



Vegetation Monitoring in Goat Prairies at Effigy Mounds National Monument

2001–2017

Natural Resource Report NPS/HTLN/NRR—2020/2120



ON THE COVER

Sonia Bingham records vegetation data at Effigy Mounds National Monument, July 2017.
Photography by NPS/Heartland Inventory and Monitoring Network

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Executive Summary

Effigy Mounds National Monument has diverse vegetation because of its proximity to the Mississippi River, geologic formations, and cultural history. One of the unique plant communities within this landscape is goat prairie. Also called oak openings, juniper glades, or hill prairies, goat prairies are typically located on south-west facing aspects on the edges of bluffs. They typically have shallow soil with rocky limestone or sandstone substrates and a scattered overstory of oak and juniper trees. Goat prairie vegetation is diverse and includes species characteristically found in prairies, savannas, or woodlands. Historically, fire was an important ecological disturbance maintaining these plant communities.

The Heartland Inventory and Monitoring Network established vegetation monitoring sites in the goat prairies because of their unique plant species composition. Vegetation has been monitored at eight goat prairie sites three times since 2001. Monitoring of canopy closure, midstory and overstory composition, ground cover, and ground flora composition and abundance occurred in 2001, 2005, and 2017. We also developed a 23-year record of the Palmer Drought Severity Index and a spatial fire occurrence record to complement the monitoring data. Although invasive species treatments have occurred, a quantitative assessment of those efforts is presented elsewhere (Bell and Young 2017).

Ecological disturbances were limited in the goat prairie sites. During the monitoring period, the mean Palmer Drought Severity Index indicated that most years had adequate or wetter than normal conditions. Some high wind events occurring in or near the park also had the potential to affect the monitoring sites, but documentation of how these events impacted the sites was not available. Furthermore, very little prescribed fire occurred within the goat prairie sites. Tree reduction occurred in the vicinity of one goat prairie (Site 14), and crews noted herbicide damage at one site (Site 4) in 2017. Overall, a limited suite of management actions have occurred in the eight sites.

The tree layers indicate that succession may be occurring. Canopy closure is progressing, consistent with a long-term remote sensing study. Midstory and overstory trees have increased in basal area, but tree density has not increased. Tree species characteristic of these xeric communities continue to be present, including white oak (*Quercus alba*), bur oak (*Q. macrocarpa*), and chinkapin oak (*Q. muehlenbergii*). Regeneration of all size classes has been variable through the monitoring period, although large saplings appear to have declined.

Ground flora species richness and diversity exhibited a complex pattern. While gamma diversity (park-wide diversity) increased, site species richness declined. Beta diversity (diversity across sites) also increased, signaling sites may be differentiating into more unique communities. An analysis of six species characteristic of either prairie or forest communities showed that there is a great deal of variability in species abundances across the eight sites. No clear trend was determined among this suite of species. Guild abundances demonstrated decline in most guilds in 2005. No clear source for this decline was apparent. A few non-native species were present in low abundance in the goat prairie sites.

The goat prairie sites continued to have characteristic overstory and ground flora species, but some metrics indicate that management actions could benefit these sites, such as methods that reduce the overstory within and possibly adjacent to the sites. Given that plant communities in the uplands at the park are on a continuum of soil depth and substrate with more shallow soils occurring near the bluff edges, resetting the successional trajectory using fire or thinning treatments throughout the continuum could be beneficial.

Acknowledgments

We are grateful for the contributions of previous staff who helped to monitor vegetation at Effigy Mounds National Monument. Jaye Maxfield and Jesse Bennett provided botanical support in 2017. We also appreciate field support from the park. Some of the language of this report was taken from James et.al. (2009), particularly the methods. J. Haack-Gaynor provided maps. Mary Short provided forest expertise and analysis support.

Introduction

Effigy Mounds National Monument is situated along the west side of the Mississippi River in Iowa. This area is often referred to as the *driftless zone* or Paleozoic plateau of northeastern Iowa (Glenn-Lewin et al. 1984). This area has unique flora as compared to the glaciated zones surrounding it (Glenn-Lewin et al. 1984; Pusateri et al. 1993). Topography of the park varies from lowland riverine areas to upland bluffs and cliffs. Along the bluff edges, thin soiled areas commonly called goat prairies are part of a continuum of community types (Glenn-Lewin et al. 1984). Mesic forests graduate to more xeric woodlands, savanna, and hill prairies or oak openings as aspect, proximity to bluff edges, and soil depth change. The soil often becomes thinner closer to the bluff edges and plant communities function much like glades known from the Ozarks and Appalachian regions.

We will refer to these xeric open bluff edge communities as goat prairies although they are sometimes referred to by other names (hill prairies, juniper glades, oak openings; Hayden 1945; Eilers and Roosa 2010; Pusateri et al. 1993).

Historically, goat prairie vegetation was influenced by fire and thin soils with underlying limestone or sandstone substrate (Hayden 1945; Rosburg 1999). A key role of fire was to prevent expansion of trees including eastern redcedar (*Juniperus virginiana*) into the goat prairies (Hayden 1945; Glenn-Lewin et al. 1984).

Land conversion to agriculture occurred rapidly in Iowa with 28.6 million acres being converted within the first 70 years of Euro-American settlement



Mike DeBacker and Sonia Bingham record vegetation data at Effigy Mounds National Monument, July 2017.

(Smith 1998). In a subsequent evaluation of prairies to conserve in the state, Hayden (1945) included the hill prairies of northeastern Iowa among those to preserve. Many of these goat prairie areas at the park are limited in size and are remote in nature.

The park implemented conservation measures that were aimed to conserve the goat prairies and associated woodlands (Quinn Evans Architects et al. 2016). The goat prairies are difficult to quantify as a community because of the small community patch size. One estimate calculated 183.3 ha of goat prairie within the park, about 1.3% of the park (Hop et al. 2005). An analysis which calculated community sizes for a variety of vegetation at the park detected a loss of the goat prairies but lumped them with savanna/woodland (Narumalani et al. 2004). They found a decrease in mean patch size of 6.9 ha between the 1940s and 1990s. A 1997 proposal recommended thinning at one of the goat prairie monitoring sites (Site 14) based on an overall increase in canopy cover since 1960 (Grabner et al. 1997). Treatment recommendations were implemented based on observations of downed trees by monitoring field and descriptions in planning documents, but no direct

documentation of spatial distribution of treatments was available (Quinn Evans Architects et al. 2016). The park suspended these forest and prairie management efforts beginning in 2009 to invest in long-term comprehensive planning efforts, and the effect of this break in land management treatments is not fully known.

The Heartland Inventory and Monitoring Network began monitoring vegetation of the goat prairies in 1998. Long-term monitoring is designed to detect trends over time to support managers in decision making. Vegetation monitoring sites were modified from Heartland Network's standard design to accommodate the limited spatial extent of the goat prairies while maintaining a statistically viable sample design (James et al. 2009; HTLN 2019). Both ground flora and overstory data have been collected in the park goat prairie sites. This report is the first to provide a trend analysis of the vegetation including all eight goat prairie sites, although there are annual status reports from past sampling efforts for 1997 (DeBacker et al. 1998), 1998 (DeBacker 1999), 2001 (DeBacker 2002), and 2009 (James and Guck 2010).

Methods

Study Site

Long-term vegetation sampling sites are located in the goat prairie community type (Blewett 1986) at Effigy Mounds National Monument (Figure 1). Sample sites were added in 1997 (N = 5) and 2001

(N = 3) to total 8 sites (Table 1). Because the goat prairie community is limited in size by topographic and soil constraints the site design was modified to fit the community type when necessary.

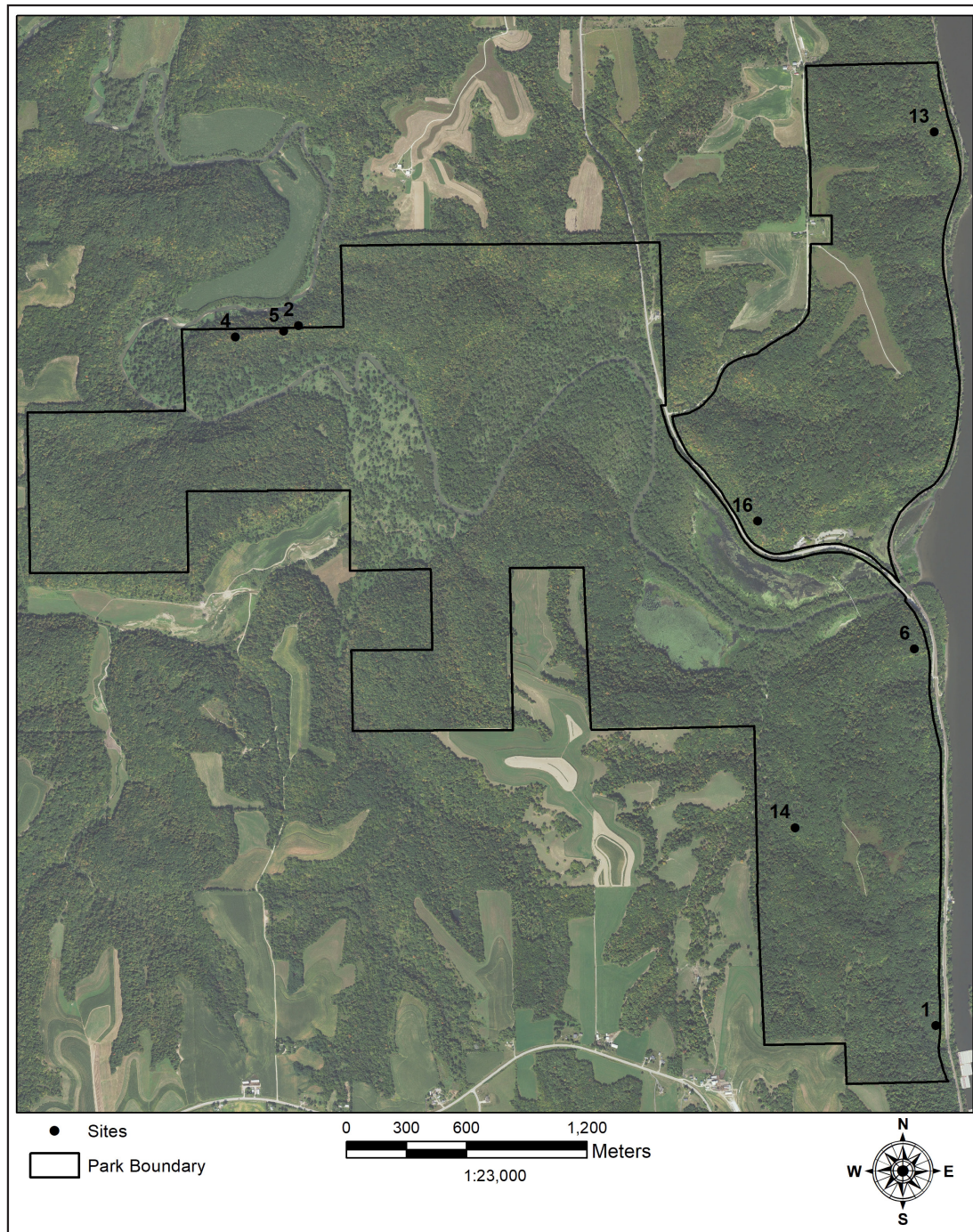


Figure 1. Heartland Network vegetation monitoring sites in the goat prairie community at Effigy Mounds National Monument, Iowa. Not all goat prairie communities have monitoring sites within them.

Table 1. Goat prairie site installation and description. Community types follow Hop et al. (2005). Plot counts within sites are listed with modifications to the monitoring design for 2001, 2005, and 2017.

Site Number	Community From Vegetation Map	Date Installed	Number of Plots (n)	Site Modifications
1	split type	05-Jun-97	10	9 plots (2017)
2	–	06-Jun-01	5	–
4	White Oak - Red Oak Forest (white oak - chinquapin oak phase)	06-Jun-01	5	–
5	White Oak - Red Oak Forest (white oak - chinquapin oak phase) - split between red cedar phase and white oak - chinquapin oak phase	06-Jun-01	5	–
6	split type	03-Jun-97	9 (2001)	8 plots (2005), 7 plots (2017)
13	split type	11-Jun-97	8	–
14	White Oak - Red Oak Forest (oak - hickory phase)	07-Jun-97	10	–
16	White Oak - Red Oak Forest (white oak - chinquapin oak phase)	08-Jun-97	10 (2001)	5 plots (2005), 9 plots (2017)

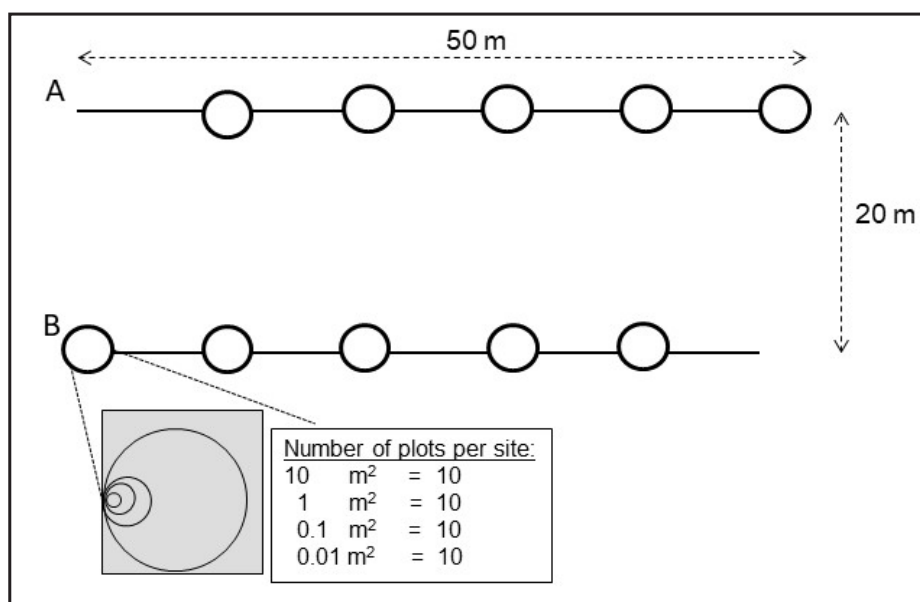


Figure 2. Plant community site monitoring design for Heartland Network parks.

