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STRUCTURE AND COMPOSITION OF PLANT COMMUNITIES IN FIRE-MANAGED GRASSLANDS AT BIG OAKS NATIONAL WILDLIFE REFUGE

Gary L. Basey and **Kemuel S. Badger**: Department of Biology, Ball State University, Muncie, Indiana 47306 USA

ABSTRACT. Big Oaks National Wildlife Refuge, formerly Jefferson Proving Grounds, is one of Indiana's largest natural areas (approximately 22,000 ha). No studies have been conducted to quantify the grassland communities at Big Oaks National Wildlife Refuge. Establishing a baseline of information regarding the plant community composition and structure would be helpful to monitor changes resulting from current management practices. Sixty permanently-marked 10 m radius circular plots were established in three managed grassland communities within the refuge. Three vegetation layers (overstory, understory, and ground layer) were sampled during July-August 2001. Overstory trees (> 10 cm dbh) were sampled in each plot and consisted mainly of *Carya ovata*, *Liquidamber styraciflua*, and *Nyssa sylvatica*. The understory (< 1.5 m but > 0.5 m) was sampled in sixty 2 × 2 m subplots in each grassland area. The understory was dominated by *Rhus copallinum*, *Sassafras albidum*, and *Liquidamber styraciflua*. The ground layer (all herbaceous species and those woody stem > 0.5 m) was sampled using 1 × 1 m subplots in each grassland. Fifty-four different species were sampled in the ground layer. *Andropogon virginicus* and *Solidago juncea* were the dominant plant species in the permanent plots.

Keywords: Big Oaks NWR, Indiana, fire management, grassland community, biodiversity

In July 2000, the U.S. Army military site, formerly known as Jefferson Proving Ground, was re-dedicated as Big Oaks National Wildlife Refuge (Big Oaks NWR). Big Oaks NWR contains large grassland areas that have been increased and maintained by the frequent use of fire as a management tool as well as wildfires associated with munitions testing from 1941–1994 (USFWS 2001). The use of fire as a management tool is essential in maintaining the biodiversity associated with the grassland habitats within Big Oaks NWR. These extensive grasslands support viable populations of many species of plants and animals that are declining elsewhere throughout their range. No quantitative studies have been completed to describe the plant community composition of these grassland areas.

Two plant inventories were conducted prior to the formation of the refuge (Hedge et al. 1993; Hedge et al. 1999). These inventories identified vascular plants listed within the site as endangered, threatened, rare, or watch list. These inventories are important to document occurrences of these species. A quantitative study can provide additional information to describe the plant community structure and composition of these grassland areas.

Prescribed burning is used to maintain the integrity of fire-dependent plant communities (Bond & Van Wilgen 1992). These fire-dependent communities support populations of plant and animal species of special concern. The primary function of the use of fire as a management tool at Big Oaks National Wildlife Refuge is to maintain the grassland habitats by reducing the density of woody vegetation (USFWS 2001). The current fire management plan for Big Oaks National Wildlife Refuge divides the grasslands into fire management units. Portions of the management units are burned each year to produce spatial variation in grassland maturity for any given year.

Collecting vegetation data in permanently-marked monitoring plots is the most reliable method of assessing changes in plant communities (Elzinga et al. 2001). This study was designed to establish a baseline of information to monitor the effect that prescribed burns have on structure and composition of grassland communities within Big Oaks NWR. Monitoring provides a logical and objective basis for taking management actions and expands current knowledge of ecosystem prop-

Figure 1.—Big Oaks National Wildlife Refuge, a 22,000 hectare preserve formerly known as the Jefferson Proving Ground, is located in Jefferson, Jennings, and Ripley counties in southeastern Indiana.

erties and processes (Spellerberg 1994). Vegetation monitoring will provide information leading to a greater understanding of grassland habitats within Big Oaks NWR. This information provides feedback, for resource managers, concerning the achievement of fire management objectives and the impact of prescribed burns on specific locations.

