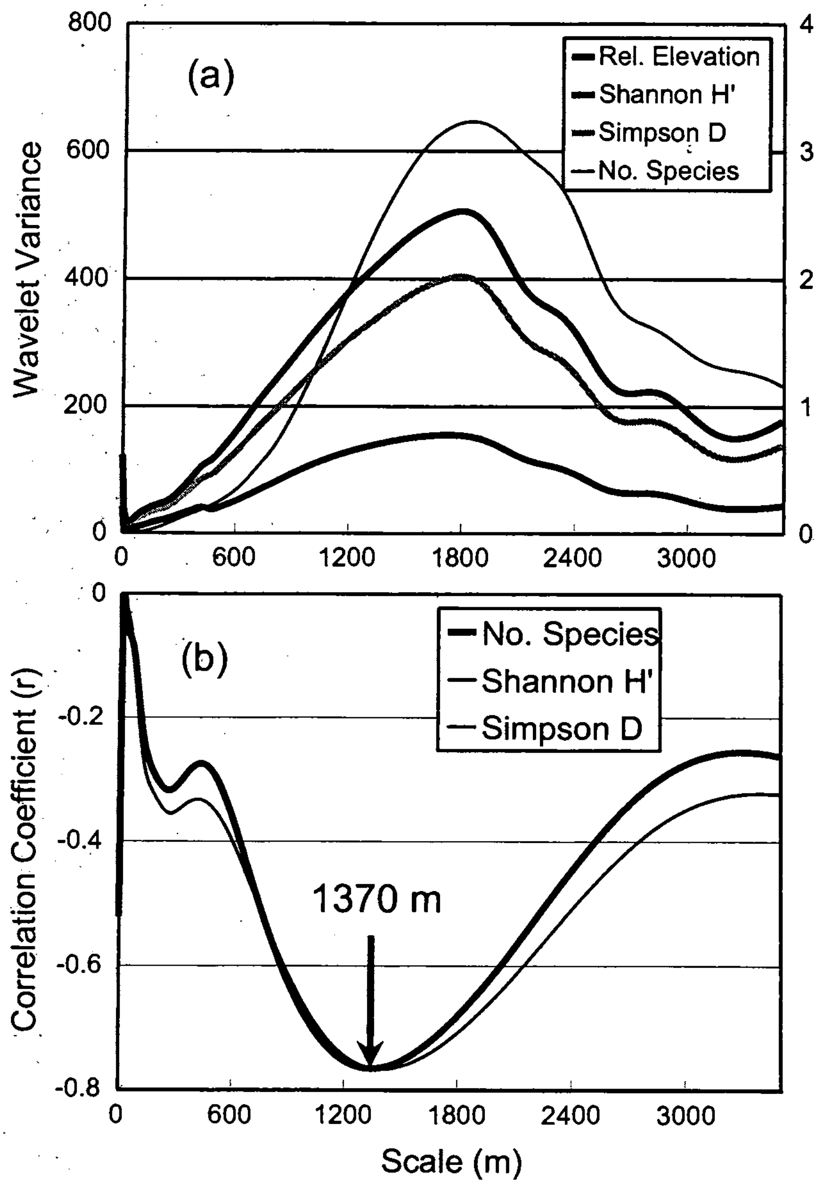


Figure 7.—*Wavelet variance peaks (i.e., patterns are strongest) for the three diversity measurements and relative elevation at scales between 1,500 m and 2,100 m (a). However, the correlations between the wavelet transforms of relative elevation and species diversity are strongest at a scale of 1,370 m (b). The two lines representing Shannon and Simpson indices are almost identical and the differences cannot be visually detected in (b).*

We found that spatial distributions of plants were dependent upon their relative position in the landscape. For the southeastern Missouri Ozarks, where vegetation is relatively homogeneous, landscape structure such as soils and RE are likely the dominant structural features affecting ecological characteristics across the landscape. Current and future management attention should be directed to the bottomlands in the Ozarks, because they provide habitats for a large number of understory species. However, based on our results that the correlation between species abundance and elevation is location dependent, it suggests that conservation planning may have to be undertaken on a site-specific (fine-scale) basis. The determinants of understory richness and distributions of certain species may vary among geographic locations (Huebner *et al.* 1995, McKenzie and Halpern 1999). This research provides further support for the use of ecological land types not only in understanding vegetation patterns but also in predicting vegetation types using physiography (Barnes *et al.* 1982, Cleland *et al.* 1994).

Wavelet analysis was used recently in landscape ecology to explore the changes in patterns and their relationships with landscape processes across scales (Bradshaw *et al.* 1992, Dale and Mah 1998, Saunders *et al.* 1998). Although our spatial data were collected along a single transect, due to limitations of time and labor requirements in the field, we would expect the results from the wavelet variance to be similar along additional transects at similar or different orientations within this landscape. The wavelet variances indicated that the patch patterns of relative elevation and diversity measurements could be best described at a scale of about 1,800 m (fig. 7), while the best scale for examining their spatial relationships was 1,400 m. At scales between 1,370 and 1,400 m, the wavelet transforms of diversity and elevation exhibited clear and strong negative correlations (fig. 6). These results supported recent theories that "choosing the right scale" (Holling 1992) and "exploring the pattern-process relationship at multiple scales" (Levin 1992) are both important. Indeed, we propose that the "right" scale or scale "range" may vary with locations across the landscape, suggesting that different "right" scales could be applied for the same landscape. Analysis of determinants of understory plant distributions in the Pacific Northwest similarly demonstrated that the best predictive models changed with both scale and geographic location. Response patterns of species to elevation, slope, moisture, and overstory cover at one scale may not parallel responses at other ecological levels (McKenzie and Halpern 1999). Further, although species distributions may have some common causes across scales, finer scale floristic variation may be only weakly related to larger scale patterns and be primarily the product of causes that are relatively unimportant at broad scales (Palmer 1990).

It appeared that the peaks in wavelets variance at 1,340-1,400 m scales reflect the topographical settings of the Ozarks. More importantly, RE alone can explain a large proportion of the variance in the distribution of plant species across the landscape (R = 0.78). However, correlation analysis suggested only weak correlations between diversity measurements and relative elevation (fig. 5). We believe that scale might be the explanation for these low correlations. When examined at appropriate and multiple scales, these correlations should be strengthened. With further information on overstory vegetation, soils, roads, and both human and natural disturbances, we are confident that one could develop a highly predictive model to explain the distribution of plants across scales in the Ozarks landscape.

Landscape structure can be quantified using different variables, such as vegetation or physical conditions. We are exploring how plant distributions are affected or related at multiple scales to ecological landtype, canopy coverage, amount of coarse woody debris (CWD), leaf area (e.g., NDVI), and microclimate along the transect. We expect a comprehensive image will be developed to predict the effects of various land management activities and/or changes in landscape structure on plant species. For example, ecological indicators of change in forest conditions at specific scales and in the scale- and location-specific associations between plant diversity and landform may be identified by examining the influence of reproductive biology and life history traits we recorded (e.g., see Dibble *et al.* 1999). If such patterns exist, this information could be useful in predicting the establishment, spread, and persistence of plant species in particular habitats and disturbance regimes. The latter may be especially useful in predicting the potential impact of invasive exotic species and the potential loss or recovery of threatened species in a given landscape.

## ACKNOWLEDGMENTS

This study was fully supported by the Missouri Department of Conservation through its Missouri Ozark Forest Ecosystem Project (MOFEP). We thank Ming Xu and Wuyuang Yin who established the transect in 1995 and collected the GPS data in 1996. Malanding Jaiteh, Daolan Zheng, and Greg Corace assisted in reestablishing the lost-flags along the transect in 1997. The following individuals assisted the principal investigators in collecting all 2,002 vegetation plots in 1997: Aaron Handzlik, Lisa Kruse, Raelene Crandall, Kyle Johnson, Andrew Lutz, Chris Williams, and Rose Horonzy. Aaron Everet and John Moses helped to identify the functional group of each species. Randy Jensen, Brian Brookshire, Dave Larson, and Terry Robinson provided many useful suggestions for experimental design in the early period of this study. Carl Mize, Steve Sheriff, Steve Shifley, John Kabrick, and an anonymous reviewer provided valuable suggestions to improve the quality of this paper.

## LITERATURE CITED


Barnes, B.V.; Pregitzer, K.S.; Spies, T.A.; Spooner, V.H. 1982. Ecological forest site classification. Journal of Forestry. 80(8): 493-498.