All eight sites were sampled in 2001, 2005, and 2017 and these years were used for analysis. In 1997, 2002, 2009, and 2013, some sites (but not all) were sampled. The inherent variability of these sites also leads to a great deal of statistical variability and increasing uncertainty when forming conclusions. The use of years with equal sample sizes reduced that statistical uncertainty. The exception is that the overstory of site 14 was sampled in 2002 rather than 2001. It was included under 2001 for simplicity.

Sample sizes were reduced at some sites in 2017 to increase safety for observers as the bluffs have eroded in some places over time. The layout of each site is

described in a previous report (HTLN 2019). Site means and total area for scaling were adjusted based on the number of plots and total area sampled for each sampling year and site.

Sampling Design

Monitoring methods followed the standard operating procedures outlined in the vegetation community monitoring protocol (James et al. 2009). Monitoring sites were 50 m x 20 m (0.1 ha) in size with two focal transects bounding the site on the 50-m sides (Figure 2) unless otherwise noted (Table 1). For this protocol, overstory tree (diameter at breast height [DBH] >

5.0 cm) data were collected within the entire rectangular site (tree data included DBH, species, live/dead, and tree status—coppice or single stemmed), while all other metrics were collected within subplots located along the site boundaries (canopy closure, ground cover, species and abundance of ground flora, including tree regeneration). Each subplot consisted of a series of nested frames (0.01 m², 0.1 m², 1 m², and 10 m²), but only observations at the 10-m² scale were summarized to the site scale (0.1 ha) for this analysis. See James et al. (2009) for additional details on sampling design.

Data Summary

Tree regeneration and ground flora were measured within the 10-m² subplots in each site. Foliar cover serves as an estimate of abundance for ground flora species. The cover class intervals are converted to midpoint values to estimate percent cover for each herbaceous and shrub species (Table 2). Mean percent cover is then calculated as the species percent cover for a sampling unit, averaged for all subplots. Sampling unit (site) means were then used to calculate community level means.

Table 2. Modified Daubenmire cover value scale used to determine ground flora species cover for the Heartland Network parks.

Cover Class Codes	Range of Cover (%)	Class Midpoints (%)
7	95–100	97.5
6	75–95	85.0
5	50–75	62.5
4	25–50	37.5
3	5–25	15.0
2	1–5	2.5
1	0–0.99	0.5

It is important to note that the monitoring protocol was changed in 2009 (see appendices in James et al. 2009). The revisit design changed from two-season sampling to one-season sampling in monitored years. We expected a small decline in species richness as a result. A specific estimate was not calculated, but other parks typically expected a drop of 6 to 9 species.

SPSS (Version 24; IBM 2016) and PCord (McCune and Mefford 2016) were used for summary statistics.

All site means were calculated based on the number of sampled subplots for each year (for number of sites see Table 1), and confidence intervals (95%) were calculated.

Climate

The Palmer Drought Severity Index (PDSI) was used to describe the climate over the period of monitoring at the park (Heggen 1993; Vose et al. 2014). Data were obtained from the [NOAA/National Climatic Data Center](https://www7.ncdc.noaa.gov/CDO/CDODivisionalSelect.jsp#) (<https://www7.ncdc.noaa.gov/CDO/CDODivisionalSelect.jsp#>; accessed September 25, 2019). Monthly data were acquired for the northeastern region of Iowa and averaged by year.

Recent Fire Occurrence

Fire occurrence records (primarily prescribed fire) are included for the years 1994 through 2017. Recent fire histories for the goat prairies of Effigy Mounds National Monument were determined using a spatial fire history organized in a geodatabase. Although our fire occurrence data begins in 1950, we started the fire history analyses in 1994 to match with the history of vegetation monitoring and provide context prior to site installation. A 30-m buffer was constructed from the center point of each monitoring site. If the buffered area was more than 30% burned (i.e., ≥ 848 m²), the whole site was considered burned. On the ground observations in 2009 validated that year's spatial data. Time since last fire (TSF) was then calculated from this dataset for each monitoring site-year combination. TSF fire site values were then averaged for further analysis.

Goat Prairie Overstory and Midstory

Seven of the eight sites were monitored for tree composition because one site (5) could not accommodate an overstory monitoring plot as a result of the narrow ridge it is located on. Tree composition in the goat prairies was based on individual tree measurements in each site, including species identification, DBH measurements, and status (live or dead) for each tree greater than 5.0 cm DBH. Snags were calculated separately from live trees for overstory analysis. Basal area and stem density were calculated within size class categories (Table 3) as described in James et al. (2009). We distinguished class 1 (midstory trees) from classes 2 to 5 (overstory trees) for interpretation. DBH and stem density were scaled to the hectare for analysis.

Table 3. Diameter at breast height (DBH) measurement range (cm) and size class midstory and overstory trees.

DBH (cm)	Size Class	Type
5.0 - 14.9	1	Midstory
15.0 - 24.9	2	Overstory
25.0 - 34.9	3	Overstory
35.0 - 44.9	4	Overstory
≥ 45	5	Overstory

Canopy closure data were collected using a densitometer. Densitometer readings were collected in the four cardinal directions in each of the 10-m² subplots and converted to canopy closure (multiplied by 1.04). Plot level mean canopy cover (n = 4 per subplot) was used to calculate site-level mean canopy cover. A grand mean was then calculated for all sites (N = 8).

Goat Prairie Understory

Woody regeneration and ground flora were measured within the 10-m² subplots in each site. Foliar cover serves as an estimate of abundance for ground flora species. The cover class intervals are converted to midpoint values to estimate percent cover for each herbaceous and shrub species (Table 2). Mean percent cover is then calculated as the species percent cover for a sampling unit averaged for all subplots (see Table 1 for n values for each site). Sampling unit means were then used to calculate community-level means.

Tree Regeneration

Tree regeneration stems were tallied by species in the 10-m² subplots of each site and reported in three size classes: (1) seedlings = stems < 0.5 m tall; (2) small saplings = stems ≥ 0.5 m tall, but < 2.5 cm DBH; and (3) large saplings = stems ≥ 0.5 m tall and DBH > 2.5 cm and < 5.0 cm. We calculated stems/ha for each individual species and pooled species to look at total stems/ha. In both cases, stems were summed and averaged across sites.

Vegetation

Species Diversity Indices

Diversity indices describe the number of species and their abundances (based on foliar cover measurements) and can be compared across prairie communities in the park. Mean site cover for all non-tree species was calculated using all subplots within each

site. For each site within the community, species richness (S), Shannon diversity index (H') and evenness (J') were calculated. Species richness, synonymous with *alpha* diversity, represents the number of species observed. PC-ORD (version 7.02) was used to calculate these diversity indices (IBM 2016; McCune and Mefford 2016). A grand mean was then calculated for all sites in a community.

Initial plant diversity for each site was calculated using the Shannon diversity index:

$$\text{Shannon Index: } H' = -\sum_{i=1}^n p_i \ln p_i$$

where p_i is the relative cover of species i (Shannon 1949).

Species distribution evenness (J') is calculated by site according to Pielou (1969):

$$\text{Evenness: } J' = \frac{H'}{\ln(S)}$$

where H' is the Shannon index and $\ln(S)$ is the maximum possible Shannon diversity for a given number of species if all species were present in equal abundance. Evenness is a measure of distribution of species within a community as compared to equal distribution and maximum diversity (Pielou 1969). A value of 1 indicates even communities whereas 0 indicates a heterogeneous community.

Community Diversity Metrics

Community richness metrics evaluate how species richness differs across monitoring sites and the park. We limited these calculations to understory herbaceous species.

$$\text{Beta Diversity} = (\text{gamma}/\text{alpha}) - 1$$

Alpha diversity is synonymous with species richness at the site scale (i.e., mean number of species per monitoring site). *Gamma* diversity is the community level richness (i.e., total number of species in the community) observed across all monitoring sites. *Beta* diversity is a measure of heterogeneity in species distributions across monitoring sites such that small values (near 0) indicate a high degree of similarity in species occurrence across monitoring sites and greater values (>5) indicate a higher degree of variation in species between sites (more differentiated communities; McCune and Grace 2002).

Guild Abundance

Understory plant species were also summarized by guilds, also known as functional groups (designations per the USDA Plants database; James et al. 2009; USDA NRCS 2017). Guild assignments were grasses, forbs, grass-like (species including sedges and rushes), and woody species. A complete species list along with guild assignment is provided in Appendix A. Mean cover values were calculated for each guild-site-year combination. A grand mean was then calculated across all sites.

The abundance of native versus nonnative (e.g. exotic) species was assessed using mean cover values. Mean cover values for species within a site were summed by origin and analyzed by prairie community type.

Ground Cover

Ground cover was assessed using cover classes (Table 2). A site mean was calculated by averaging the cover class midpoints for subplots in each site. We observed aerial cover of grass litter, leaf litter (deciduous plant leaves), rock (exposed rock), bare ground (soil), and the cover of woody debris (e.g. branches and sticks). Total unvegetated area reflects space unoccupied by stem basal area in the subplots (James et al. 2009).

Results

Climate

Analysis of the Palmer Drought Severity Index (PDSI) for the northeast region of Iowa indicates that the park maintained adequate or above normal moisture levels for the majority of the monitoring history (Figure 3). Average annual rainfall for Allamakee County, Iowa, is 87.6 cm (34.47 in). The mean PDSI only dropped into the mild-moderate drought category in one year during this time frame.

Recent Fire Occurrence

The goat prairie sites were infrequently burned during this period of record (1994–2017; Figure 4). The maximum number of times a single site was burned was three. Thirty-three additional fires, not included in this assessment, were recorded in the park between 1950 and 1993 but only four

occurred in the goat prairie monitoring sites. The number of years between burns (fire return interval) ranged from 3 to 24 years for the eight goat prairie sites (1994–2017). For 2017, mean time since fire across the eight sites was 15.6 years.

Historically, fire occurred via lightning strike or human ignition and would have prevented tree invasion (Hayden 1945; Glenn-Lewin et al. 1984), maintaining an open character in the dry oak woodlands and savannas that grade into the goat prairies (Glenn-Lewin et al. 1984). The target historical fire frequency for goat prairies in northeastern Iowa was unclear. A fire management plan for Effigy Mounds National Monument was developed in 1987 in response to a perceived need to manage the goat prairies and prairie restorations (Quinn Evans Architects et al. 2016).

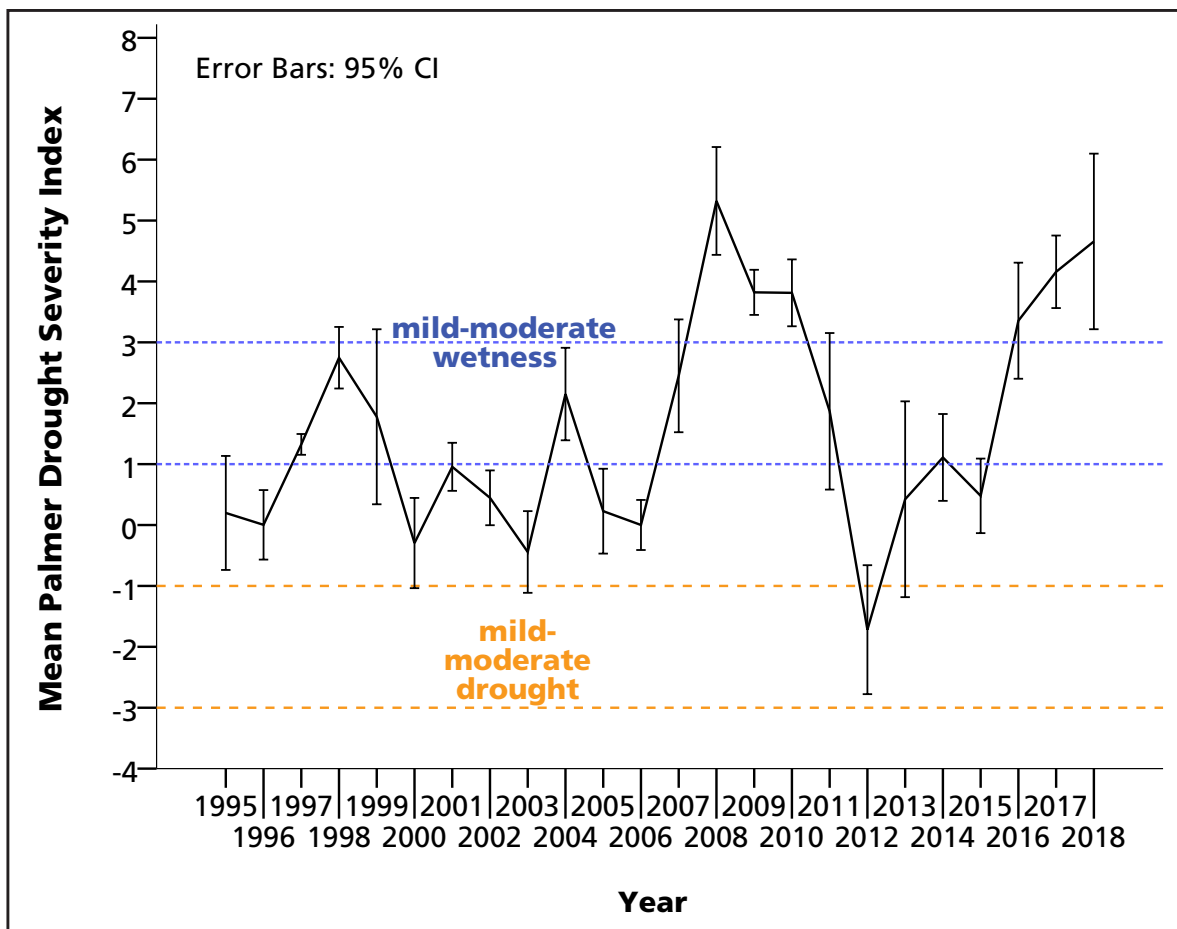


Figure 3. Mean Palmer Drought Severity Index for Effigy Mounds National Monument, Iowa, 1995–2018.