STUDY SITE

Big Oaks NWR is a 22,000 ha (51,000 acres) area located in Jefferson, Ripley, and Jennings counties in southeastern Indiana (Fig. 1). Prior to being used as an ordnance test facility, the open areas were used for agriculture. Remnants of these earlier settlements can be observed throughout the refuge. The road system created during settlement was maintained by the U.S. military to provide for easy access throughout the property.

The open areas used for agriculture became the primary sites for ammunition testing. During the 55 years Jefferson Proving Ground operated, over 22 million pieces of ordnance were dropped on what is now the wildlife refuge (USFWS 2001). An estimated 1.3 million pieces of unexploded ordnance (UXO), remain on or just below the surface. Because of the presence of UXO, a perimeter fence is maintained around the property and a large portion of Big Oaks is restricted from access to human activities. Unrestricted areas, those cleared of UXO, were identified for establishing permanent monitoring plots.

The grassland areas, created by agriculture and maintained through prescribed burns, contain a unique combination of herbaceous and woody plant species that attract a diversity of wildlife species. The grasslands were divided into 27 units ranging in size from 10–1010 ha. The designated units contain large forested tracts intermixed with grassland areas.

Permanent plots were established in three unrestricted grassland areas in designated fire management units within the refuge. Plot locations were identified with the assistance of Big Oaks NWR management personnel. Selection was based on management concerns for plant and animal species occurring in those grassland areas.

The first grassland site, located in Management Area 5, is a 53 ha area formerly used as a UXO demonstration site where the U.S. Army tested ordnance-removal techniques. This site has been heavily altered by fire, mowing, and extensive earth movement. This area was last burned during the Spring of 2000 and mowing continues within the demonstration area. The permanent plots were placed outside of the mowed area.

The second grassland site, located in Management Area 16, was cleared of UXO and has been heavily altered by management practices. Small woodland patches (<0.5 ha) occur along stream corridors within the grassland. Fire tolerant woody shrub species are beginning to invade the grassland area, but few trees are present. Some felled trees, cut prior to the study period, were observed in the grassland area.

The third grassland site, located in Management Area 26, is a 61 ha area that was last burned in 1999. The area is predominately open grasslands with small isolated woodlands. There is an old home-site located within the area with remnants of vegetation planted by former settlers.

Although these grasslands do not constitute typical tallgrass prairies, these areas are dominated by native plant species. These species are fire-resistant and tolerant of strongly acidic soils. The underlying soil conditions, both acidity and permeability, as well as current management practices, are likely to ensure that the present species composition will persist in the future.

The monitoring protocol developed in this study provides an efficient method to assess plant community structure and composition. Resampling these permanently marked plots would provide meaningful information concerning long-term trends in plant community structure. The information concerning the three vegetation strata can be used as a benchmark for future monitoring efforts. Maintaining these unique midwestern grasslands is vital to maintain the unique biodiversity at Big Oaks National Wildlife Refuge.

METHODS

Within each grassland area, 20 circular plots, each 10 m in radius, were randomly placed within 10 m of an 800 m baseline. Each baseline was oriented so that it occurred entirely within a single grassland. The center of each plot was permanently marked with a steel stake, and Universal Trans Mercatur (UTM) coordinates (NAD 83) were recorded using the Global Positioning System (GPS) with a Garmin GPS III+ receiver. Three different vegetation layers were sampled within each 10 m radius plot. All sampling was conducted from July-August when herbaceous vegetation was fully developed.

Overstory.—The overstory layer was defined as woody plants with a diameter at breast height (dbh) >10 cm. All individual tree stems within the 10 m radius plot were recorded. A stem was considered to be inside the plot if half or more of the stem was within 10 m of the center stake. Species identity and diameter at 1.4 m above ground (dbh) for stems >10 cm dbh were recorded.

Stand tables were created for overstory species in each grassland area. Stand tables contained frequency of plots in which species occurred, density, basal area, and importance values for each species. Importance values provided a measure of the influence of each species relative to other species present in the vegetation layer. Importance values were calculated for each species in the overstory layer by determining the sum of the relative frequency, relative density, and relative basal area and dividing that sum by three.