Bart, J.; Forsman, E.D. 1992. Dependence of northern spotted owls *(Strix occidentalis caurina)* on old-growth forests in the western USA. Biological Conservation. 62: 95-100.

Bradshaw, G.A. 1991. Hierarchical analysis of pattern and processes of Douglas-fir forests. Corvallis, OR: Oregon State University. Ph.D. Dissertation.

Bradshaw, G.A.; Spies, T.A. 1992. Characterizing canopy gap structure in forests using wavelet analysis. Journal of Ecology. 80: 205-215

Brookshire, B.L.; Shifley, S.R., eds. 1997. Proceedings of the Missouri Ozark Forest Ecosystem Project symposium: An experimental approach to landscape research; 1997 June 3-5; St. Louis, MO. Gen. Tech. Rep. NC-193. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 378 p.

Brosofske, K.D.; Chen, J.; Crow, T.R.; Saunders, S.C. 1999. Vegetation responses to landscape structure at multiple spatial scales across a northern Wisconsin, USA, pine barrens landscape. Plant Ecology. 143: 203-218.

Brown, J.H.; Lomolino, M.V. 1998. Biogeography. 2d ed. Sunderland, MA: Sinuaer Associates, Inc. 691 p.

Burnett, M.B.; August, P.; Brown, J.; Killingbeck, K.T. 1998. The influence of geomorphological heterogeneity on biodiversity: I. A patch-scale perspective. Conservation Biology. 12: 363-370.

Carey, A.B.; Hornton, S.P.; Biswell, P.L. 1992. Northern spotted owls: influence of prey base and landscape characters. Ecological Monographs. 62: 223-250.

Chen, J.; Xu, M.; Brosofske, K.D. 1997. Microclimatic characteristics in the southeastern Missouri Ozarks. In: Brookshire, B.L.; Shifley, S.R., eds. Proceedings of the Missouri Ozark Forest Ecosystem Project symposium: An experimental approach to landscape research; 1997 June 3-5; St. Louis, MO. Gen. Tech. Rep. NC-193. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 120-133.

Chen, J.; Saunders, S.C.; Crow, T.; Brosofske, K.D.; Mroz, G.; Naiman, R.; Brookshire, B.; Franklin, J. 1999a. Microclimatic perspectives in forest ecosystems and landscapes. Bioscience. 49: 288-297.

Chen, J.; Londo, H.A.; Megown, R.; Zhang, Q.; Boelema, B.; Glade, S.; Heitzman, E.; Hoefferle, A.; Jacob, L.; Londo, A.; Markovic, K.; Owens, K.; Pappas, C.; Plante, M. 1999b. Stream structure across five mountainous watersheds in the continental United States. Acta Ecologica Sinica. 19: 31-41.

Cleland, D.T.; Hart, J.B.; Host, G.E.; Pregitzer, K.S.; Ramm, C.W. 1994. Field guide: Ecological classification and inventory system of the Huron-Manistee National Forests. St. Paul, MN: U.S. Department of Agriculture, Forest Service.

Dale, M.R.T.; Mah, M. 1998. The use of wavelets for spatial pattern analysis in ecology. Journal of Vegetation Science. 9: 805-814.

Dibble, A.C.; Brissette, J.C.; Hunter, M.L. 1999. Putting community data to work: some understory plants indicate red spruce regeneration habitat. Forest Ecology and Management. 114: 275-291.

Donovan, T.M.; Thompson, F.R., III; Faaborg, J.; Probst, J.R. 1995. Reproductive success of migratory birds in habitat sources and sinks. Conservation Biology. 9: 1380-1395.

Dunning, J.B.; Danielson, B.J.; Pulliam, H.R. 1992. Ecological processes that affect populations in complex landscapes. Oikos. 65: 169-175.

Frankel, O.H.; Brown, A.H.D.; Burdon, J.J. 1995. The conservation of plant biodiversity. Cambridge, GB: Cambridge University Press. 299 p.

Franklin, J.F. 1993. Preserving biodiversity: species, ecosystems, or landscapes? Ecological Applications. 3: 202-205.

Gao, W.; Li, B.-L. 1993. Wavelet analysis of coherent structures at the atmosphere-forest interface. Journal of Applied Meteorology. 32: 1717-1725.

Gleason, H.A.; Cronquist, A. 1991. Manual of vascular plants of northeastern United States and adjacent Canada. Bronx, NY: The New York Botanical Garden.

Grabner, J.K.; Larsen, D.R.; Kabrick, J.M. 1997. An analysis of MOFEP ground flora: pre-treatment conditions. In: Brookshire, B.L.; Shifley, S.R., eds. Proceedings of the Missouri Ozark Forest Ecosystem Project symposium: An experimental approach to landscape research; 1997 June 3-5; St. Louis, MO. Gen. Tech. Rep. NC-193. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 169-197.

Graps, A. 1995. An introduction to wavelets. Computational and Scientific Engineering. 2: 50-61.

Gustafson, E.J.; Gardner, R.H. 1996. The effect of landscape heterogeneity on the probability of patch colonization. Ecology. 77: 94-107.

Guyette, R.P.; Dey, D.C. 1997. Historic shortleaf pine (*Pinus echinata* Mill.) abundance and fire frequency in a mixed oak-pine forest (MOFEP, site 8). In: Brookshire, B.L.; Shifley, S.R., eds. Proceedings of the Missouri Ozark Forest Ecosystem Project symposium: An experimental approach to landscape research; 1997 June 3-5; St. Louis, MO. Gen. Tech. Rep. NC-193. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 136-149.

Hahn, D.C.; Hatfield, J.S. 1995. Parasitism at the landscape scale: cowbirds prefer forests. Conservation Biology. 9: 1415-1424.

Hammer, R.D. 1997. Missouri Ozark forest soils: perspectives and realities. In: Brookshire, B.L.; Shifley, S.R., eds. Proceedings of the Missouri Ozark Forest Ecosystem Project symposium: An experimental approach to landscape research; 1997 June 3-5; St. Louis, MO. Gen. Tech. Rep. NC-193. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 106-122.

Hansen, A.J.; Urban, D.L. 1992. Avian response to landscape pattern: the role of species' life histories. Landscape Ecology. 7: 163-180.

Holling, C.S. 1992. Cross-scale morphology, geometry, and dynamics of ecosystems. Ecological Monographs. 62: 447-502.

Huebner, C.D.; Randolph, J.C.; Parker, G.R. 1995. Environmental factors affecting understory species diversity in second-growth deciduous forests. American Midland Naturalist. 134(1): 155-165.

Larsen, D.R.; Shifley, S.R.; Thompson, F.R., III; Brookshire, B.L.; Dey, D.C.; Kurzejeski, E.; England, K. 1997. Ten guidelines for ecosystem researchers: Lessons from Missouri. Journal of Forestry. 95(4): 4-9.

Levin, S.A. 1992. The problem of pattern and scale in ecology. Ecology. 73: 1943-1967.

Li, B.-L.; Loehle, C. 1995. Wavelet analysis of multiscale permeabilities in the subsurface. Geophysical Research Letters. 22: 3123-3126.

MacArthur, R.H.; MacArthur, J.W. 1961. On bird species diversity. Ecology. 42: 594-598.

McGarigal, K.; McComb, W.C. 1995. Relationships between landscape structure and breeding birds in the Oregon Coast Range. Ecological Monographs. 65: 235-260.

McKenzie, D.; Halpern, C.B. 1999. Modeling the distributions of shrub species in Pacific Northwest forests. Forest Ecology and Management. 114: 293-307.

Magurran, A.E. 1988. Ecological diversity and its measurement. Princeton, NJ: Princeton University Press. 179 p.

Palmer, M.W. 1990. Spatial scale and patterns of vegetation, flora, and species richness in hardwood forest of the North Carolina piedmont. Coenoses. 5: 89-96.

Robinson, S.K.; Thompson, F.R., III; Donovan, T.M.; Whitehead, D.R.; Faaborg, J. 1995. Regional forest fragmentations and the nesting success of migratory birds. Science. 267: 1987-1990.

Rosenzweig, M.L. 1995. Species diversity in space and time. Cambridge, GB: Cambridge University Press. 436 p.

Rubio, A.; Gavilán, R.; Escudero, A. 1999. Are soil characteristics and understorey composition controlled by forest management? Forest Ecology and Management. 113: 191-200.

Saunders, S.C.; Chen, J.; Crow, T.R.; Brosofske, K.D. 1998. Hierarchical relationships between landscape structure and temperature in a managed forest landscape. Landscape Ecology. 13: 381-395.