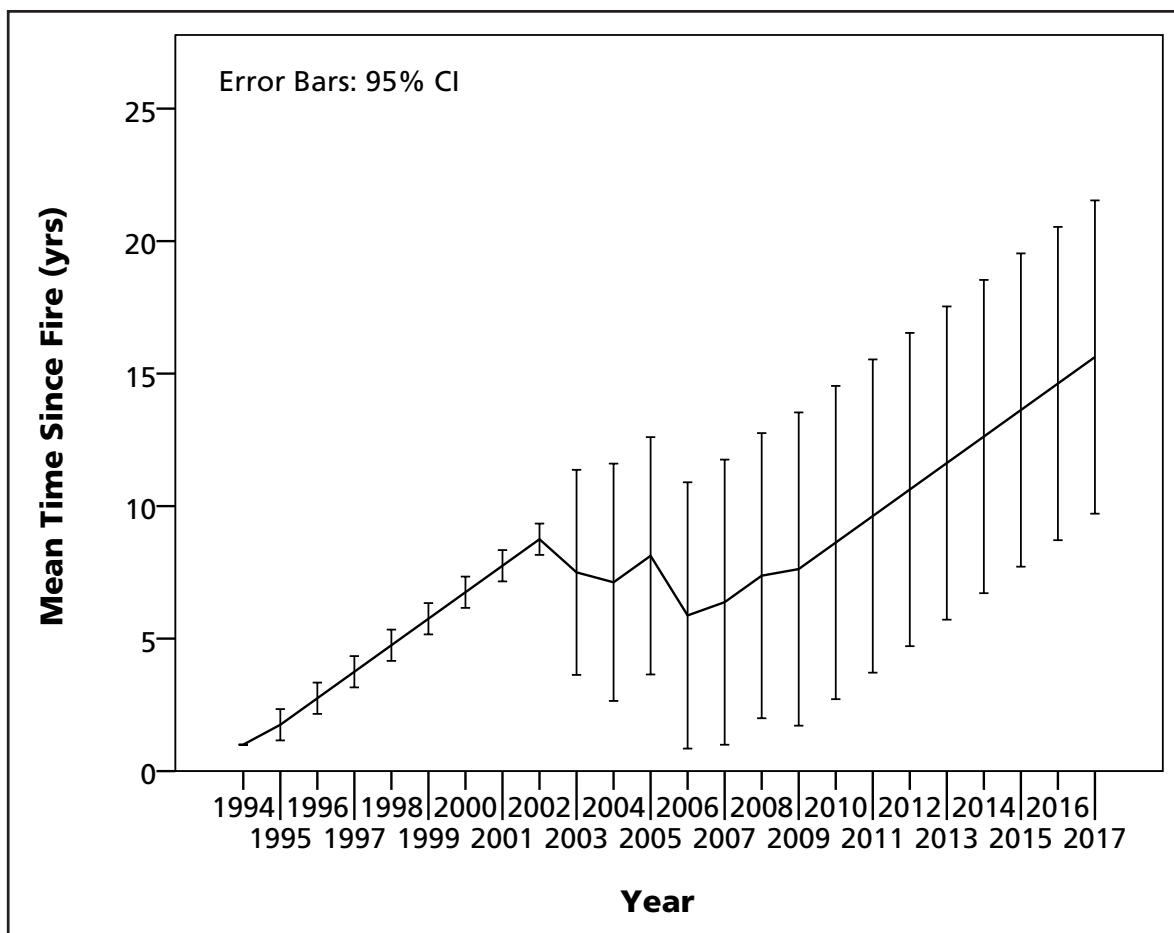


Figure 4. Mean time since fire for the goat prairie sites at Effigy Mounds National Monument, Iowa, 1994–2017. Values prior to 1994 are not necessarily known, so the fire history is within the context of the time period presented.

Canopy Closure

Savanna provides a relative benchmark for canopy closure for goat prairies. A common threshold for savanna is up to about 30% canopy closure (Nelson 2005). Much like glades, goat prairie canopy is characteristically heterogeneous in space and time. The mean canopy closure for goat prairie sites at the park exceeded the savanna benchmark at the initiation of monitoring (Figure 5; Appendix B). The canopy appears to be more closed in 2017 than in 2001 and more indicative of an open woodland community. Site 1, the most open of the eight, was 27% more closed in 2017 than in 2001. Site 16, the most closed site, became 10% more closed in 2017 than in 2001. Despite thinning efforts in the vicinity of site 14 prior to this study, its canopy closure increased by 13% during the monitoring period. This progression of canopy closure is consistent with that discussed by Quinn Evans Architects et al. (2016). They report canopy at Effigy Mounds National Monument increased greatly between 1930 and the 1950s and continued through the subsequent decades.

Midstory and Overstory Trees

There is a great deal of variability in basal area among the goat prairie sites, and it appears that the total amount of basal area increased across years (average $\pm$ SE: 25 ± 1.6 , 27 ± 1.9 , and 29 ± 2.3 m²/ha in 2001, 2005, and 2017, respectively), similar to the increase in canopy closure (Figure 6). Site 14 had been targeted for thinning treatments prior to this monitoring study but gained a minimal amount of 3 m²/ha in basal area between 2001 and 2017. The site's basal area was greater than the target level of 20 m²/ha at the start of monitoring and increased to 26 m²/ha by 2017 (Grabner et al. 1997). Mean basal area of the eight sites was distributed across the size classes with class 3 (25–34.9 cm DBH) consistently having the greatest basal area.

The increases in canopy cover and basal area we observed were consistent with that reported by Narumalani et al. (2004). In a remote sensing study of Effigy Mounds National Monument, they observed a substantial loss of savanna with a concomitant gain in deciduous forest from 1940 to 1990.

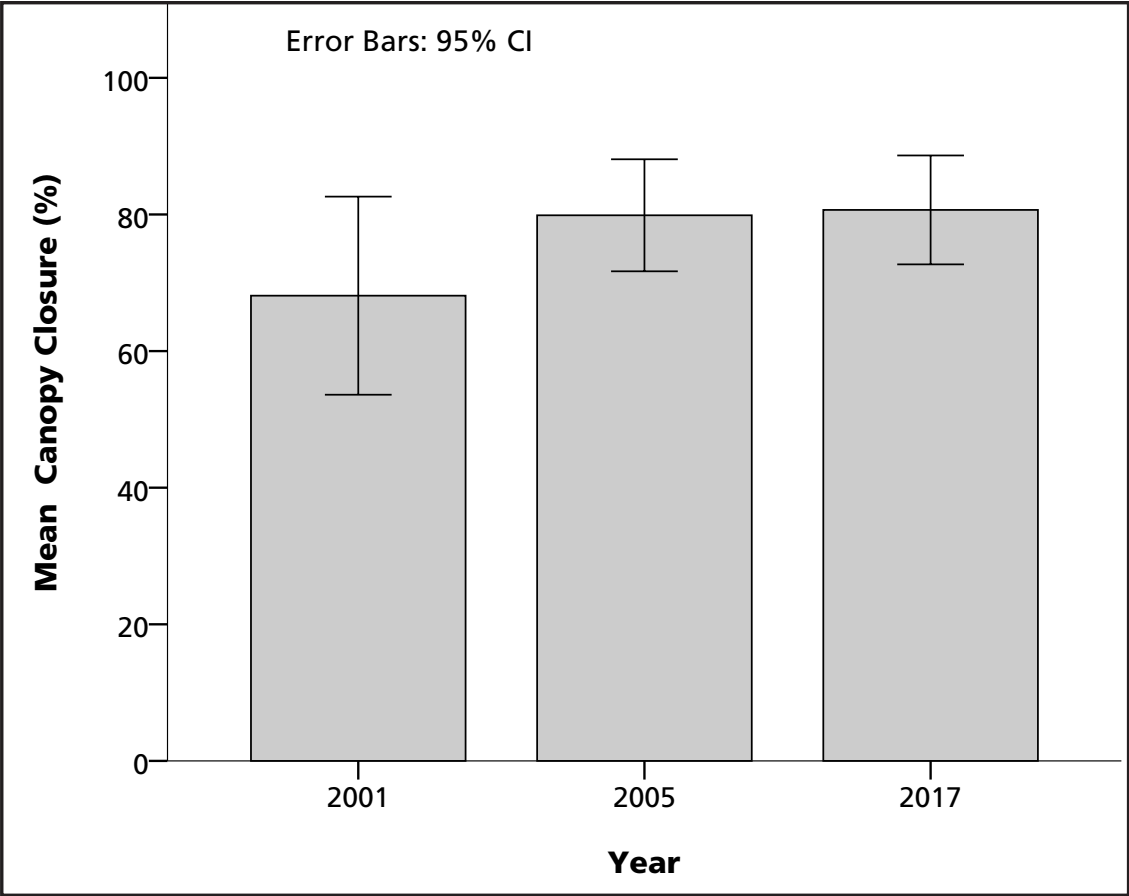


Figure 5. Mean percent canopy closure in goat prairie sites at Effigy Mounds National Monument, Iowa, 2001–2017.

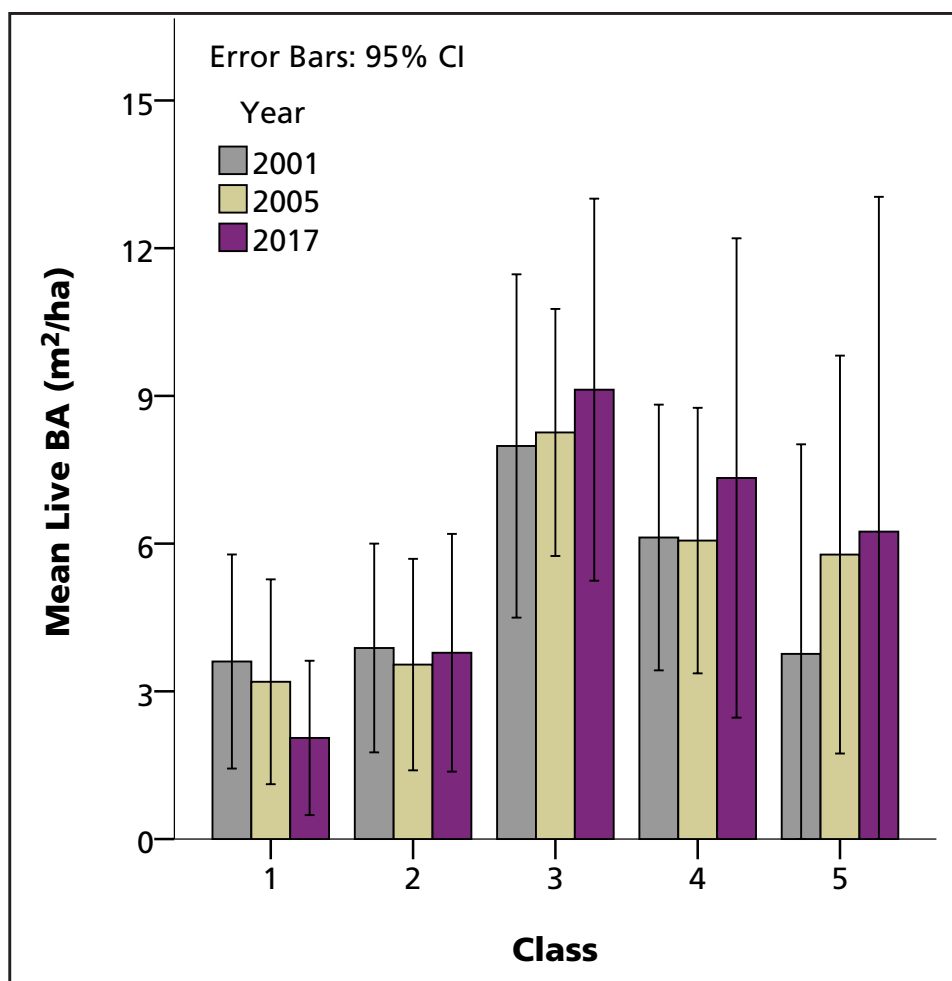


Figure 6. Midstory and overstory live tree basal area in goat prairie sites at Effigy Mounds National Monument, Iowa, 2001–2017. Classes range from midstory (class1: DBH = 5.0–14.9 cm) to large overstory trees (class 5: DBH ≥ 45 cm).