Understory.—Sixty understory subplots were established in each grassland area. Three 2 × 2 m subplots were placed 1, 5, and 9 m from the center stake along a transect originating from the center of each overstory plot. The transect was oriented along one cardinal direction beginning with the first plot's transect facing north and rotating the direction 90 degrees clockwise in each subsequent plot. The understory was defined as woody plants <1.5 m tall and >0.5 m tall. The number of stems was recorded for each species of woody plant identified in the subplots.

A stand table was created for the understory vegetation layers in each grassland area. The table consisted of the frequency, density, and importance values for each species occurring in this layer. The importance value for each species in this layer was calculated by determining the mean of the relative frequency and relative density for that species.

Ground layer.—The ground layer consisted of all herbaceous plants and woody plants <0.5 m tall. Three 1 × 1 m plots were placed at 1, 5 and 9 m along the same transect as the understory subplots. Ground layer subplots were marked with flags to aid in relocating the plots in the future.

Within each ground layer subplot, species cover was estimated using a modified Daubenmire classification system (Daubenmire 1968). Cover is defined as the area of ground within a subplot that is occupied by the above ground parts of each plant species. A species was considered to be present if any of the aerial portion of the plant was within the 1 × 1 m subplot. Each species occurring in a subplot was assigned a cover category based on an estimate of the percent cover of the subplot for that species. Only those species with a cover category >2 were considered in the subsequent analysis.

Frequency and average cover were determined for each species that occurred in >5% of the ground layer subplots in an area. Average cover for each species was determined by taking the sum of all cover estimates for each individual subplot and dividing by the total number of herbaceous subplots (n = 60). Importance values were also calculated by determining the mean of the relative frequency and relative cover for each species occurring in this layer.

Nomenclature followed Gleason & Cronquist (1991). Voucher specimens were collected from areas adjacent to the permanent plots and were placed in the Ball State University Herbarium (BSUH). To establish a record for future monitoring efforts, specimens were collected for all species observed in the plot, regardless of frequency.

RESULTS

Overstory.—Fourteen species were recorded in the overstory (dbh >10 cm) in the three grassland areas sampled (Table 1). All overstory trees had a clumped distribution. No species occurred in the overstory of all three areas. *Juglans nigra* had the highest frequency, occurring in 4 of 60 (6.7%) overstory plots. Total overstory stem density was 39.8, 55.8, and 60.2 per ha in Area 5, Area 16, and Area 26, respectively (Table 1).

Area 5 had nine overstory species in 2001. *Aescules glabra* had the highest density (Table 1). *Carya ovata* had the largest basal area (0.37 m^2/ha) and ranked highest in importance value (25.0%). *Aescules glabra*, *Cornus florida*, and *Liquidamber styraciflua* all had importance value >10%. *Sassafras albidum* was the only other species represented by more than one individual (Table 1). One standing dead tree, apparently killed in the previous fire, was observed in the overstory plots.

Four species of woody plants occurred in the plots in Area 16. Trees occurred in only 2 (10%) of the overstory plots. Trees ranged in size from 10.0–36.6 cm dbh. *Liquidamber styraciflua* and *Carya ovata* were the dominant tree species with importance values of 40.9% and 33.7%. No standing dead trees were observed in the plots, but some trees were cut prior to this study.

Area 26 had seven species occurring in the overstory. *Nyssa sylvatica* had the highest stem density and ranked highest in importance value (Table 1). *Juglans nigra* and *Juniperus virginiana* also occurred in more than one plot and ranked second and third in importance with 19.7% and 10.1%.

Understory.—There were 16 species in the understory of the three grassland areas in 2001 (Table 2). Four species (*Rhus copallinum*, *Liquidamber styraciflua*, *Sassafras albidum*, and *Diospyros virginiana*) occurred in all three plots. *Rhus copallinum*, the dominant species in this layer, was found in 42.2% (76 of 180) understory subplots, had the highest stem densities in two areas, and ranked highest in importance value in both Area 5 and Area 26 (Table 2).