Storch, I. 1997. The importance of scale in habitat conservation for an endangered species: the capercaillie in Central Europe. In: Bissonette, J.A., ed. Wildlife and Landscape Ecology. New York, NY: Springer-Verlag: 310-330.

Turner, M.G.; Pearson, S.M.; Romme, W.H.; Wallace, L.L. 1997. Landscape heterogeneity and ungulate dynamics: what spatial scales are important? In: Bissonette, J.A., ed. Wildlife and Landscape Ecology. New York, NY: Springer-Verlag: 331-348.

Vogt, K.A.; Gordon, J.C.; Wargo, J.P.; and others. 1996. Ecosystems: balancing science with management. New York, NY: Springer-Verlag. 470 p.

Wherry, E.T. 1995. The fern guide. New York, NY: Dover Publications, Inc. 318 p.

Whitcomb, B.L.; Whitcomb, R.F.; Bystrak, D. 1977. Island biogeography and habitat islands of eastern forest III. Long-term turnover and effects of selective logging on the avifauna of forest fragments. American Birds. 31: 17-23.

Wiens, J.A. 1989. Spatial scaling in ecology. Functional Ecology. 3: 385-397.

Xu, M.; Saunders, S.C.; Chen, J. 1997. Landscape structure within the Southeast Missouri Ozarks. In: Brookshire, B.L.; Shifley, S.R., eds. Proceedings of the Missouri Ozark Forest Ecosystem Project symposium: An experimental approach to landscape research; 1997 June 3-5; St. Louis, MO. Gen. Tech. Rep. NC-193. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 41-53.

Appendix I.—*Species characteristics and their frequency and coverage encountered along a 10-km transect in the southeast Missouri Ozark landscape. See table 2 for their forms, life spans, origins, N-fixation, and seed dispersal mechanisms. The species noted with * were not found in the MOFEP database (Grabner et al. 1997).*

| Scientific name | Common name | Life span | Origin | N-fixation | Dispersal mechanism | Cover (%) | Max cover (%) | Relative freq (%) | Frequency |
|---|---|---|---|---|---|---|---|---|---|
| *Desmodium nuttallii* | Nuttall's trefoil | 2 | 1 | 1 | 2 | 2.7 | 23.6 | 47.5 | 475 |
| *Parthenocissus quinquefolia* | Virginia creeper | 2 | 1 | 1 | 4 | 1.8 | 37.5 | 37.0 | 370 |
| *Amphicarpa bracteata* | Hog peanut | 2 | 1 | 2 | 4 | 1.7 | 18.5 | 29.2 | 292 |
| *Vitis aestivalis* | Summer grape | 2 | 1 | 1 | 4 | 1.3 | 21.8 | 23.8 | 238 |
| *Vaccinium vacillans* | Low blueberry | 2 | 1 | 1 | 4 | 1.5 | 13.9 | 21.2 | 212 |
| *Carex nigromarginata* | Black-edged sedge | 2 | 1 | 1 | 4 | 0.3 | 3.0 | 17.5 | 175 |
| *Panicum boscii* | Bosc's panic grass | 2 | 1 | 1 | 4 | 0.4 | 2.0 | 16.7 | 167 |
| *Viola sororia* | Hairy wood violet | 1 | 1 | 1 | 4 | 0.6 | 10.5 | 13.0 | 130 |
| *Potentilla simplex* | Common cinquefoil | 2 | 1 | 1 | 4 | 0.8 | 12.5 | 12.3 | 123 |
| *Pteridium aquilinum* | Bracken fern | 2 | 1 | 1 | 4 | 1.2 | 11.5 | 12.3 | 123 |
| *Solidago ulmifolia* | Elm-leaved goldenrod | 2 | 1 | 1 | 1,3 | 0.6 | 4.5 | 10.0 | 100 |
| *Desmodium glutinosum* | Pointed tick trefoil | 2 | 1 | 1 | 2 | 1.5 | 16.5 | 8.5 | 85 |
| *Toxicodendron radicans* | Poison ivy | 2 | 1 | 1 | 1,3 | 2.2 | 17.3 | 7.4 | 74 |
| *Aristolochia serpentaria* | Virginia snakeroot | 2 | 1 | 1 | 4 | 0.2 | 0.5 | 7.2 | 72 |
| *Dioscorea quaternata* | Four-leaf yam | 2 | 1 | 1 | 4 | 0.9 | 3.0 | 7.1 | 71 |
| *Vaccinium stamineum* | Deerberry | 2 | 1 | 1 | 4 | 1.2 | 7.0 | 7.1 | 71 |
| *Carex* spp. | Sedge | | | | | 0.3 | 6.5 | 7.0 | 70 |
| *Galium circaezans* | Wild licorice | 2 | 1 | 1 | 4 | 0.2 | 1.0 | 6.9 | 69 |
| *Panicum dichotomiflorum* | Knee grass | 1 | 1 | 1 | 4 | 0.3 | 2.0 | 6.9 | 69 |
| *Smilacina racemosa* | F. False Solomon's seal | 2 | 1 | 1 | 4 | 0.6 | 2.9 | 6.2 | 62 |
| *Brachyelytrum erectum* | Long-awned grass | 2 | 1 | 1 | 4 | 1.2 | 10.0 | 5.8 | 58 |
| *Phryma leptostachya* | Lopseed | 2 | 1 | 1 | 4 | 0.4 | 2.9 | 5.8 | 58 |
| *Sanicula* spp. | Snakeroot | | | | | 0.6 | 13.1 | 5.6 | 56 |
| *Viola triloba* | Three-leaved violet | 1 | 1 | 1 | 4 | 0.2 | 1.3 | 4.9 | 49 |
| *Cunila organoides* | Dittany | 2 | 1 | 1 | 4 | 0.6 | 2.8 | 4.9 | 49 |
| *Vitis* spp. | Grape | | | | | 0.1 | 0.7 | 4.8 | 48 |
| *Panicum commutatum* | Panic grass | 2 | 1 | 1 | 4 | 0.3 | 2.6 | 4.7 | 47 |
| *Carex blanda* | Wood sedge | 2 | 1 | 2 | 4 | 0.6 | 4.0 | 4.6 | 46 |
| *Acalypha virginica* | Virginia mercury | 2 | 1 | 1 | 4 | 0.3 | 1.3 | 4.6 | 46 |
| *Bromus purgans* | Woodland brome | 2 | 2 | 1 | 4 | 0.6 | 10.0 | 4.6 | 46 |
| *Monarda russeliana* | Bradbury beebalm | 2 | 1 | 1 | 4 | 0.6 | 4.9 | 4.5 | 45 |
| *Helianthus strumosus* | Pale-leaved sunflower | 2 | 1 | 1 | 4 | 0.5 | 2.1 | 4.4 | 44 |
| *Danthonia spicata* | Poverty oat grass | 2 | 1 | 1 | 4 | 0.4 | 2.5 | 4.3 | 43 |
| *Galium concinnum* | Shining bedstraw | 2 | 1 | 1 | 4 | 0.4 | 2.0 | 4.3 | 43 |
| *Rubus enslenii* | Southern dewberry | 2 | 1 | 1 | 4 | 1.3 | 7.5 | 4.1 | 41 |
| *Galium arkansanum* | Arkansas bedstraw | 2 | 1 | 1 | 4 | 0.2 | 1.0 | 4.0 | 40 |
| *Geranium maculatum* | Wild geranium | 1 | 1 | 1 | 4 | 0.6 | 2.5 | 4.0 | 40 |
| *Uvularia grandiflora* | Bellwort | 2 | 1 | 1 | 4 | 0.7 | 4.5 | 3.9 | 39 |
| *Geum canadense* | White avens | 2 | 1 | 1 | 4 | 0.9 | 2.6 | 3.7 | 37 |
| *Aster anomalus* | Blue aster | 2 | 1 | 1 | 1,3 | 0.5 | 2.0 | 3.7 | 37 |
| *Desmodium dillenii* | Tall tick clover | 2 | 1 | 1 | 2 | 1.0 | 9.1 | 3.7 | 37 |
| *Aster patens* | Spreading aster | 2 | 1 | 1 | 1,3 | 0.4 | 1.5 | 3.6 | 36 |
| *Silphium asteriscus* | Starry rosinweed | 2 | 1 | 1 | 4 | 0.5 | 2.3 | 3.6 | 36 |
| *Uniola latifolia* | Spike grass | 2 | 1 | 1 | 4 | 0.8 | 3.5 | 3.5 | 35 |
| *Symphoricarpos orbiculatus* | Coralberry | 2 | 1 | 1 | 4 | 1.5 | 7.0 | 3.5 | 35 |