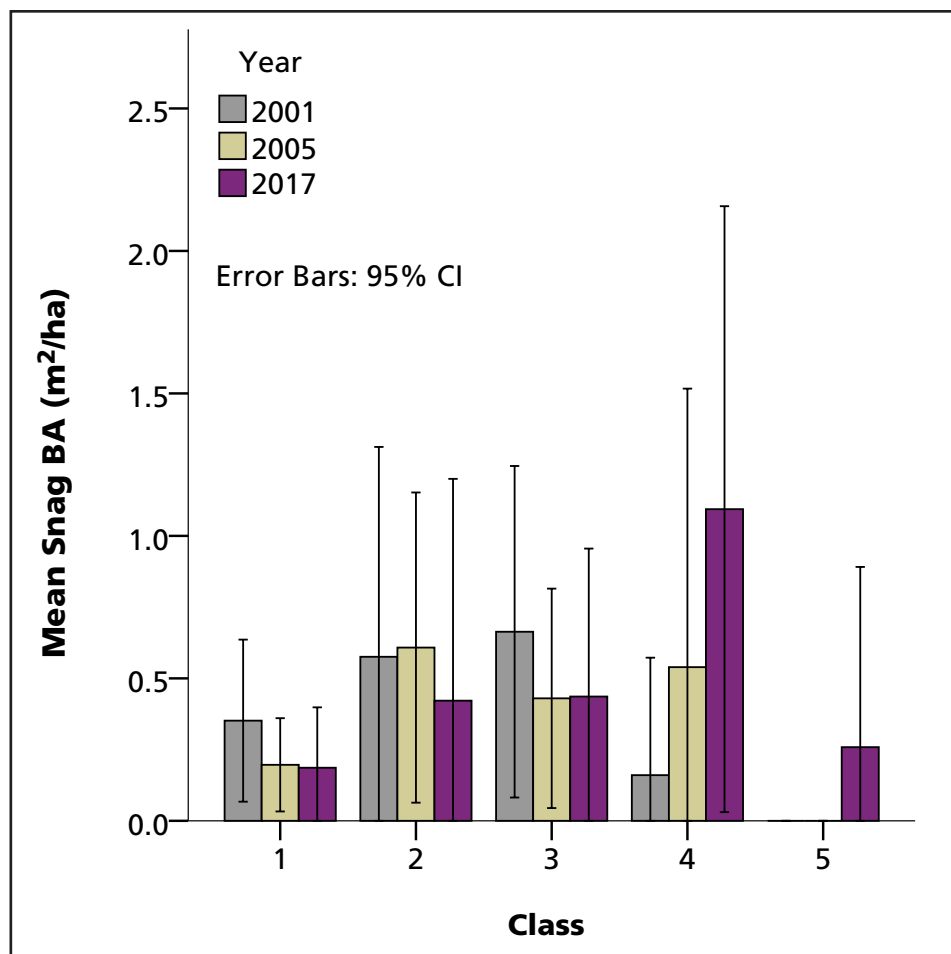


Figure 7. Midstory and overstory snag tree tree basal area in goat prairie sites at Effigy Mounds National Monument, Iowa, 2001–2017. Classes range from midstory (class1: DBH = 5.0–14.9 cm) to large overstory trees (class 5: DBH ≥ 45 cm).

Mean snag density was the same in 2001 and 2017 with class 4 snag trees encompassing at least twice the basal area of other categories (Figure 7). Class 5 snags were only found in 2017. Although girdling treatments occurred around 1998, we did not have pretreatment data to assess the effects of that treatment. Windstorms and tornadoes are known to have occurred in and near the park, but we do not have spatially explicit data on park localities affected. Windstorms may have contributed to snag creation and woody debris estimates with the most recent event occurring days before vegetation monitoring commenced in 2017. Tornadoes were also recorded in the county in 1998, 2000, and 2002 (NOAA 2016).

Twenty-four tree species were observed in the eight monitoring sites. White oak (*Quercus alba*), bur oak (*Q. macrocarpa*), and red oak (*Q. rubra*) dominated the overstory (Figure 8). Glenn-Lewin et al. (1984) described white oak and red oak dominated

communities as separate forest types. White oak tends to dominate on exposed or upper slopes and dry flat uplands, whereas red oak communities tend to be on more heterogeneous sites with less sun exposure. Bur oak was associated with the edges of areas historically dominated by prairie ground flora. Another forest type, oak-juniper glades, included a diversity of species similar to our observations in the goat prairies. The oak-juniper glades may transition into the white oak or red oak communities depending on the soil and topography (Glenn-Lewin et al. 1984). As the goat prairie communities experience succession resulting from lack of disturbance, they may actually represent a diverse suite of communities.

Although white oak expanded, eastern redcedar (*Juniperus virginiana*) and basswood (*Tilia americana*) had greater proportional gains (82.7%) in basal area from 2001 levels. Basswood was a minor

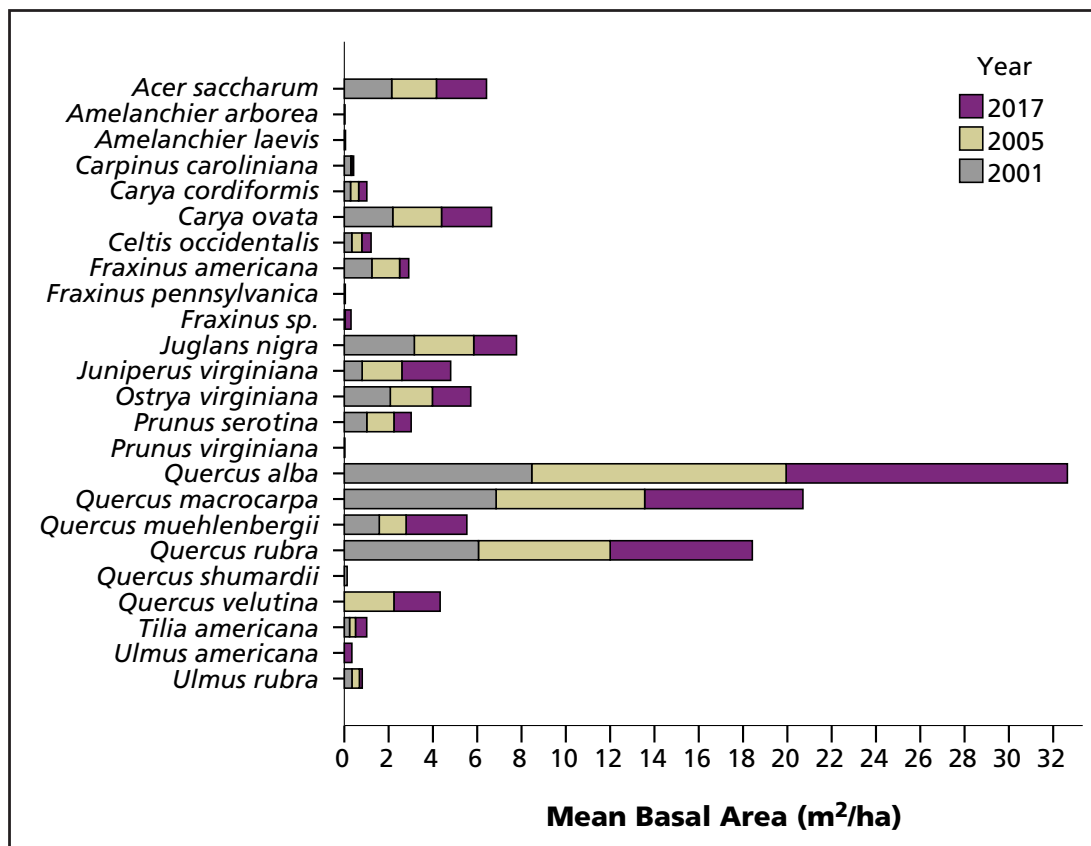


Figure 8. Cumulative mean basal area (m²/ha) for tree species in goat prairie sites at Effigy Mounds National Monument, Iowa, 2001–2017. Color bands represent mean basal area by year.

component of both the midstory and overstory with less than 5% of the total basal area (Figure 8 and Table 4). Eastern redcedar increases are likely related to lack of fire, but basswood is often associated with more mesic systems. Basswood trees observed were class 1 midstory trees (5–15 cm DBH), except for two trees in 2017 that transitioned to the overstory. Even though the basswood expansion is consistent with the PDSI indicating a moist period and processes of mesophication (Nowaki and Abrams 2008), other more dominant mesic species, like sugar maple (*Acer saccharum*) and walnut (*Juglans nigra*), declined leaving uncertainty in explaining species patterns through time.

Table 4. Change in mean basal area and stem density of dominant midstory and overstory tree species in Effigy Mounds National Monument goat prairie sites (2017–2001). Negative values for change indicate greater basal area in 2001 than in 2017.

Species	Percent change 2017–2001	
	Basal Area (m ² /ha)	Density (stems/ha)
<i>Acer saccharum</i>	-9.41	-62.97
<i>Carya ovata</i>	10.62	-14.49
<i>Juglans nigra</i>	-47.63	-76.62
<i>Juniperus virginiana</i>	56.69	-31.14
<i>Ostrya virginiana</i>	-28.50	-43.19
<i>Quercus alba</i>	28.61	6.85
<i>Quercus macrocarpa</i>	-10.62	-14.29
<i>Quercus rubra</i>	27.15	-2.12

Tree density appeared to decline over the monitoring period indicating that trees were getting larger rather than adding more stems (Figure 9). This trend was reflective of limited ecological disturbance in the goat prairie sites. The large amount of class 1 trees in 2001 could be attributed to treatments aimed at reducing trees (Figure 9). In 1998, trees were cut and girdled in the vicinity of at least one site (Grabner et al. 1997; Quinn Evans Architects et al. 2016). The process of recovery after tree reduction could have led to the 2001 spike. After 2001, it is possible that those trees could not then persist because of the thin soils or because subsequent prescribed fires reduced them, but it is unclear.

Similar to forest types in the driftless area of Iowa (Glenn-Lewin et al. 1984), *Ostrya virginiana* (American hophornbeam) had high stem density in the park's goat prairies (Figure 10), but stem density was reduced by 43% between 2001 and 2017 (Table 4). The patterns of dominant species reflect that of basal area. Sugar maple stands out as having reduced stem density in 2017 along with eastern redcedar (Table 4). If mesophication were occurring, we would expect mesic species to increase. Basswood did increase in stem density similar to basal area, but sugar maples actually decreased. Interestingly, eastern redcedar trees grew larger (Figure 8), but reduced in number (Table 4). Some mechanisms for explaining patterns of species abundance for mesic species are inconsistent between basal area and stem density metrics.

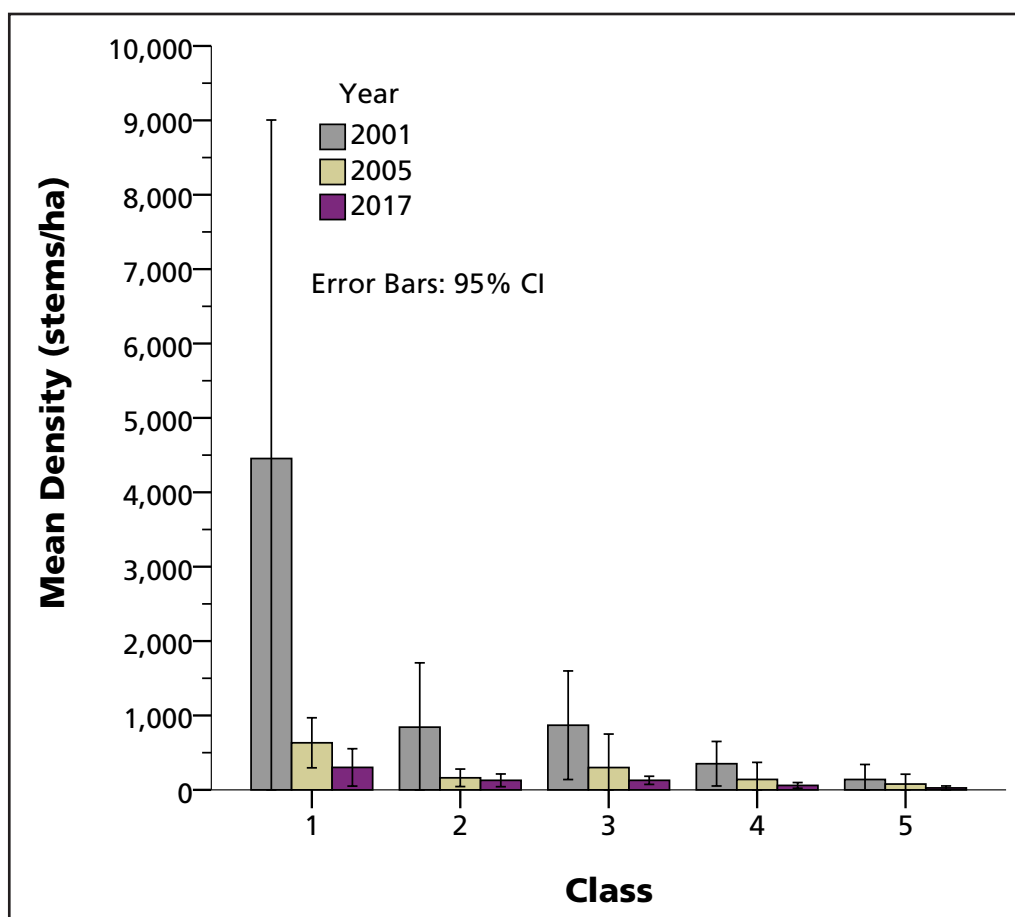


Figure 9. Mean stem density (stems/ha) for tree species in goat prairie sites at Effigy Mounds National Monument, Iowa, 2001–2017. Classes range from midstory (class 1: DBH = 5.0–14.9 cm) to large overstory trees (class 5: DBH ≥ 45 cm).