Area 5 had eight species found in the understory layer but was dominated by *Rhus copallinum* (76.6 I.V.) due to high stem density (3792 stems/ha). *Rhus copallinum* was found in 95% (57 of 60) of ground layer subplots in the area. *Liquidamber styraciflua* was ranked second in importance and *Rubus allegheniensis* was third (Table 2).

Seven species of woody plants were observed in the understory layer of Area 16 (Table 2). Understory subplots had an overall density of 1,666.7 stems/ha. Twenty-eight out of 60 (46.7%) subplots had understory woody vegetation.

Liquidamber styraciflua was the most frequent understory species, occurred in 18% of the subplots, and had a 39.2% importance value. *Rhus copallinum*, the second most dominant species, occurred in only four subplots (6%) and ranked second in importance value (Table 2). *Robinia pseudoacacia* occurred in three subplots (5%) and had an importance value of 14.1%.

Ten species were sampled in the understory layer of Area 26 (Table 2). *Rhus copallinum* and *Sassafras albidum* were the most dominant species observed. *Rhus copallinum* was observed in 75% of the subplots with an estimated density of 2917 stems/ha. The density of *Sassafras albidum* was 1694 stems/ha. Several dead stems of *Rhus copallinum*, many with new sprouts, were observed in the subplots.

Ground layer.—The three grassland areas had a similar species composition (Table 3). The ground layer was the most diverse layer with 54 species occurring in this stratum. Twenty-five of the 54 species (46.3%) occurred in more then one grassland area. Eleven species (20%) occurred in all three areas.

Area 5 had 19 species and had a frequency >5% in the ground layer subplots (Table 3). Herbaceous dominants included *Andropogon virginicus*, *Danthonia spicata*, and *Solidago juncea*. The importance values for these species were 22.1%, 16.4%, and 12.9%, respectively. *Andropogon virginicus* occurred in 46

Table 1.—Stand table for overstory trees sampled during the summer of 2001 at Big Oaks National Wildlife Refuge. Frequency = number of plots in which species occurred; density = number of stems/ha; basal area = m^2/ha; importance value = (relative density + relative basal area + relative frequency)/3.

	Area 5				Area 16				Area 26			
Species	Frequency	Density	Basal area	IV	Frequency	Density	Basal area	IV	Frequency	Density	Basal area	IV
Acer rubrum	0	0.0	0.00	0.0	0	0.0	0.00	0.0	1	1.6	0.10	4.2
Aesculus glabra	1	12.7	0.06	16.3	0	0.0	0.00	0.0	0	0.0	0.00	0.0
Carya ovata	1	8.0	0.37	25.0	1	25.5	0.38	33.7	0	0.0	0.00	0.0
Cornus florida	1	6.4	0.11	13.2	0	0.0	0.00	0.0	1	1.6	0.01	4.2
Diospyros virginiana	0	0.0	0.00	0.0	1	3.2	0.03	11.1	0	0.0	0.00	0.0
Fraxinus americana	1	1.6	0.05	6.7	0	0.0	0.00	0.0	0	0.0	0.00	0.0
Juglans nigra	1	1.6	0.04	6.3	0	0.0	0.00	0.0	3	9.6	0.22	19.7
Juniperus virginiana	0	0.0	0.00	0.0	0	0.0	0.00	0.0	2	3.2	0.80	9.8
Liquidamber styraciflua	2	3.2	0.06	11.9	1	25.5	0.65	40.9	0	0.0	0.00	0.0
Nyssa sylvatica	1	1.6	0.02	5.6	0	0.0	0.00	0.0	2	38.2	0.70	44.5
Populus × *jackii*	0	0.0	0.00	0.0	0	0.0	0.00	0.0	1	1.6	0.16	7.6
Prunus serotina	1	1.6	0.05	6.8	0	0.0	0.00	0.0	0	0.0	0.00	0.0
Quercus palustris	0	0.0	0.00	0.0	1	1.6	0.19	14.4	0	0.0	0.00	0.0
Sassafras albidum	1	3.2	0.06	8.2	0	0.0	0.00	0.0	1	3.2	0.22	10.1
Total		39.8	0.83	100.0		55.8	0.61	100.0		58.92	1.40	100.0