(*Appendix continued on next page*)

(*Appendix continued*)

| Scientific name | Common name | Life span | Origin | N-fixation | Dispersal mechanism | Cover (%) | Max cover (%) | Relative freq (%) | Frequency |
|---|---|---|---|---|---|---|---|---|---|
| *Asplenium platyneuron* | Ebony spleenwort | 2 | 1 | 1 | 4 | 0.4 | 3.3 | 3.4 | 34 |
| *Viola* spp. | Violet | | | | | 0.1 | 0.4 | 3.4 | 34 |
| *Rubus pensilvanicus* | Yankee blackberry | 2 | 1 | 1 | 4 | 2.0 | 20.0 | 3.4 | 34 |
| *Euphorbia corollata* | Flowering spurge | 1 | 1 | 1 | 1,3 | 0.3 | 2.5 | 3.3 | 33 |
| *Carex umbellata* | Umbel - like sedge | 2 | 1 | 1 | 4 | 0.2 | 0.9 | 3.2 | 32 |
| *Helianthus hirsutus* | Oblong sunflower | 2 | 1 | 1 | 4 | 0.8 | 3.5 | 3.1 | 31 |
| *Phlox divaricata* | Blue phlox | 2 | 1 | 1 | 4 | 0.3 | 1.4 | 3.1 | 31 |
| *Dioscorea villosa* | Wild yam | 2 | 1 | 1 | 4 | 0.7 | 2.1 | 3.0 | 30 |
| *Parthenium integrifolium* | Wild quinine | 2 | 1 | 1 | 4 | 0.6 | 2.5 | 3.0 | 30 |
| *Antennaria plantaginifolia* | Pussy's toes | 2 | 1 | 1 | 4 | 0.3 | 1.1 | 2.9 | 29 |
| *Vitis vulpina* | Frost grape | 2 | 1 | 1 | 4 | 1.1 | 7.0 | 2.9 | 29 |
| *Cimicifuga racemosa* | Black cohosh | 2 | 1 | 1 | 4 | 2.6 | 7.0 | 2.8 | 28 |
| *Elymus villosus* | Silky wild rye | 2 | 1 | 2 | 4 | 1.3 | 4.8 | 2.8 | 28 |
| *Pilea pumila* | Clearweed | 1 | 1 | 1 | 4 | 3.9 | 18.5 | 2.8 | 28 |
| *Sanicula canadensis* | Canadian black snakeroot | 3 | 2 | 1 | 4 | 0.6 | 6.5 | 2.8 | 28 |
| *Carex complanata hirsuta* | Hirsute sedge | 2 | 1 | 1 | 4 | 0.8 | 9.0 | 2.8 | 28 |
| Unknown | | | | | | 0.5 | 6.5 | 2.7 | 27 |
| *Solidago hispida* | White goldenrod | 2 | 1 | 1 | 1,3 | 0.6 | 2.6 | 2.7 | 27 |
| *Lespedeza repens* | Creeping bush clover | 2 | 1 | 1 | 2 | 0.3 | 1.6 | 2.7 | 27 |
| *Verbesina alternifolia* | Yellow ironweed | 2 | 1 | 1 | 4 | 0.8 | 3.0 | 2.6 | 26 |
| *Panicum lanuginosum* | Wooly panic grass | 2 | 1 | 1 | 4 | 0.3 | 0.6 | 2.6 | 26 |
| *Ipomoea pandurata* | Wild sweet potato | 2 | 1 | 1 | 4 | 0.6 | 1.8 | 2.5 | 25 |
| *Solidago flexicaulis* | Broad-leaved goldenrod | 2 | 1 | 1 | 1,3 | 0.8 | 3.1 | 2.4 | 24 |
| *Krigia biflora* | False dandelion | 1 | 1 | 1 | 4 | 0.3 | 1.5 | 2.4 | 24 |
| *Panicum linearfolium* | Slender-leaved panic grass | 2 | 1 | 1 | 4 | 0.5 | 4.3 | 2.4 | 24 |
| *Lespedeza procumbens* | Trailing bush clover | 2 | 1 | 1 | 2 | 1.5 | 11.5 | 2.4 | 24 |
| *Verbesina helianthoides* | Wing-stem | 2 | 1 | 1 | 4 | 1.5 | 13.0 | 2.2 | 22 |
| *Galium triflorum* | Sweet-scented bedstraw | 2 | 1 | 1 | 4 | 0.8 | 6.5 | 2.2 | 22 |
| *Polygonum scandens* | Climbing false buckwheat | 2 | 1 | 1 | 4 | 0.4 | 1.0 | 2.2 | 22 |
| *Clitoria mariana* | Butterfly pea | 2 | 1 | 2 | 4 | 0.6 | 2.0 | 2.2 | 22 |
| *Lysimachia lanceolata* | Lance-leaved loosestrife | 2 | 1 | 1 | 4 | 0.4 | 1.0 | 2.2 | 22 |
| *Lespedeza hirta* | Hairy bush clover | 2 | 1 | 1 | 2 | 0.8 | 5.0 | 2.1 | 21 |
| *Solidago* spp. | Goldenrod | | | | | 0.3 | 0.8 | 2.1 | 21 |
| *Eupatorium rugosum* | White snakeroot | 2 | 1 | 1 | 4 | 0.7 | 1.6 | 2.0 | 20 |
| *Carex cephalophora* | Woodbank sedge | 2 | 1 | 1 | 4 | 0.4 | 1.3 | 2.0 | 20 |
| *Scutellaria elliptica* | Hairy skullcap | 2 | 1 | 1 | 4 | 0.6 | 3.5 | 2.0 | 20 |
| *Festuca subverticillata* | Fescue | | | | | 0.3 | 0.8 | 2.0 | 20 |
| *Erechtites hieracifoilia* | Fireweed | 1 | 1 | 1 | 4 | 1.2 | 5.0 | 2.0 | 20 |
| *Viola striata* | Cream violet | 1 | 1 | 1 | 4 | 1.6 | 8.0 | 2.0 | 20 |
| *Muhlenbergia sobolifera* | Rock satin grass | 2 | 1 | 1 | 4 | 0.5 | 2.0 | 1.9 | 19 |
| *Geum* spp. | Avens | | | | | 0.7 | 6.4 | 1.9 | 19 |
| *Panicum sphaerocarpon* | Round-fruited panic grass | 2 | 1 | 2 | 4 | 0.1 | 0.3 | 1.8 | 18 |
| *Carex retroflexa* | Reflexed sedge | 2 | 1 | 1 | 4 | 1.5 | 20.0 | 1.8 | 18 |

(*Appendix continued on next page*)

(*Appendix continued*)