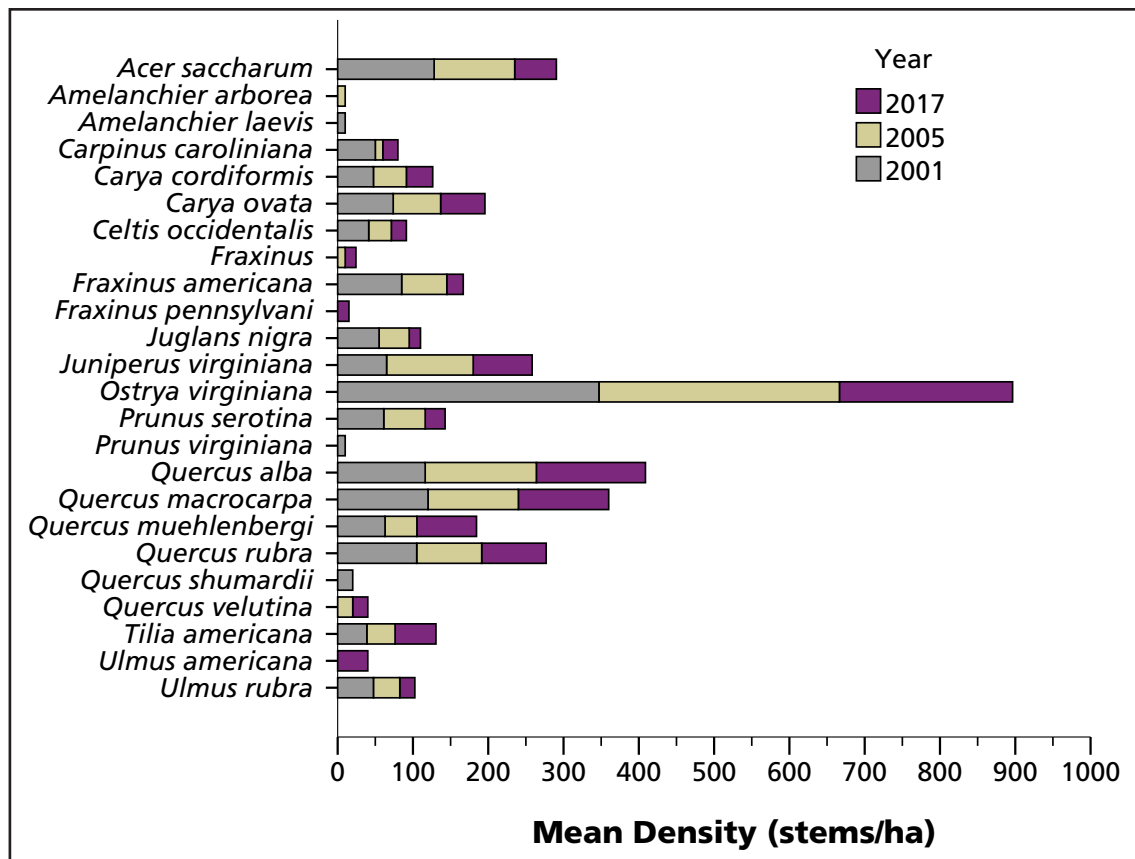


Figure 10. Cumulative mean stem density (stems/ha) for tree species in goat prairie sites at Effigy Mounds National Monument, Iowa, 2001–2017. Color bands represent mean stem density for a given year.

Regeneration

Regeneration density was highly variable across the monitoring sites (Figures 11 and 12). Seedlings make up the greatest portion of the regeneration classes. Large saplings appeared to decline between 2005 and 2017. The mechanism for the decline is unclear, however, oak species tend to need open canopy to reach later stages of regeneration (Johnson et al. 2009).

Ground Cover

Monitoring sites became more vegetated over time (Figure 13). Bare ground declined as well as bare rock, grass litter, and woody debris. This trend is consistent with limited ecological disturbance; ecological disturbance often creates bare ground. The increase in canopy closure could have allowed for more moisture to be captured by vegetation. Thin soiled communities like the juniper-oak glades described by Glenn-Lewin et al. (1984) are limited by water availability and changes in the water dynamics likely led to an increase in vegetated cover.

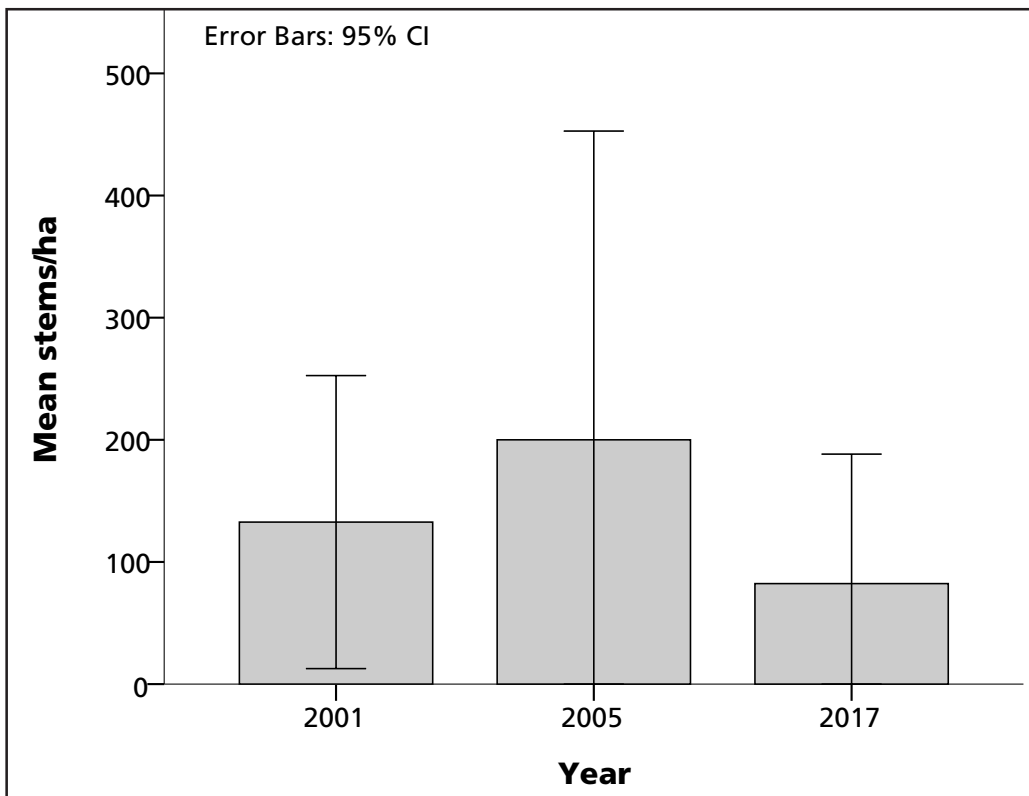


Figure 11. Large sapling (stems ≥ 0.5 m tall and DBH > 2.5 cm and < 5.0 cm) density in goat prairie sites at Effigy Mounds National Monument, Iowa, 2001–2017.

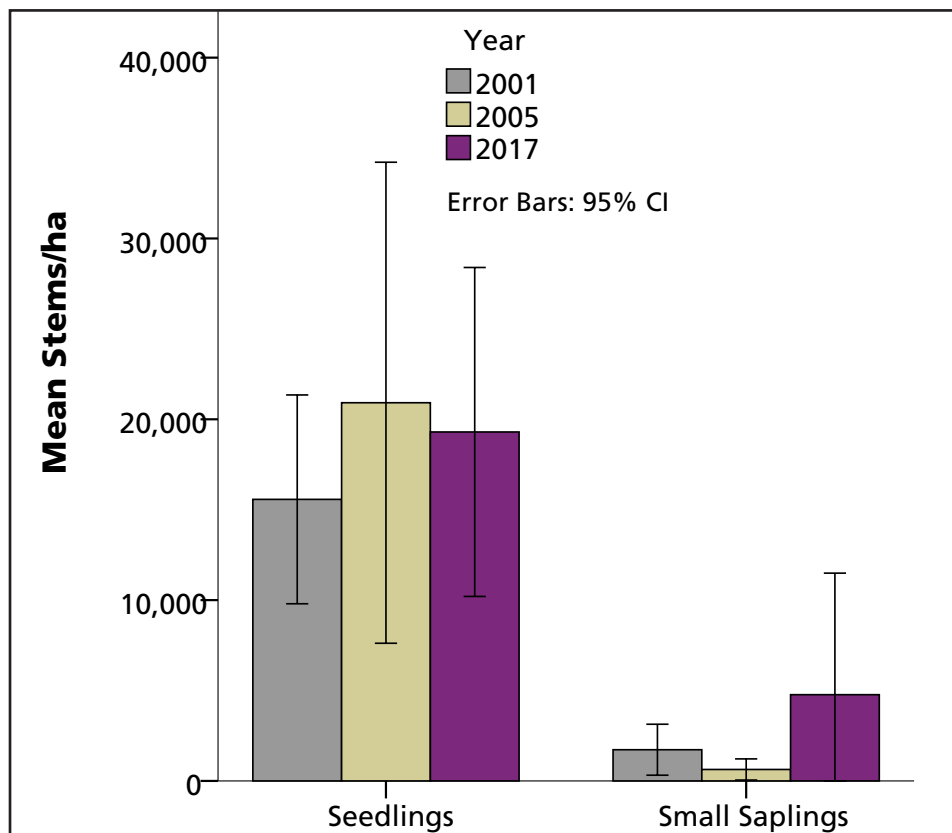


Figure 12. Seedling (< 0.5 m tall) and small sapling (≥ 0.5 m tall, but DBH < 2.5 cm) density in goat prairie sites at Effigy Mounds National Monument, Iowa, 2001–2017.

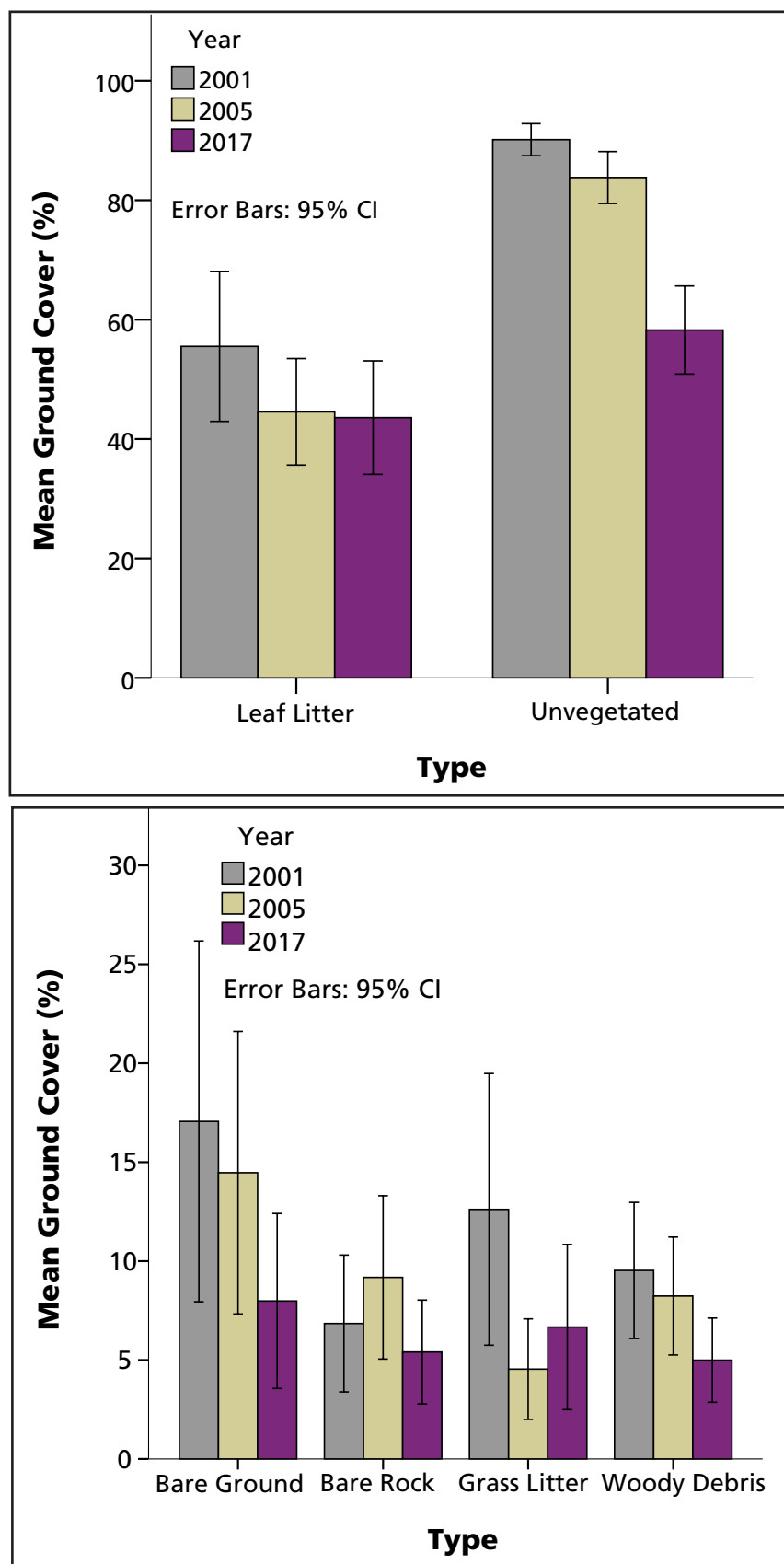


Figure 13. Percent ground cover at Effigy Mounds National Monument, Iowa for 2001-2017: leaf litter and unvegetated categories (top graph) and bare ground, bare rock, grass litter, and woody debris categories (bottom graph).

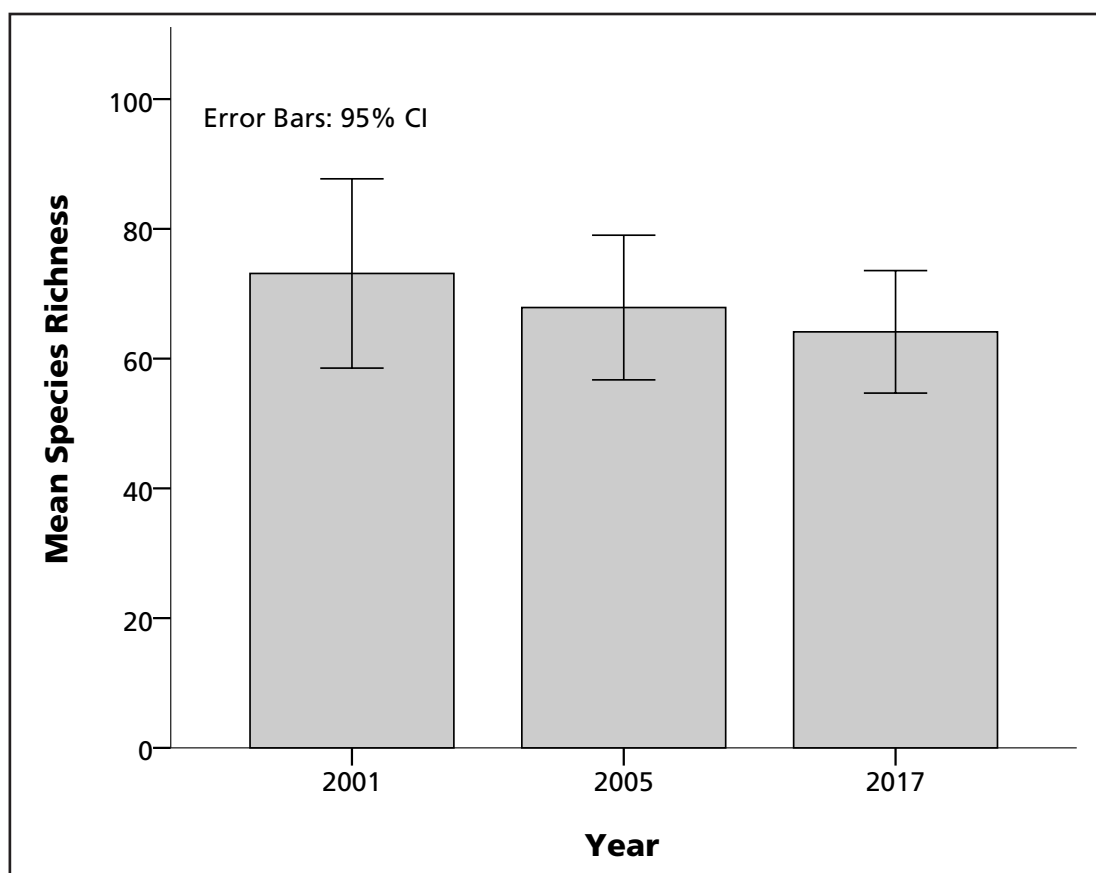


Figure 14. Mean species richness of ground flora in goat prairie sites at Effigy Mounds National Monument, Iowa, 2001–2017.

Ground Flora Diversity

Species

Mean species richness appeared to decline slightly (9 fewer species) between 2001 and 2017 (Figure 14), although there was a great deal of variability among the sites. We did expect a small decline in species richness as a result of shifting from two-season sampling to one-season sampling in 2009; although an estimate was not quantified prior to the change in sampling.

Diversity (H') also declined in 2017, but variability in this index increased (Figure 15). This increase in variability may be related to changes in canopy or tree basal area, but our monitoring is not designed to fully understand the cause and effect of these trends. Quinn Evans Architects et al. (2016) described a decline in diversity as sites transition from oak woodlands to maple-basswood dominated forests.

Community

Gamma diversity (community-level richness), was greatest in 2017 while alpha diversity (mean species richness across sites) declined from 2001 levels (Table 5). The increase in beta diversity (heterogeneity in species distributions across monitoring sites) indicates that sites became slightly more distinct in 2017. Simultaneously, a change in the monitoring revisit design could have influenced the decline in alpha diversity in 2017.

Table 5. Mean native species community diversity of ground flora in goat prairie sites at Effigy Mounds National Monument, Iowa, 2001–2017.

Year	Gamma Diversity	Beta Diversity	Alpha Diversity
2001	189	1.6	73.1
2005	174	1.6	67.9
2017	193	2.0	64.4

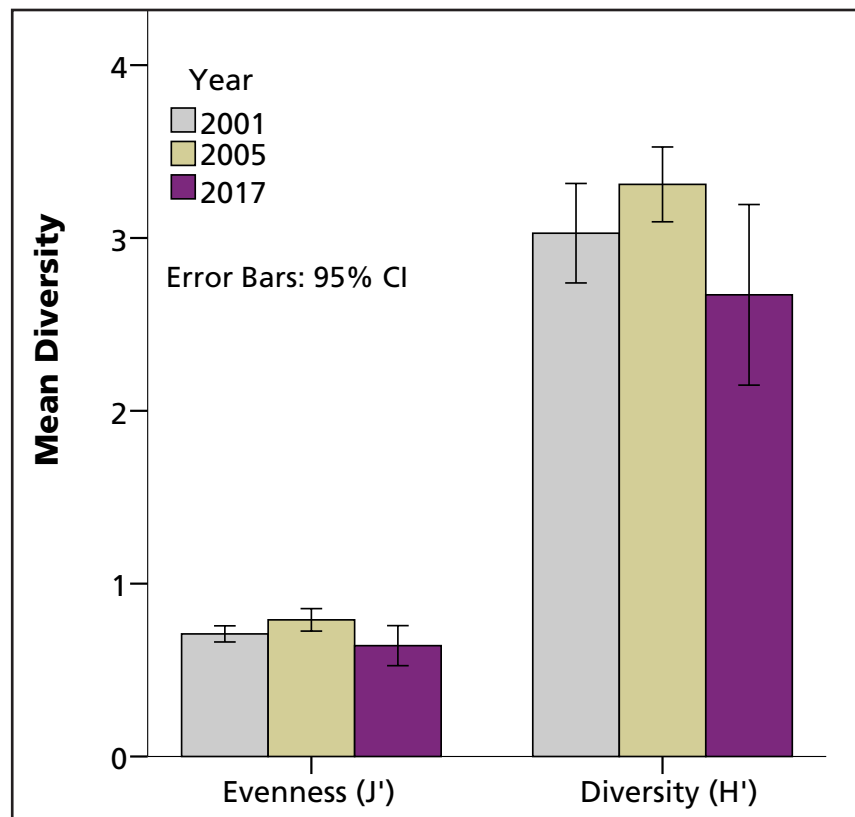


Figure 15. Mean native species evenness and diversity of ground flora in goat prairie sites at Effigy Mounds National Monument, Iowa 2001-2017.

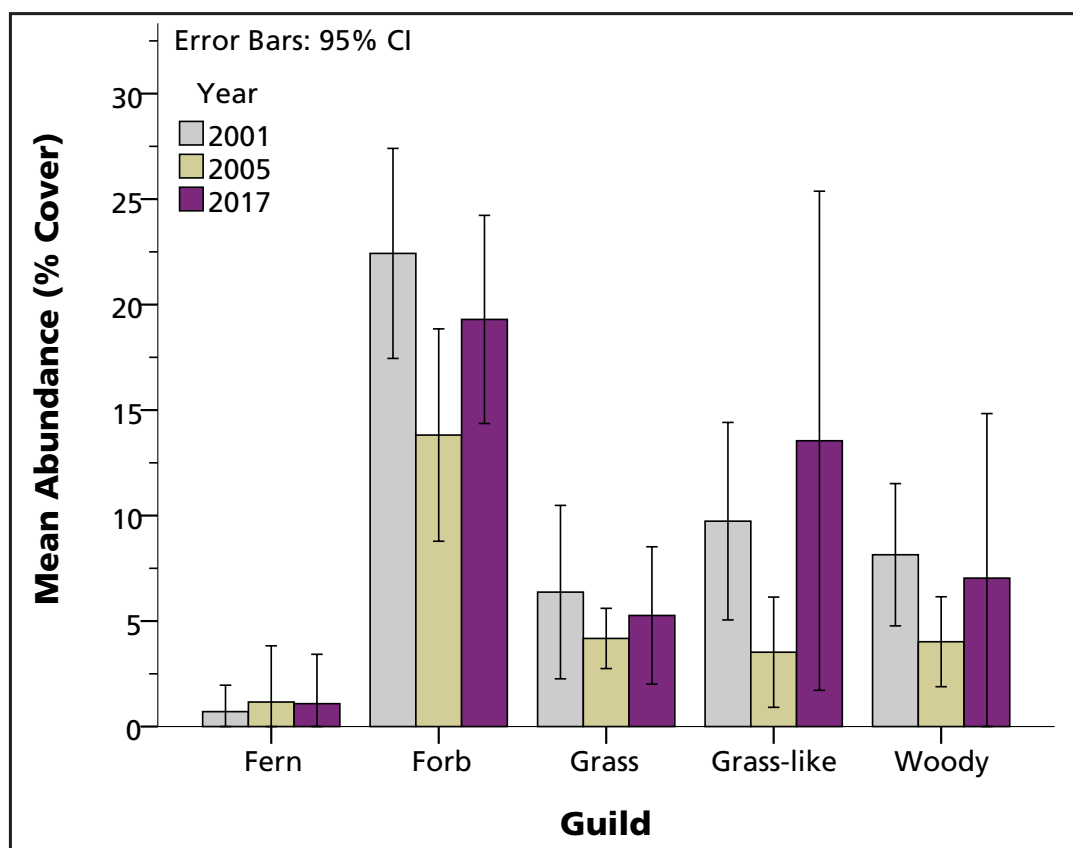


Figure 16. Mean native species abundance by guild in goat prairie sites at Effigy Mounds National Monument, Iowa, 2001–2017.

Guild

Similar to alpha and beta diversity, abundance by plant guild showed a temporary decline in most guilds in 2005 (Figure 16). This was during a period of more active burning in the goat prairies, but it is difficult to determine the cause of this trend. There was a great deal of variability across the sites in guild abundance.

We also assessed a suite of species that are characteristic of prairies and woodlands to understand whether a shift in community type may be occurring (Figure 17). Big bluestem (*Andropogon gerardii*), butterfly weed (*Asclepia tuberosa*), and little bluestem (*Schizachyrium scoparium*) are species most often found in prairies and to some extent in savanna while

pointedleaf ticktrefoil (*Desmodium glutinosum*), Canadian woodnettle (*Laportea canadensis*) and Virginia creeper (*Parthenocissus quinquefolia*) are most often found in woodlands and forest (Rosburg 1999; Eilers and Roosa 2010). Most of these species were low in abundance and variable through time and across sites. The prairie species patterns did not exhibit a clear pattern of change with the exception of decline in 2005. *D. glutinosum* did appear to change substantially and *L. canadensis* became more common although still a minor component of the flora between 2001 and 2017. These indicator species patterns suggest that the prairie savanna component persists, but there is some invasion by woodland and forest species occurring.

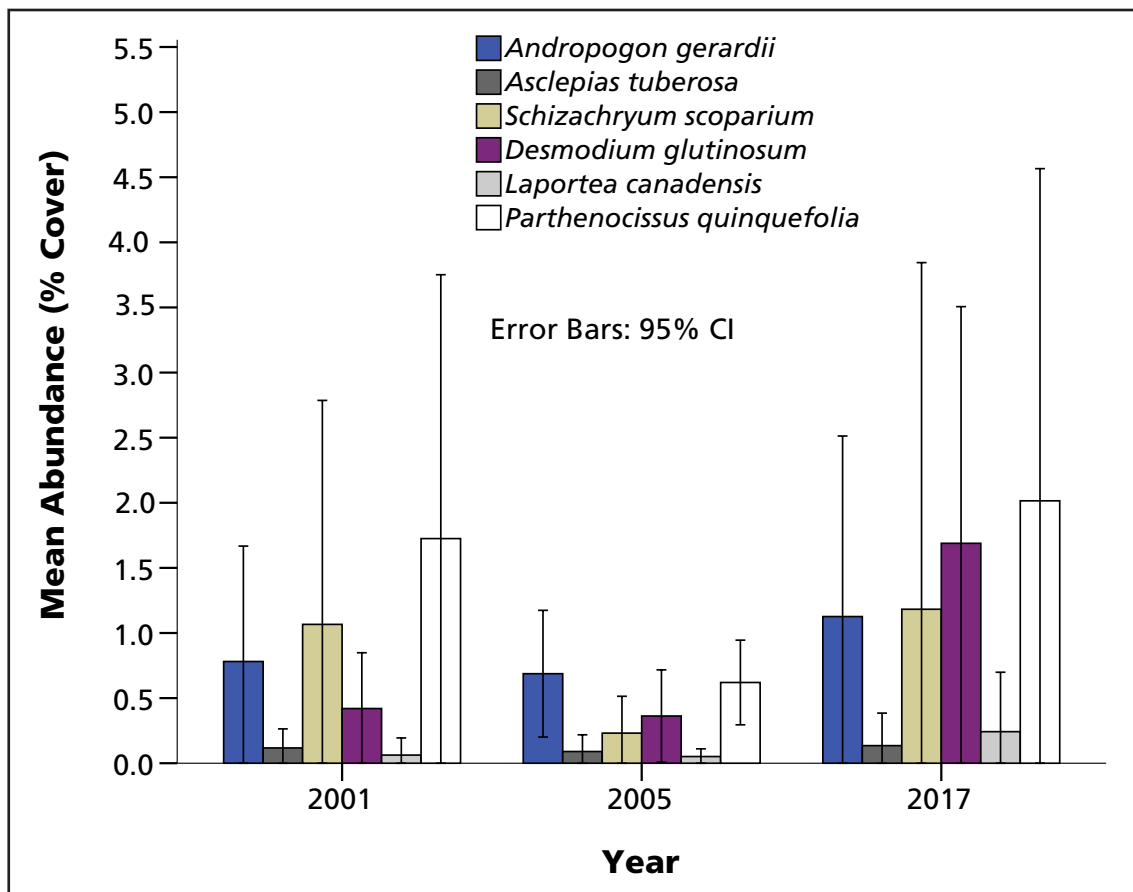


Figure 17. Indicator species abundances in goat prairie sites at Effigy Mounds National Monument, Iowa, 2001–2017.

Non-native species

There were few non-native species across the goat prairie sites (Figure 18). Interestingly, during the period of reduced guild abundance (2005; Figure 16), non-native species peaked. Mean abundance of non-native species in 2017 was less than 0.5% cover for each species at the park scale (Table 6). Non-native treatments have focused on garlic mustard (*Alliaria petiolata*) in recent years, but we had limited

information about whether the treatments affected these monitoring sites. We did note an area of about 5 m² at site 4 in 2017 that had previously been treated for garlic mustard, but we had not detected the species in that site previously. A quantitative assessment of garlic mustard treatments was described by Bell and Young (2017).