| Scientific name | Common name | Life span | Origin | N-fixation | Dispersal mechanism | Cover (%) | Max cover (%) | Relative freq (%) | Frequency |
|---|---|---|---|---|---|---|---|---|---|
| *Polygonum virginianum* | Virginia knotweed | 2 | 1 | 1 | 4 | 1.3 | 3.6 | 1.8 | 18 |
| *Solidago nemoralis* | Old-field goldenrod | 2 | 1 | 1 | 1,3 | 0.4 | 2.0 | 1.8 | 18 |
| *Desmodium laevigatum* | Smooth tick trefoil | 2 | 1 | 1 | 2 | 0.8 | 4.0 | 1.7 | 17 |
| *Rubus* spp. | Blackberry/raspberry | | | | | 1.1 | 5.6 | 1.7 | 17 |
| *Hydrangea arborescens* | Wild hydrangea | 2 | 1 | 1 | 4 | 3.8 | 14.9 | 1.7 | 17 |
| *Botrychium virginianum* | Rattlesnake fern | 2 | 1 | 1 | 4 | 0.3 | 0.8 | 1.7 | 17 |
| *Heiracium gronovii* | Hairy hawkweed | 2 | 1 | 1 | 4 | 0.3 | 1.0 | 1.7 | 17 |
| *Ranunculus hispidus* | Hispid buttercup | 2 | 1 | 1 | 4 | 0.4 | 1.1 | 1.7 | 17 |
| *Smilax bona-nox* | Saw greenbriar | 2 | 2 | 1 | 4 | 0.8 | 4.1 | 1.6 | 16 |
| *Rubus allegheniensis* | Common blackberry | 2 | 1 | 1 | 4 | 2.6 | 12.1 | 1.6 | 16 |
| *Rosa carolina* | Pasture rose | 2 | 1 | 1 | 1,3 | 0.5 | 2.4 | 1.6 | 16 |
| *Desmodium nudiflorum* | Bare trefoil | 2 | 1 | 1 | 2 | 2.3 | 7.8 | 1.6 | 16 |
| *Passiflora lutea* | Yellow passion flower | 2 | 1 | 1 | 4 | 0.3 | 1.0 | 1.5 | 15 |
| *Desmodium rotundifolium* | Round-leaved trefoil | 2 | 1 | 1 | 2 | 0.7 | 2.3 | 1.5 | 15 |
| *Lonicera flava* | Yellow honeysuckle | 2 | 1 | 1 | 4 | 0.9 | 4.1 | 1.5 | 15 |
| *Desmodium paniculatum* | Panicled trefoil | 2 | 1 | 1 | 2 | 0.5 | 0.8 | 1.5 | 15 |
| *Agrimonia pubescens* | Soft agrimony | 2 | 1 | 1 | 4 | 0.4 | 1.3 | 1.5 | 15 |
| *Oxalis dillenii* | Yellow wood sorrel | 2 | 1 | 1 | 4 | 0.3 | 0.8 | 1.5 | 15 |
| *Lespedeza intermedia* | Wandlike bush clover | 2 | 1 | 1 | 2 | 0.3 | 1.4 | 1.5 | 15 |
| *Galium pilosum* | Hairy bedstraw | 2 | 1 | 1 | 4 | 0.2 | 0.5 | 1.5 | 15 |
| *Specularia perfoliata* | Venus' looking glass | 1 | 1 | 1 | 4 | 0.4 | 1.0 | 1.4 | 14 |
| *Ambrosia artemisiifolia* | Common ragweed | 2 | 1 | 1 | 1,3 | 0.2 | 0.5 | 1.4 | 14 |
| *Sanicula gregaria* | Black snakeroot | 2 | 1 | 1 | 4 | 5.8 | 25.0 | 1.4 | 14 |
| *Ceanothus americanus* | New Jersey tea | 2 | 1 | 1 | 4 | 0.3 | 1.3 | 1.4 | 14 |
| *Lespedeza virginica* | Bush clover | 2 | 1 | 1 | 2 | 0.3 | 0.5 | 1.4 | 14 |
| *Smilax herbacea lasionuera* | Carrion flower | 2 | 1 | 1 | 4 | 0.9 | 6.0 | 1.4 | 14 |
| *Smilax tamnoides hispida* | Bristly greenbriar | 1 | 2 | 1 | 4 | 0.4 | 1.5 | 1.4 | 14 |
| *Silene stellata* | Starry campion | 2 | 1 | 1 | 4 | 0.4 | 1.5 | 1.4 | 14 |
| *Polystichum acrostichoides* | Christmas fern | 2 | 1 | 1 | 4 | 0.5 | 2.0 | 1.3 | 13 |
| *Hypericum hypercoides* | St. Andrew's cross | 2 | 1 | 1 | 4 | 0.5 | 1.3 | 1.3 | 13 |
| *Oxalis* spp. | Wood sorrel | | | | | 0.3 | 1.9 | 1.3 | 13 |
| *Laportea canadensis* | Wood nettle | 2 | 1 | 1 | 4 | 4.6 | 13.0 | 1.3 | 13 |
| *Asclepias quadrifolia* | Four-leaved milkweed | 2 | 1 | 2 | 2,4 | 0.2 | 0.8 | 1.3 | 13 |
| *Panicum clandestinum* | Deer tongue grass | 2 | 1 | 1 | 4 | 0.6 | 1.8 | 1.2 | 12 |
| *Hepatica nobilis obtusa* | Round-lobed hepatica | 2 | 1 | 1 | 4 | 0.7 | 3.0 | 1.2 | 12 |
| *Galactia volubilis* | Milk pea | 2 | 1 | 1 | 4 | 0.4 | 1.5 | 1.2 | 12 |
| *Cacalia atriplicifolia* | Plain Indian plantain | 2 | 1 | 1 | 4 | 1.0 | 5.9 | 1.1 | 11 |
| *Lespedeza violacea* | Violet bush clover | 2 | 1 | 1 | 2 | 0.5 | 1.3 | 1.1 | 11 |
| *Cassia nictitans* | Wild sensitive plant | 1 | 1 | 1 | 4 | 0.2 | 0.3 | 1.1 | 11 |
| *Leersia virginica* | White grass | 2 | 1 | 1 | 4 | 0.3 | 1.0 | 1.1 | 11 |
| *Salvia lyrata* | Lyre-leaved sedge | 2 | 1 | 1 | 4 | 0.5 | 1.0 | 1.0 | 10 |
| *Rubus occidentalis* | Black raspberry | 2 | 1 | 1 | 4 | 4.6 | 25.0 | 1.0 | 10 |
| *Tephrosia virginiana* | Goat's rue | 2 | 1 | 2 | 2 | 0.5 | 2.1 | 1.0 | 10 |
| *Gillenia stipulata* | Indian physic | 2 | 1 | 1 | 4 | 0.4 | 0.8 | 0.9 | 9 |
| *Andropogon scoparius* | Little bluestem | 2 | 1 | 2 | 4 | 0.5 | 2.5 | 0.9 | 9 |
| *Aster turbinellus* | Prairie aster | 2 | 1 | 1 | 1,3 | 0.4 | 1.0 | 0.9 | 9 |
| *Gerardia flava* | Smooth false foxglove | 2 | 1 | 1 | 4 | 0.7 | 2.6 | 0.9 | 9 |
| *Aster sagittifolius* | Arrow-leaved aster | 2 | 1 | 1 | 1,3 | 0.5 | 1.0 | 0.8 | 8 |
| *Veronicastrum virginicum* | Culver's root | 2 | 1 | 1 | 4 | 1.6 | 3.3 | 0.8 | 8 |
| *Andropogon gerardi* | Big bluestem | 2 | 1 | 2 | 4 | 0.7 | 4.5 | 0.8 | 8 |

(*Appendix continued on next page*)

(*Appendix continued*)