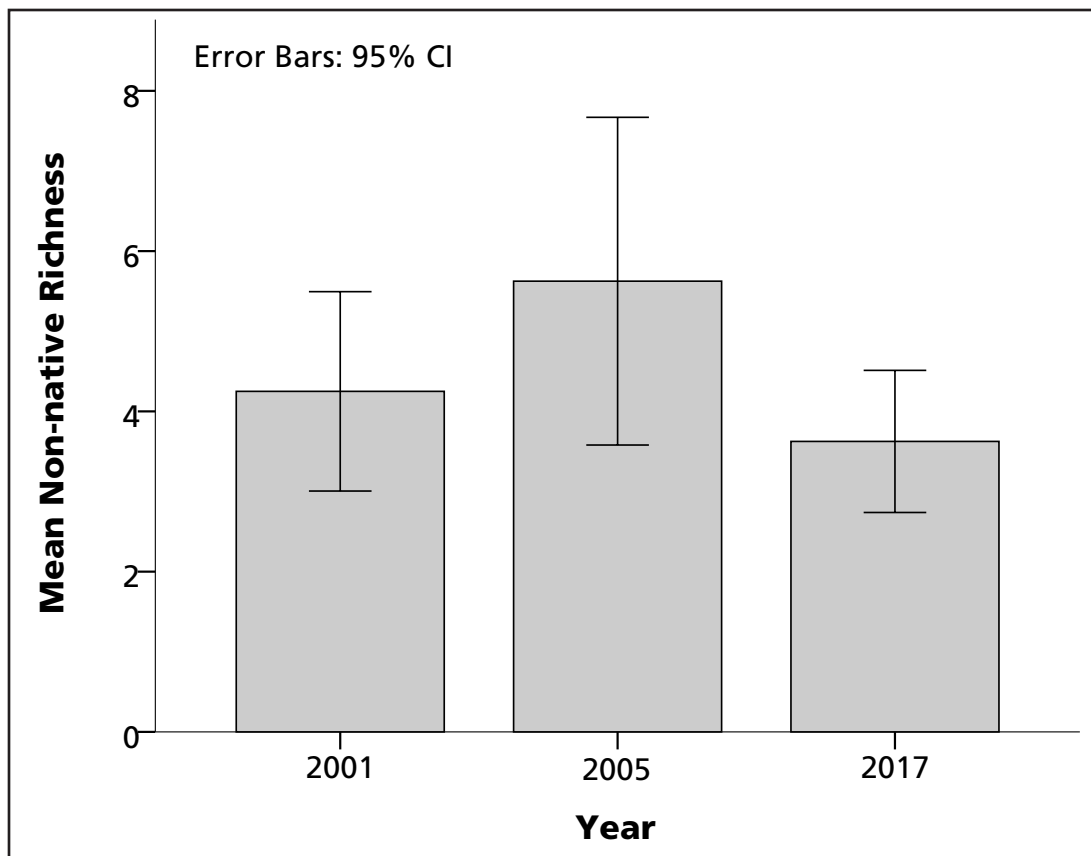


Figure 18. Mean non-native species richness of ground flora in goat prairie sites at Effigy Mounds National Monument, Iowa, 2001–2017.

Table 6. Nonnative plant species observed and mean abundance (mean percent cover) in 2017 in goat prairies at Effigy Mounds National Monument, Iowa. SD = standard deviation.

Species	Common Name	Guild	2017 Mean Abundance (% cover)	SD	Occurrence (% sites observed)
<i>Alliaria petiolata</i>	garlic mustard	forb	0.01	0.04	12.5
<i>Dactylis glomerata</i>	orchardgrass	grass	0.01	0.04	12.5
<i>Echinochloa crus-galli</i>	barnyardgrass	grass	0.01	0.04	12.5
<i>Elymus repens</i>	quackgrass	grass	0.01	0.02	12.5
<i>Lonicera</i> sp.	honeysuckle	woody	0.04	0.05	50
<i>Lonicera morrowii</i>	Morrow's honeysuckle	woody	0.04	0.12	12.5
<i>Lonicera tatarica</i>	Tatarian honeysuckle	woody	0.01	0.04	12.5
<i>Melilotus officinalis</i>	yellow sweetclover	forb	0.01	0.04	12.5
<i>Phalaris arundinacea</i>	reed canarygrass	grass	0.38	1.06	12.5
<i>Poa compressa</i>	Canada bluegrass	grass	0.08	0.22	12.5
<i>Poa pratensis</i>	Kentucky bluegrass	grass	0.19	0.16	87.5
<i>Rhamnus cathartica</i>	common buckthorn	woody	0.02	0.04	25
<i>Taraxacum officinale</i>	common dandelion	forb	0.07	0.05	75
<i>Tragopogon dubius</i>	yellow salsify	forb	0.01	0.02	12.5

Conclusions

This report represents the first completed trend analysis based on long-term monitoring of goat prairie sites at Effigy Mounds National Monument. Although the park implemented limited forest management actions since 1998, including tree thinning and prescribed fire, we do not have spatially explicit knowledge of the thinning locations. Succession of the goat prairie sites toward a deciduous forest community type has slowly progressed despite management actions. This pattern was similar to another study of Effigy Mounds National Monument vegetation (Narumalani et al. 2004). Changes in herbaceous plants were not as clear during our study, but species richness and diversity signaled the potential for decline. Community diversity values also signaled change with greater gamma and beta diversity values in 2017. Species more typical of closed woodland or forest may be invading the communities formerly dominated by prairie and savanna species.

The degree of variability in many of the metrics supports the notion that the goat prairies continue to be unique communities. The process of succession towards forest may be mitigated by the shallow soils characteristic of these sites. Another study (Stolt and Howell 2005) observed little change over a 20-year time frame without disturbance, but subtle changes occurred including additional invasive species in areas where management had occurred (e.g. thinning, burning). In our analysis, the number of invasive species appeared to decline rather than increase. These goat prairie sites will benefit from future management actions, such as burning and thinning, that limit tree encroachment into these communities.

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Appendix A. Native Ground Flora Species

Table A1. Native ground flora species observed in 2017 in goat prairies at Effigy Mounds National Monument, mean abundance (percent cover), and occurrence (percent of sites where species was observed). SD = standard deviation.

Species	Common Name	Guild	Mean Abundance (% cover)	SD	Occurrence (% sites observed)
<i>Achillea millefolium</i>	common yarrow	forb	0.01	0.02	12.5
<i>Ageratina altissima</i>	white snakeroot	forb	0.09	0.14	37.5
<i>Agrimonia pubescens</i>	soft agrimony	forb	0.03	0.07	25
<i>Ambrosia</i> sp.	ragweed	forb	0.01	0.02	12.5
<i>Ambrosia artemisiifolia</i>	annual ragweed	forb	0.04	0.07	37.5
<i>Amorpha canescens</i>	leadplant	forb	0.15	0.20	75
<i>Amphicarpaea bracteata</i>	American hogpeanut	forb	4.55	4.64	100
<i>Andropogon gerardii</i>	big bluestem	grass	1.13	1.66	87.5
<i>Anemone</i> sp.	anemone	forb	0.02	0.03	25
<i>Anemone cylindrica</i>	candle anemone	forb	0.05	0.05	62.5
<i>Anemone virginiana</i>	tall thimbleweed	forb	0.07	0.11	37.5
<i>Antennaria plantaginifolia</i>	woman's tobacco	forb	0.51	0.71	75
<i>Apocynum androsaemifolium</i>	spreading dogbane	forb	0.02	0.06	12.5
<i>Apocynum cannabinum</i>	Indianhemp	forb	0.1	0.29	12.5
<i>Aquilegia canadensis</i>	red columbine	forb	0.03	0.05	37.5
<i>Arabis canadensis</i>	sicklepod	forb	0.01	0.04	12.5
<i>Arabis lyrata</i>	lyrate rockcress	forb	0.06	0.11	37.5
<i>Aralia nudicaulis</i>	wild sarsaparilla	forb	0.01	0.02	12.5
<i>Arisaema triphyllum</i>	Jack in the pulpit	forb	0.03	0.06	25
<i>Artemisia dracunculus</i>	tarragon	forb	0.01	0.02	12.5
<i>Asarum canadense</i>	Canadian wildginger	forb	0.02	0.04	25
<i>Asclepias</i> sp.	milkweed	forb	0.01	0.04	12.5
<i>Asclepias exaltata</i>	poke milkweed	forb	0.04	0.07	37.5
<i>Asclepias hirtella</i>	green milkweed	forb	0.01	0.02	12.5
<i>Asclepias speciosa</i>	showy milkweed	forb	0.01	0.02	12.5
<i>Asclepias tuberosa</i>	butterfly milkweed	forb	0.14	0.30	37.5
<i>Asclepias verticillata</i>	whorled milkweed	forb	0.03	0.07	25
<i>Aureolaria pedicularia</i>	fernleaf yellow false foxglove	forb	0.03	0.05	25
<i>Botrychium multifidum</i>	leathery grapefern	fern	0.03	0.07	12.5
<i>Botrychium virginianum</i>	rattlesnake fern	fern	0.04	0.06	37.5
<i>Bouteloua curtipendula</i>	sideoats grama	grass	0.61	1.65	37.5
<i>Brachyelytrum erectum</i>	bearded shorthusk	grass	0.01	0.02	12.5
<i>Brickellia eupatorioides</i>	false boneset	forb	0.05	0.12	25
<i>Bromus kalmii</i>	arctic brome	grass	0.01	0.02	12.5
<i>Bromus pubescens</i>	hairy woodland brome	grass	0.39	0.67	62.5

Table A1 (continued). Native ground flora species observed in 2017 in goat prairies at Effigy Mounds National Monument, mean abundance (percent cover), and occurrence (percent of sites where species was observed). SD = standard deviation.

Species	Common Name	Guild	Mean Abundance (% cover)	SD	Occurrence (% sites observed)
<i>Calystegia spithamea</i>	low false bindweed	forb	0.04	0.10	12.5
<i>Campanula rotundifolia</i>	bluebell bellflower	forb	0.1	0.11	62.5
<i>Campanulastrum americanum</i>	American bellflower	forb	0.01	0.04	12.5
<i>Carex</i> sp.	sedge	grass-like	13.55	14.15	100
<i>Ceanothus herbaceus</i>	Jersey tea	woody	0.01	0.02	12.5
<i>Celastrus</i> sp.	bittersweet	woody	0.01	0.02	12.5
<i>Celastrus scandens</i>	American bittersweet	woody	0.01	0.03	25
<i>Circaea lutetiana</i> ssp. <i>canadensis</i>	broadleaf enchanter's nightshade	forb	0.09	0.13	50
<i>Cirsium altissimum</i>	tall thistle	forb	0.22	0.46	37.5
<i>Comandra umbellata</i>	bastard toadflax	forb	0.06	0.07	62.5
<i>Convolvulus</i> sp.	bindweed	forb	0.01	0.04	12.5
<i>Coreopsis palmata</i>	stiff tickseed	forb	0.17	0.27	50
<i>Cornus racemosa</i>	gray dogwood	woody	0.07	0.09	37.5
<i>Cornus rugosa</i>	roundleaf dogwood	woody	0.01	0.02	12.5
<i>Corylus americana</i>	American hazelnut	woody	0.01	0.04	12.5
<i>Cystopteris fragilis</i>	brittle bladderfern	fern	0.03	0.05	25
<i>Dalea purpurea</i>	purple prairie clover	forb	0.15	0.22	50
<i>Danthonia spicata</i>	poverty oatgrass	grass	0.18	0.28	50
<i>Desmodium canadense</i>	showy ticktrefoil	forb	0.02	0.05	12.5
<i>Desmodium glutinosum</i>	pointedleaf ticktrefoil	forb	1.69	2.17	75
<i>Desmodium nudiflorum</i>	nakedflower ticktrefoil	forb	0.01	0.02	12.5
<i>Diarrhena obovata</i>	obovate beakgrass	grass	0.01	0.04	12.5
<i>Dichanthelium</i> sp.	rosette grass	grass	0.31	0.24	100
<i>Dichanthelium latifolium</i>	broadleaf rosette grass	grass	0.01	0.02	12.5
<i>Dioscorea villosa</i>	wild yam	forb	0.2	0.45	62.5
<i>Dodecatheon amethystinum</i>	jeweled shootingstar	forb	0.03	0.05	25
<i>Elymus</i> sp.	wildrye	grass	0.01	0.02	12.5
<i>Elymus canadensis</i>	Canada wildrye	grass	0.01	0.02	12.5
<i>Elymus hystrix</i> var. <i>hystrix</i>	eastern bottlebrush grass	grass	0.41	0.44	100
<i>Elymus villosus</i>	hairy wildrye	grass	0.09	0.25	12.5
<i>Elymus virginicus</i>	Virginia wildrye	grass	0.15	0.42	12.5
<i>Erigeron annuus</i>	eastern daisy fleabane	forb	0.02	0.04	25
<i>Erigeron strigosus</i>	prairie fleabane	forb	0.03	0.04	37.5
<i>Eupatorium altissimum</i>	tall thoroughwort	forb	0.03	0.06	25
<i>Euphorbia corollata</i>	flowering spurge	forb	0.2	0.22	75
<i>Euphorbia cyathophora</i>	fire on the mountain	forb	0.04	0.11	12.5
<i>Festuca subverticillata</i>	nodding fescue	grass	0.04	0.08	25

Table A1 (continued). Native ground flora species observed in 2017 in goat prairies at Effigy Mounds National Monument, mean abundance (percent cover), and occurrence (percent of sites where species was observed). SD = standard deviation.