| Scientific name | Common name | Life span | Origin | N-fixation | Dispersal mechanism | Cover (%) | Max cover (%) | Relative freq (%) | Frequency |
|---|---|---|---|---|---|---|---|---|---|
| *Lobelia inflata* | Indian tobacco | 1 | 1 | 1 | 1,3 | 1.1 | 6.0 | 0.8 | 8 |
| *Carex digitalis* | Slender wood sedge | 2 | 1 | 1 | 4 | 0.3 | 0.5 | 0.8 | 8 |
| *Prenanthes altissima* | Tall white lettuce | 2 | 1 | 1 | 4 | 0.5 | 1.8 | 0.8 | 8 |
| *Phytolacca americana* | Pokeweed | 2 | 1 | 1 | 4 | 0.6 | 1.6 | 0.8 | 8 |
| *Carex oligocarpa* | Few-fruited sedge | 2 | 1 | 1 | 4 | 0.5 | 1.1 | 0.8 | 8 |
| *Poa sylvestris* | Woodland blue grass | 2 | 1 | 2 | 4 | 0.3 | 0.6 | 0.8 | 8 |
| *Menispermum canadense* | Moonseed | 1 | 1 | 1 | 4 | 1.2 | 2.5 | 0.8 | 8 |
| *Plantago pusilla* | Slender plantain | 1 | 1 | 1 | 4 | 1.0 | 4.4 | 0.7 | 7 |
| *Tridens flavus* | False redtop | 2 | 1 | 2 | 4 | 0.4 | 1.5 | 0.7 | 7 |
| *Panicum laxiflorum* | Lax-flowered panic grass | 2 | 1 | 1 | 4 | 0.7 | 1.5 | 0.7 | 7 |
| *Rudbekia lacinata* | Wild golden glow | 3 or 2 | 1 | 1 | 1,3 | 2.1 | 7.5 | 0.7 | 7 |
| *Agrimonia rostellata* | Beaked agrimony | 2 | 1 | 1 | 4 | 1.2 | 5.5 | 0.7 | 7 |
| *Ligusticum canadense* | Angelico | 2 | 1 | 1 | 4 | 0.8 | 2.0 | 0.7 | 7 |
| *Lespedeza striata* | Japanese bush clover | 1 | 2 | 1 | 2 | 0.2 | 0.3 | 0.7 | 7 |
| *Lacuta canadensis* | Wild lettuce | 1 | 1 | 1 | 4 | 0.4 | 1.0 | 0.6 | 6 |
| *Zizia* spp. | Golden Alexanders | | | | | 0.4 | 0.9 | 0.6 | 6 |
| *Perilla frutescens* | Beefsteak plant | 1 | 2 | 1 | 4 | 0.4 | 1.0 | 0.6 | 6 |
| *Rubus flagellaris* | Common dewberry | 2 | 1 | 1 | 4 | 2.9 | 7.5 | 0.6 | 6 |
| *Desmodium cuspidatum* | Bracted tick trefoil | 2 | 1 | 1 | 2 | 1.1 | 2.5 | 0.6 | 6 |
| *Anenome virginiana* | Tall anenome | 2 | 1 | 1 | 4 | 0.5 | 1.5 | 0.6 | 6 |
| *Lespedeza cuneata* | Silky bush clover | 2 | 1 | 1 | 2 | 0.4 | 0.7 | 0.6 | 6 |
| *Liatris aspera* | Rough blazing star | 2 | 1 | 1 | 4 | 0.3 | 0.5 | 0.6 | 6 |
| *Carex glaucodea* | Blue sedge | 2 | 1 | 1 | 4 | 0.2 | 0.5 | 0.6 | 6 |
| *Ranunculus recurvatus* | Hooked buttercup | 2 | 1 | 1 | 4 | 0.3 | 0.5 | 0.6 | 6 |
| *Apocynum cannabinum* | Prairie dogbane | 2 | 1 | 2 | 4 | 0.4 | 0.5 | 0.6 | 6 |
| *Scutellaria ovata* | Heart-leaved skullcap | 2 | 1 | 1 | 4 | 1.3 | 4.1 | 0.6 | 6 |
| *Silene virginica* | Fire pink | 2 | 1 | 1 | 4 | 0.3 | 0.4 | 0.5 | 5 |
| *Cryptotaenia canadensis* | Honewort | 2 | 1 | 1 | 4 | 0.8 | 1.0 | 0.5 | 5 |
| *Scleria triglomerata* | Tall nut rush | 2 | 1 | 1 | 4 | 0.4 | 0.5 | 0.5 | 5 |
| *Scleria* spp. | Nut rush | | | | | 0.1 | 0.1 | 0.5 | 5 |
| *Carex artitecta* | Bellows-beaked sedge | 2 | 1 | 1 | 4 | 0.8 | 2.9 | 0.5 | 5 |
| *Cassia fasciculata* | Partridge pea | 1 | 1 | 1 | 4 | 0.2 | 0.4 | 0.5 | 5 |
| *Carex convoluta* | Stellate sedge | 2 | 1 | 1 | 4 | 1.2 | 4.0 | 0.5 | 5 |
| *Rosa multiflora* | Multiflora rose | 2 | 1 | 1 | 1,3 | 2.3 | 6.5 | 0.5 | 5 |
| *Cirsium altissimum* | Tall thistle | 3 | 1 | 1 | 1,3 | 1.3 | 3.5 | 0.5 | 5 |
| *Schrankia uncinata* | Sensitive briar | 2 | 1 | 1 | 2 | 0.8 | 1.5 | 0.5 | 5 |
| *Scrophularia marilandica* | Late figwort | 2 | 1 | 1 | 4 | 1.4 | 5.3 | 0.5 | 5 |
| *Euphorbia dentata* | Toothed spurge | 1 | 1 | 1 | 1,3 | 0.2 | 0.3 | 0.5 | 5 |
| *Anemonella thalictroides* | Rue anenome | 2 | 1 | 1 | 4 | 0.2 | 0.5 | 0.5 | 5 |
| *Rudbekia hirta* | Black-eyed susan | 3 or 2 | 1 | 1 | 1,3 | 0.5 | 1.3 | 0.5 | 5 |
| *Hypericum* spp. | St. John's wort | | | | | 0.5 | 1.5 | 0.4 | 4 |
| *Aralia racemosa* | Spikenard | 2 | 1 | 1 | 4 | 0.2 | 0.3 | 0.4 | 4 |
| *Corylus americana* | American hazelnut | 2 | 1 | 1 | 4 | 1.8 | 6.3 | 0.4 | 4 |
| *Ambrosia trifidia* | Horseweed | 2 | 1 | 1 | 1,3 | 0.5 | 1.0 | 0.4 | 4 |
| *Juncus tenuis* | Roadside rush | 2 | 1 | 1 | 4 | 0.3 | 0.7 | 0.4 | 4 |
| *Aster cordiformis* | Heart-leaved aster | 2 | 1 | 1 | 1,3 | 0.2 | 0.5 | 0.4 | 4 |
| *Rudbekia subtomentosa* | Sweet black-eyed Susan | 3 or 2 | 1 | 1 | 1,3 | 0.7 | 1.4 | 0.4 | 4 |
| *Erigeron canadensis* | Daisy fleabane | 1 | 1 | 1 | 4 | 0.3 | 0.3 | 0.4 | 4 |

(*Appendix continued on next page*)

(*Appendix continued*)

| Scientific name | Common name | Life span | Origin | N-fixation | Dispersal mechanism | Cover (%) | Max cover (%) | Relative freq (%) | Frequency |
|---|---|---|---|---|---|---|---|---|---|
| *Baptisa leucophaea* | Cream wild indigo | 2 | 1 | 1 | 2 | 0.1 | 0.3 | 0.4 | 4 |
| *Lespedeza* spp. | Lespedeza | | | | | 0.2 | 0.3 | 0.4 | 4 |
| *Chenopodium album* | Lamb's quarters | 1 | 1 | 1 | 4 | 0.6 | 1.8 | 0.4 | 4 |
| *Smilax pulverulenta* | Carrion flower | 2 | 1 | 1 | 4 | 0.6 | 1.8 | 0.4 | 4 |
| *Poa* spp. | Kentucky bluegrass | | | | | 0.1 | 0.3 | 0.4 | 4 |
| *Triosteum aurantiacum* | Horse gentian | 2 | 1 | 1 | 4 | 0.4 | 0.5 | 0.4 | 4 |
| *Campanula americana* | Tall bellflower | 2 | 1 | 1 | 4 | 1.2 | 3.3 | 0.4 | 4 |
| *Thaspium trifoliatum flavum* | Meadow parsnip | 3 | 1 | 1 | 4 | 0.3 | 0.5 | 0.4 | 4 |
| *Heliopsis helianthoides* | False sunflower | 2 | 1 | 1 | 4 | 0.3 | 0.5 | 0.4 | 4 |
| *Lacuta floridana* | Blue lettuce | 2 | 1 | 1 | 4 | 0.3 | 1.0 | 0.4 | 4 |
| *Elymus virginicus* | Virginia wild rye | 2 | 1 | 2 | 4 | 0.2 | 0.3 | 0.4 | 4 |
| *Coreopsis tripteris* | Tall coreopsis | 2 | 1 | 1 | 4 | 0.3 | 0.5 | 0.4 | 4 |
| *Physalis heterophylla* | Clammy ground cherry | 2 | 1 | 1 | 4 | 2.3 | 6.3 | 0.3 | 3 |
| *Asarum canadense* | Wild ginger | 2 | 1 | 1 | 4 | 1.1 | 2.0 | 0.3 | 3 |
| *Smilax rotundifolia* | Horsebriar | 2 | 1 | 1 | 4 | 1.0 | 2.3 | 0.3 | 3 |
| *Erigeron annuus* | Daisy fleabane | 1 | 1 | 1 | 4 | 0.9 | 2.0 | 0.3 | 3 |
| *Vicia caroliniana* | Wood vetch | 2 | 1 | 1 | 2 | 0.5 | 1.0 | 0.3 | 3 |
| *Hedeoma pulegioides* | American pennyroyal | 1 | 1 | 1 | 4 | 0.9 | 1.8 | 0.3 | 3 |
| *Teucrium canadense* | Germander | 1 | 1 | 1 | 4 | 1.7 | 4.0 | 0.3 | 3 |
| *Hamamelis virginiana* | Witch hazel | 2 | 1 | 1 | 4 | 0.5 | 1.1 | 0.3 | 3 |
| *Ruellia humilis* | Hairy ruellia | 2 | 1 | 1 | 4 | 0.2 | 0.3 | 0.3 | 3 |
| *Elephantopus carolinianus* | Elephant's foot | 2 | 1 | 1 | 4 | 0.5 | 0.8 | 0.3 | 3 |
| *Viburnum rufidulum* | Southern black haw | 2 | 1 | 1 | 4 | 0.4 | 0.8 | 0.3 | 3 |
| *Cyperus strigosus* | Straw-colored flatsedge | 2 | 1 | 1 | 4 | 0.6 | 1.4 | 0.3 | 3 |
| *Lobelia spicata* | Pale spiked lobelia | 1 | 1 | 1 | 1,3 | 0.4 | 0.8 | 0.3 | 3 |
| *Senecio obovatus* | Round-leaved ragwort | 2 | 1 | 1 | 4 | 0.3 | 0.5 | 0.3 | 3 |
| *Aster azurens* | Azure aster | 2 | 1 | 1 | 1,3 | 0.5 | 0.9 | 0.3 | 3 |
| *Celtis occidentalis* | Hackberry | 2 | 1 | 1 | 4 | 0.2 | 0.3 | 0.3 | 3 |
| *Asclepias verticillata* | Whorled milkweed | 2 | 1 | 2 | 2,4 | 0.4 | 0.5 | 0.3 | 3 |
| *Viola pedata* | Bird's foot violet | 1 | 1 | 1 | 4 | 0.4 | 0.5 | 0.3 | 3 |
| *Coreopsis palmata* | Prairie coreopsis | 2 | 1 | 1 | 4 | 0.1 | 0.3 | 0.3 | 3 |
| *Luzula bulbosa* | Wood rush | 2 | 1 | 1 | 4 | 0.2 | 0.3 | 0.3 | 3 |
| *Cocculus carolinianus* | Carolina snailseed | 2 | 1 | 1 | 4 | 0.3 | 0.3 | 0.3 | 3 |
| *Sisyrinchium bermudiana* | Pointed blue-eyed grass | 2 | 1 | 1 | 4 | 0.3 | 0.3 | 0.3 | 3 |
| *Physalis virginiana* | Lance-leaved ground cherry | 2 | 1 | 1 | 4 | 0.3 | 0.5 | 0.3 | 3 |
| *Sporobolus clandestinus* | Rough rush grass | 2 | 1 | 2 | 4 | 0.7 | 1.0 | 0.3 | 3 |
| *Penstemon pallidus* | Pale beard tongue | 2 | 1 | 1 | 4 | 0.1 | 0.3 | 0.3 | 3 |
| *Commelina virginica* | Virginia dayflower | 2 | 1 | 1 | 4 | 0.1 | 0.3 | 0.3 | 3 |
| *Solidago caesia* | Blue-stemmed goldenrod | 2 | 1 | 1 | 1,3 | 0.7 | 1.0 | 0.2 | 2 |
| *Matelea decipiens* | Climbing milkweed | 2 | 1 | 1 | 4 | 2.3 | 4.5 | 0.2 | 2 |
| *Rhus radicans* | Poison ivy | 2 | 1 | 1 | 1,3 | 1.6 | 2.0 | 0.2 | 2 |
| *Stylosanthes biflora* | Pencil flower | 2 | 1 | 1 | 4 | 0.5 | 0.8 | 0.2 | 2 |
| *Achillea millefolium* | Yarrow | 2 | 1 | 2 | 4 | 0.5 | 0.8 | 0.2 | 2 |
| *Carex jamesii* | Grass sedge | 2 | 1 | 1 | 4 | 0.9 | 1.5 | 0.2 | 2 |
| *Hybanthus concolor* | Green violet | 2 | 1 | 1 | 4 | 0.6 | 0.8 | 0.2 | 2 |
| *Rhus copallina latifolia* | Shining sumac | 2 | 1 | 1 | 4 | 1.7 | 2.5 | 0.2 | 2 |
| *Prunus mexicana* | Mexican plum | 2 | 1 | 1 | 4 | 1.3 | 1.9 | 0.2 | 2 |

(*Appendix continued on next page*)

(*Appendix continued*)

| Scientific name | Common name | Life span | Origin | N-fixation | Dispersal mechanism | Cover (%) | Max cover (%) | Relative freq (%) | Frequency |
|---|---|---|---|---|---|---|---|---|---|
| *Kuhnia eupatorioides* | False boneset | 2 | 1 | 1 | 4 | 0.1 | 0.1 | 0.2 | 2 |
| *Prunella vulgaris lanceolata* | Heal-all | 2 | 1 | 1 | 4 | 0.1 | 0.1 | 0.2 | 2 |
| *Physostegia virginiana* | Dragonhead mint | 2 | 1 | 1 | 4 | 0.3 | 0.3 | 0.2 | 2 |
| *Carex meadii* | Mead's sedge | 2 | 1 | 1 | 4 | 0.3 | 0.3 | 0.2 | 2 |
| *Ranunculus abortivus* | Small-flowered crowfoot | 2 | 1 | 1 | 4 | 0.1 | 0.1 | 0.2 | 2 |
| *Carex rosea* | Stellate sedge | 2 | 1 | 1 | 4 | 0.1 | 0.1 | 0.2 | 2 |
| *Plantago major* | Common plantain | 1 | 1 | 1 | 4 | 0.1 | 0.1 | 0.2 | 2 |
| *Sphenopholis intermedia* | | 2 | 1 | 1 | 4 | 0.2 | 0.3 | 0.2 | 2 |
| *Paronychia fastigiata* | Chickweed | 1 | 2 | 1 | 4 | 0.3 | 0.4 | 0.2 | 2 |
| *Gerardia grandiflora* | Big-flowered gerardia | 2 | 1 | 1 | 4 | 0.2 | 0.3 | 0.2 | 2 |
| *Paronychia canadensis* | Forked chickweed | 1 | 2 | 1 | 4 | 0.4 | 0.5 | 0.2 | 2 |
| *Oxalis stricta* | Common wood sorrel | 2 | 1 | 1 | 4 | 0.3 | 0.4 | 0.2 | 2 |
| *Oxalis violacea* | Violet wood sorrel | 2 | 1 | 1 | 4 | 0.2 | 0.3 | 0.2 | 2 |
| *Impatiens capensis* | Touch-me-not | 1 | 1 | 1 | 4 | 1.0 | 1.0 | 0.2 | 2 |
| *Bidens frondosa* | Common beggar's ticks | 1 | 1 | 1 | 4 | 0.3 | 0.3 | 0.2 | 2 |
| *Gallinea stipulata* | | | | | | 0.3 | 0.4 | 0.2 | 2 |
| *Cinna arodinaceae* | | 2 | 1 | 1 | 4 | 0.4 | 0.5 | 0.2 | 2 |
| *Desmodium marilandicum* | Small-leaved tick trefoil | 2 | 1 | 1 | 2 | 0.4 | 0.5 | 0.2 | 2 |
| *Eryngium yuccifolium* | Rattlesnake master | 1 | 1 | 1 | 4 | 0.1 | 0.1 | 0.2 | 2 |
| *Erigeron strigosus* | Daisy fleabane | 1 | 1 | 1 | 4 | 0.6 | 0.6 | 0.1 | 1 |
| *Rumex obtusifolius* | Bitter dock | 1 | 1 | 1 | 4 | 0.4 | 0.4 | 0.1 | 1 |
| *Vernonia crinita* | Great ironweed | 2 | 1 | 1 | 1,3 | 0.5 | 0.5 | 0.1 | 1 |
| *Verbesina virginica* | White crownbeard | 2 | 1 | 1 | 4 | 0.8 | 0.8 | 0.1 | 1 |
| *Ruellia strepens* | Smooth ruellia | 2 | 1 | 1 | 4 | 0.5 | 0.5 | 0.1 | 1 |
| *Cornus florida* | Flowering dogwood | 2 | 1 | 1 | 4 | 0.1 | 0.1 | 0.1 | 1 |
| *Polytaenia nuttallii* | Prairie parsley | 2 | 1 | 1 | 4 | 0.1 | 0.1 | 0.1 | 1 |
| *Lysimachia nummularia* | Moneywort | 2 | 1 | 1 | 4 | 0.1 | 0.1 | 0.1 | 1 |
| *Verbena urticifolia* | White vervain | 2 | 1 | 1 | 1,3 | 0.6 | 0.6 | 0.1 | 1 |
| *Verbena stricta* | Hoary vervain | 2 | 1 | 1 | 1,3 | 0.3 | 0.3 | 0.1 | 1 |
| *Verbascum thapsus* | Common mullien | 3 | 1 | 1 | 4 | 0.9 | 0.9 | 0.1 | 1 |
| *Smilax ecirrhata* | Carrion flower | 2 | 1 | 1 | 4 | 0.5 | 0.5 | 0.1 | 1 |
| *Polygala senega* | Seneca snakeroot | 2 | 1 | 1 | 4 | 0.1 | 0.1 | 0.1 | 1 |
| *Thaspium barbinode* | Hairy meadow parsnip | 2 | 1 | 1 | 4 | 0.1 | 0.1 | 0.1 | 1 |
| *Liparis liliifolia* | Purple twayblade | 1 | 1 | 1 | 4 | 0.1 | 0.1 | 0.1 | 1 |
| *Panicum* spp. | Panic grass | | | | | 0.5 | 0.5 | 0.1 | 1 |
| *Fragaria virginiana* | Wild strawberry | 2 | 1 | 1 | 4 | 0.1 | 0.1 | 0.1 | 1 |
| *Cystopteris fragilis* | Fragile fern | 1 | 1 | 1 | 4 | 0.3 | 0.3 | 0.1 | 1 |
| *Coreopsis lanceolata* | Sand coreopsis | 2 | 1 | 1 | 4 | 0.1 | 0.1 | 0.1 | 1 |
| *Lindera benzoin* | Spicebush | 2 | 1 | 1 | 4 | 0.3 | 0.3 | 0.1 | 1 |
| *Sorghastrum nutans* | Indian grass | 2 | 1 | 2 | 4 | 0.8 | 0.8 | 0.1 | 1 |
| *Carex vulpinoidea* | Fox sedge | 2 | 1 | 1 | 4 | 0.1 | 0.1 | 0.1 | 1 |
| *Carex albursina* | White bear sedge | 2 | 1 | 1 | 4 | 0.1 | 0.1 | 0.1 | 1 |
| *Liatris cylindracea* | Cylindrical blazing star | 2 | 1 | 1 | 4 | 0.1 | 0.1 | 0.1 | 1 |
| *Cypripedium reginae* | Showy lady's slipper | 2 | 1 | 1 | 4 | 0.4 | 0.4 | 0.1 | 1 |
| *Hypericum punctatum* | Spotted St. John's wort | 2 | 1 | 1 | 1,3 | 0.4 | 0.4 | 0.1 | 1 |
| *Eupatorium perfoliatum* | Common boneset | 2 | 1 | 1 | 4 | 0.3 | 0.3 | 0.1 | 1 |
| *Orchis spectabilis* | Snowy orchis | 1 | 1 | 1 | 4 | 0.3 | 0.3 | 0.1 | 1 |
| *Houstonia longifolia* | Long-leaved bluets | 2 | 1 | 1 | 4 | 0.3 | 0.3 | 0.1 | 1 |
| *Melica nitens* | Tall melic grass | 2 | 1 | 1 | 4 | 0.1 | 0.1 | 0.1 | 1 |
| *Psoralea psoralioides* | Sampson's snakeroot | 2 | 1 | 1 | 2 | 1.5 | 1.5 | 0.1 | 1 |