Species	Common Name	Guild	Mean Abundance (% cover)	SD	Occurrence (% sites observed)
<i>Fragaria virginiana</i>	Virginia strawberry	forb	0.01	0.04	12.5
<i>Galium aparine</i>	stickywilly	forb	0.05	0.06	50
<i>Galium asprellum</i>	rough bedstraw	forb	0.15	0.32	25
<i>Galium boreale</i>	northern bedstraw	forb	0.39	0.48	75
<i>Galium circaezans</i>	licorice bedstraw	forb	0.23	0.25	75
<i>Galium concinnum</i>	shining bedstraw	forb	0.35	0.30	87.5
<i>Galium lanceolatum</i>	lanceleaf wild licorice	forb	0.06	0.12	25
<i>Galium trifidum</i>	threepetal bedstraw	forb	0.01	0.02	12.5
<i>Gentiana alba</i>	Pale gentian	forb	0.01	0.02	12.5
<i>Geranium maculatum</i>	spotted geranium	forb	0.05	0.07	37.5
<i>Geum canadense</i>	white avens	forb	0.09	0.14	50
<i>Hackelia virginiana</i>	beggarslice	forb	0.03	0.04	37.5
<i>Helianthus occidentalis</i>	fewleaf sunflower	forb	0.06	0.16	12.5
<i>Helianthus strumosus</i>	paleleaf woodland sunflower	forb	1.44	1.05	100
<i>Hepatica nobilis</i> var. <i>acuta</i>	sharplobe hepatica	forb	0.13	0.35	12.5
<i>Hepatica nobilis</i> var. <i>obtusata</i>	roundlobe hepatica	forb	0.01	0.04	12.5
<i>Hesperostipa spartea</i>	Porcupine-grass	grass	0.01	0.02	12.5
<i>Heuchera richardsonii</i>	Richardson's alumroot	forb	0.02	0.05	25
<i>Hieracium canadense</i>	Canadian hawkweed	forb	0.01	0.02	12.5
<i>Hieracium scabrum</i>	rough hawkweed	forb	0.02	0.03	25
<i>Hieracium umbellatum</i>	narrowleaf hawkweed	forb	0.01	0.02	12.5
<i>Hydrophyllum virginianum</i>	eastern waterleaf	forb	0.13	0.32	25
<i>Impatiens pallida</i>	pale touch-me-not	forb	0.01	0.02	12.5
<i>Lactuca</i> sp.	lettuce	forb	0.02	0.03	25
<i>Lactuca canadensis</i>	Canada lettuce	forb	0.08	0.09	50
<i>Laportea canadensis</i>	Canadian woodnettle	forb	0.24	0.55	25
<i>Lechea stricta</i>	prairie pinweed	forb	0.01	0.02	12.5
<i>Liatris aspera</i>	tall blazing star	forb	0.01	0.04	12.5
<i>Lithospermum</i> sp.	stoneseed	forb	0.01	0.02	12.5
<i>Lithospermum canescens</i>	hoary puccoon	forb	0.04	0.08	25
<i>Lobelia spicata</i>	palespike lobelia	forb	0.01	0.02	12.5
<i>Maianthemum racemosum</i> ssp. <i>racemosum</i>	feathery false lily of the valley	forb	0.06	0.12	37.5
<i>Maianthemum stellatum</i>	starry false lily of the valley	forb	0.02	0.03	25
<i>Menispermum canadense</i>	common moonseed	woody	0.01	0.02	12.5
<i>Monarda fistulosa</i>	wild bergamot	forb	0.38	0.57	62.5
<i>Monotropa uniflora</i>	Indianpipe	forb	0.03	0.07	25

Table A1 (continued). Native ground flora species observed in 2017 in goat prairies at Effigy Mounds National Monument, mean abundance (percent cover), and occurrence (percent of sites where species was observed). SD = standard deviation.

Species	Common Name	Guild	Mean Abundance (% cover)	SD	Occurrence (% sites observed)
<i>Muhlenbergia</i> sp.	muhly	grass	0.2	0.20	75
<i>Muhlenbergia cuspidata</i>	plains muhly	grass	0.05	0.08	37.5
<i>Muhlenbergia schreberi</i>	nimblewill	grass	0.04	0.12	12.5
<i>Muhlenbergia sobolifera</i>	rock muhly	grass	0.01	0.04	12.5
<i>Oenothera biennis</i>	common evening primrose	forb	0.01	0.02	12.5
<i>Osmorhiza</i> sp.	sweetroot	forb	0.04	0.05	37.5
<i>Osmorhiza claytonii</i>	Clayton's sweetroot	forb	0.01	0.04	12.5
<i>Osmorhiza longistylis</i>	longstyle sweetroot	forb	0.01	0.04	12.5
<i>Oxalis</i> sp.	woodsorrel	forb	0.01	0.04	12.5
<i>Oxalis violacea</i>	violet woodsorrel	forb	0.01	0.04	12.5
<i>Parthenocissus quinquefolia</i>	Virginia creeper	woody	2.02	3.05	100
<i>Pedicularis canadensis</i>	Canadian lousewort	forb	0.02	0.04	12.5
<i>Phlox pilosa</i>	downy phlox	forb	0.05	0.07	37.5
<i>Phryma leptostachya</i>	American lopseed	forb	0.41	0.69	87.5
<i>Physalis heterophylla</i>	clammy groundcherry	forb	0.01	0.04	12.5
<i>Physalis virginiana</i>	Virginia groundcherry	forb	0.06	0.10	50
<i>Pilea pumila</i>	Canadian clearweed	forb	0.02	0.04	25
<i>Piptatherum racemosum</i>	Blackseed ricegrass	grass	0.05	0.11	25
<i>Podophyllum peltatum</i>	mayapple	forb	0.01	0.03	25
<i>Polemonium reptans</i>	Greek valerian	forb	0.02	0.04	25
<i>Polygala senega</i>	Seneca snakeroot	forb	0.02	0.04	25
<i>Polygonatum biflorum</i>	smooth Solomon's seal	forb	0.01	0.02	12.5
<i>Polygonum virginianum</i>	jumpseed	forb	0.09	0.16	25
<i>Polymnia canadensis</i>	whiteflower leafcup	forb	0.01	0.04	12.5
<i>Potentilla arguta</i>	tall cinquefoil	forb	0.05	0.06	50
<i>Potentilla simplex</i>	common cinquefoil	forb	0.01	0.02	12.5
<i>Prenanthes alba</i>	white rattlesnakeroot	forb	0.07	0.07	62.5
<i>Prunus virginiana</i>	chokecherry	woody	0.01	0.04	12.5
<i>Ptelea trifoliata</i>	common hoptree	woody	0.01	0.04	12.5
<i>Pteridium aquilinum</i>	western brackenfern	fern	0.99	2.79	12.5
<i>Ranunculus abortivus</i>	littleleaf buttercup	forb	0.09	0.09	62.5
<i>Ratibida pinnata</i>	pinnate prairie coneflower	forb	0.12	0.14	75
<i>Ribes</i> sp.	currant	woody	0.07	0.14	37.5
<i>Ribes missouriense</i>	Missouri gooseberry	woody	0.06	0.14	25
<i>Rosa</i> sp.	rose	woody	0.05	0.07	37.5
<i>Rubus</i> sp.	blackberry	woody	0.78	1.27	50
<i>Sanguinaria canadensis</i>	bloodroot	forb	0.07	0.09	50

Table A1 (continued). Native ground flora species observed in 2017 in goat prairies at Effigy Mounds National Monument, mean abundance (percent cover), and occurrence (percent of sites where species was observed). SD = standard deviation.

Species	Common Name	Guild	Mean Abundance (% cover)	SD	Occurrence (% sites observed)
<i>Sanicula</i> sp.	sanicle	forb	0.04	0.05	50
<i>Sanicula canadensis</i>	Canadian blacksnakeroot	forb	0.03	0.05	25
<i>Sanicula marilandica</i>	Maryland sanicle	forb	0.09	0.21	25
<i>Sanicula odorata</i>	clustered blacksnakeroot	forb	0.01	0.04	12.5
<i>Schizachyrium scoparium</i>	little bluestem	grass	1.18	3.18	50
<i>Scrophularia lanceolata</i>	lanceleaf figwort	forb	0.02	0.04	25
<i>Scutellaria parvula</i>	small skullcap	forb	0.11	0.16	50
<i>Sisyrinchium albidum</i>	white blue-eyed grass	forb	0.01	0.02	12.5
<i>Sisyrinchium campestre</i>	prairie blue-eyed grass	forb	0.05	0.07	50
<i>Smilax</i> sp.	greenbrier	woody	0.03	0.04	37.5
<i>Smilax tamnoides</i>	bristly greenbrier	woody	0.16	0.25	75
<i>Solidago</i> sp.	goldenrod	forb	0.02	0.03	37.5
<i>Solidago canadensis</i>	Canada goldenrod	forb	0.04	0.06	37.5
<i>Solidago flexicaulis</i>	zigzag goldenrod	forb	0.01	0.04	12.5
<i>Solidago nemoralis</i>	gray goldenrod	forb	0.05	0.10	25
<i>Solidago speciosa</i>	showy goldenrod	forb	0.15	0.39	37.5
<i>Solidago ulmifolia</i>	elmleaf goldenrod	forb	2.65	1.37	100
<i>Sorghastrum nutans</i>	Indiangrass	grass	0.27	0.72	25
<i>Sporobolus heterolepis</i>	prairie dropseed	grass	0.1	0.16	37.5
<i>Symphoricarpos albus</i>	common snowberry	woody	0.01	0.02	12.5
<i>Symphoricarpos orbiculatus</i>	coralberry	woody	0.05	0.13	12.5
<i>Symphyotrichum cordifolium</i>	Common blue heart-leaved wild aster	forb	0.12	0.18	50
<i>Symphyotrichum drummondii</i> var. <i>drummondii</i>	Hairy heart-leaved wild aster	forb	0.09	0.11	50
<i>Symphyotrichum ericoides</i> var. <i>ericoides</i>	Squarrose white wild aster	forb	0.01	0.02	12.5
<i>Symphyotrichum lanceolatum</i> ssp. <i>lanceolatum</i> var. <i>lanceolatum</i>	white panicle aster	forb	0.05	0.14	12.5
<i>Symphyotrichum lateriflorum</i> var. <i>lateriflorum</i>	Goblet wild aster	forb	0.01	0.04	12.5
<i>Symphyotrichum oblongifolium</i>	Aromatic wild aster	forb	0.3	0.67	62.5
<i>Symphyotrichum oolentangiense</i>	skyblue aster	forb	0.01	0.04	12.5
<i>Symphyotrichum oolentangiense</i> var. <i>oolentangiense</i>	skyblue aster	forb	0.09	0.18	25
<i>Symphyotrichum shortii</i>	Short's aster	forb	0.17	0.15	75
<i>Taenidia integerrima</i>	yellow pimpernel	forb	0.01	0.04	12.5
<i>Thalictrum thalictroides</i>	rue anemone	forb	0.08	0.14	37.5
<i>Thelypteris noveboracensis</i>	New York fern	fern	0.01	0.02	12.5

Table A1 (continued). Native ground flora species observed in 2017 in goat prairies at Effigy Mounds National Monument, mean abundance (percent cover), and occurrence (percent of sites where species was observed). SD = standard deviation.

Species	Common Name	Guild	Mean Abundance (% cover)	SD	Occurrence (% sites observed)
<i>Toxicodendron radicans</i>	eastern poison ivy	woody	0.05	0.10	25
<i>Tradescantia ohiensis</i>	bluejacket	forb	0.07	0.12	37.5
<i>Tridens flavus</i>	purpletop tridens	grass	0.01	0.02	12.5
<i>Triodanis perfoliata</i>	clasping Venus' looking-glass	forb	0.09	0.10	62.5
<i>Triosteum perfoliatum</i>	feverwort	forb	0.01	0.02	12.5
<i>Uvularia grandiflora</i>	largeflower bellwort	forb	0.05	0.07	37.5
<i>Verbena urticifolia</i>	white vervain	forb	0.01	0.02	12.5
<i>Veronicastrum virginicum</i>	Culver's root	forb	0.03	0.04	37.5
<i>Viburnum</i> sp.	viburnum	woody	0.01	0.02	12.5
<i>Viola</i> sp.	violet	forb	0.21	0.14	87.5
<i>Vitis</i> sp.	grape	woody	0.21	0.25	62.5
<i>Zanthoxylum americanum</i>	common pricklyash	woody	3.37	5.31	87.5
<i>Zizia aurea</i>	golden zizia	forb	0.01	0.02	12.5

Table A2. Species observed in 2017 but recorded to a higher level of taxonomy and species occurrence (percent of sites where species was observed).

Species	Common Name	Recorded to:	Guild	Nativity	Occurrence (% of sites observed)
<i>Carex pensylvanica</i>	Pennsylvania sedge	<i>Carex</i> sp.	grass-like	native	100
<i>Carex cephalophora</i>	oval-leaf sedge	<i>Carex</i> sp.	grass-like	native	12.5
<i>Carex eburnea</i>	bristleleaf sedge	<i>Carex</i> sp.	grass-like	native	37.5
<i>Dichanthelium latifolium</i>	broadleaf rosette grass	<i>Dichanthelium</i> sp.	grass	native	37.5
<i>Dichanthelium oligosanthos</i> var. <i>scribnerianum</i>	Scribner's rosette grass	<i>Dichanthelium</i> sp.	grass	native	12.5
<i>Oxalis stricta</i>	common yellow oxalis	<i>Oxalis</i> sp.	forb	native	12.5
<i>Rubus allegheniensis</i>	Allegheny blackberry	<i>Rubus</i> sp.	subshrub	native	12.5
<i>Rubus occidentalis</i>	black raspberry	<i>Rubus</i> sp.	subshrub	native	50.0
<i>Vitis aestivalis</i>	Summer grape	<i>Vitis</i> sp.	Woody	native	25.0
<i>Vitis riparia</i>	riverbank grape	<i>Vitis</i> sp.	woody	native	25

Appendix B. Mean Canopy Closure

Table B1. Mean canopy closure (%) by site and year.

Site	Year	Mean Canopy Closure (%)
1	2001	32.01
1	2005	69.32
1	2017	59.28
2	2001	91.57
2	2005	96.62
2	2017	86.79
4	2001	71.64
4	2005	71.15
4	2017	82.06
5	2001	68.69
5	2005	87.78
5	2017	87.15
6	2001	58
6	2005	68.74
6	2017	74.95
13	2001	74.7
13	2005	84.01
13	2017	84.34
14	2001	70.88
14	2005	80.29
14	2017	83.51
16	2001	77.4
16	2005	81.12
16	2017	87.26

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