(*Appendix continued on next page*)

*(Appendix continued)*

| Scientific name | Common name | Life span | Origin | N-fixation | Dispersal mechanism | Cover (%) | Max cover (%) | Relative freq (%) | Frequency |
|---|---|---|---|---|---|---|---|---|---|
| *Mirabilis albida* | Pale umbrellawort | 2 | 1 | 1 | 4 | 0.3 | 0.3 | 0.1 | 1 |
| *Elaeagnus umbellata* | Autumn olive | 2 | 1 | 1 | 4 | 0.6 | 0.6 | 0.1 | 1 |
| *Heliotropium tenellum* | Glade heliotrope | 1 | 1 | 1 | 4 | 0.1 | 0.1 | 0.1 | 1 |
| *Helenium autumnale* | Sneezeweed | 1 | 1 | 1 | 4 | 1.0 | 1.0 | 0.1 | 1 |
| *Quercus alba* | White oak | 2 | 1 | 1 | 2 | 6.5 | 6.5 | 0.1 | 1 |
| *Monarda fistulosa* | Wild bergamot | 2 | 1 | 1 | 4 | 0.3 | 0.3 | 0.1 | 1 |
| *Podophyllum peltatum* | May apple | 2 | 1 | 1 | 4 | 3.5 | 3.5 | 0.1 | 1 |
| *Pyrrhopappus carolinianus* | False dandelion | 1,3 | 1 | 1 | 4 | 0.5 | 0.5 | 0.1 | 1 |
| *Elymus* sp. | Wild rye | | | | | 0.1 | 0.1 | 0.1 | 1 |
| *Rudbekia triloba* | Brown-eyed Susan | 3 or 2 | 1 | 1 | 1,3 | 0.5 | 0.5 | 0.1 | 1 |
| *Panicum virgatum* | Switch grass | 2 | 1 | 2 | 4 | 0.1 | 0.1 | 0.1 | 1 |
| *Thaspium* spp. | Meadow parsnip | | | | | 0.1 | 0.1 | 0.1 | 1 |
| *Diarrhena americana* | | 2 | 1 | 1 | 4 | 0.5 | 0.5 | 0.1 | 1 |
| *Pycnanthemum tenuifolium* | Slender mountain mint | 2 | 1 | 1 | 4 | 0.4 | 0.4 | 0.1 | 1 |
| *Rosa setigera* | Prairie rose | 2 | 1 | 1 | 1,3 | 0.5 | 0.5 | 0.1 | 1 |
| *Galium obtusum* | Wild madder | 2 | 1 | 1 | 4 | 0.1 | 0.1 | 0.1 | 1 |
| *Pellaea atropurpurea* | Purple cliff break | 2 | 1 | 1 | 4 | 0.4 | 0.4 | 0.1 | 1 |
| *Crataegus intricata* | Thicket hawthorn | 2 | 1 | 1 | 4 | 0.1 | 0.1 | 0.1 | 1 |
| *Blephilia hirsuta* | Wood mint | 2 | 1 | 1 | 4 | 0.1 | 0.1 | 0.1 | 1 |
| *Blephilia ciliata* | Ohio horse mint | 2 | 1 | 1 | 4 | 0.4 | 0.4 | 0.1 | 1 |
| *Boehmeria cylindrica* | False nettle | 2 | 1 | 1 | 4 | 1.0 | 1.0 | 0.1 | 1 |
| *Muhlenbergia tenuiflora* | Muhly grass | 2 | 1 | 1 | 4 | 0.3 | 0.3 | 0.1 | 1 |
| *Triosteum perfoliatum* | Late horse gentian | 2 | 1 | 1 | 4 | 1.0 | 1.0 | 0.1 | 1 |
| *Polygonum puntuatum* | Smartweed | 1,2 | 1 | 1 | 4 | 0.3 | 0.3 | 0.1 | 1 |
| *Iris cristata* | Crested iris | 2 | 1 | 1 | 4 | 0.1 | 0.1 | 0.1 | 1 |
| *Acaphylla rhomboides* | Rhombic | 2 | 1 | 2 | 4 | 0.3 | 0.3 | 0.1 | 1 |
| *Triosteum angustifolium* | Yellow-flowered horse gentian | 2 | 1 | 1 | 4 | 0.3 | 0.3 | 0.1 | 1 |
| *Corallorhiza odontorhiza* | Late coral root | 3 | 1 | 1 | 4 | 0.6 | 0.6 | 0.1 | 1 |
| *Daucus carota* | Queen Anne's lace | 2 | 1 | 1 | 4 | 0.1 | 0.1 | 0.1 | 1 |
| *Hypericum spathulatum* | Shrubby St. John's Wort | 2 | 1 | 1 | 1,3 | 0.1 | 0.1 | 0.1 | 1 |
| *Amelanchier arborea* | Shadbush | 2 | 1 | 1 | 4 | 0.1 | 0.1 | 0.1 | 1 |
| *Solanum carolinense* | Horse nettle | 2 | 1 | 1 | 4 | 3.5 | 3.5 | 0.1 | 1 |
| *Phaseolus polystachios* | Wild bean | 2 | 1 | 1 | 4 | 0.4 | 0.4 | 0.1 | 1 |
| *Rudbekia fulgida umbrosa* | Coneflower | 3 or 2 | 1 | 1 | 3 | 0.1 | 0.1 | 0.1 | 1 |
| *Ciracea quadrisulcata canadensis* | Enchanter's nightshade | 2 | 1 | 1 | 4 | 0.3 | 0.3 | 0.1 | 1 |