Table 2.—Stand table for understory vegetation in three grassland areas of Big Oaks National Wildlife Refuge. Frequency = number of plots in which species was found; density = number of stems/ha; importance value (IV) = (relative density + relative frequency)/2.

	Area 5			Area 16			Area 26		
Species	Frequency	Density	IV	Frequency	Density	IV	Frequency	Density	IV
Carya cordiformis	3	13.9	1.8	0	0.0	0.0	0	0.0	0.0
Carya ovata	0	0.0	0.0	1	41.7	3.0	0	0.0	0.0
Cornus florida	0	0.0	0.0	0	0.0	0.0	5	430.6	9.4
Diospyros virginiana	3	13.9	1.8	6	7.5	14.5	3	152.8	4.7
Juglans nigra	0	0.0	0.0	0	0.0	0.0	3	97.2	4.2
Liquidamber styraciflua	12	166.7	8.5	11	652.8	39.2	1	152.8	2.4
Lonicera tatarica	0	0.0	0.0	0	0.0	0.0	1	83.3	1.8
Nyssa sylvatica	3	13.9	1.8	0	0.0	0.0	3	41.7	3.8
Populus × *jackii*	0	0.0	0.0	0	0.0	0.0	1	27.8	1.4
Prunus serotina	6	41.7	3.7	0	0.0	0.0	2	4.6	2.6
Quercus palustris	0	0.0	0.0	2	69.4	5.7	0	0.0	0.0
Rhus copallinum	57	3791.7	76.6	4	416.7	19.6	15	2916.7	42
Robinia pseudoacacia	0	0.0	0.0	3	291.7	14.1	0	0.0	0.0
Rubus allegheniensis	6	69.4	4.1	0	0.0	0.0	4	194.4	6.2
Sassafras albidum	3	13.9	1.8	1	69.4	5.7	5	1694.4	20.2
Vitus aestivalis	0	0.0	0.0	0	0.0	0.0	1	13.9	1.3
Total		4125.0	100.0		1666.7	100.0		5847.2	100.0

Table 3.—Stand table for ground layer subplots (n = 60) at Big Oaks NWR. Frequency = number of subplots in which species occurred; Average Cover = average cover estimate for species; Importance Value = (relative cover + relative frequency)/2. Woody plants are denoted by an asterisk.

Species	Area 5 Frequency	Area 5 Average cover	Area 5 IV	Area 16 Frequency	Area 16 Average cover	Area 16 IV	Area 26 Frequency	Area 26 Average cover	Area 26 IV
Achillea millefolium	17	0.60	6.4	26	1.28	9.7	16	0.58	7.4
Agrostis alba	3	1.30	1.4	4	0.18	1.8	8	0.33	3.9
Ambrosia artemisiifolia	0	0.00	0.0	17	0.67	5.4	0	0.00	0.0
Andropogon virginicus	46	2.62	22.1	33	1.50	11.8	24	1.25	13.3
Antenaria sp.	6	0.20	2.2	0	0.00	0.0	3	0.32	2.6
Carex bushii	3	0.10	1.1	0	0.00	0.0	0	0.00	0.0
Cirsium discolor	0	0.00	0.0	0	0.00	0.0	3	0.10	1.4
Dactylis glomerata	0	0.00	0.0	0	0.00	0.0	4	0.17	2.0
Danthonia spicata	36	1.85	16.4	8	0.32	3.1	0	0.00	0.0
Daucus carota	0	0.00	0.0	0	0.00	0.0	3	0.10	1.4
Desmodium canescens	0	0.00	0.0	0	0.00	0.0	4	0.20	2.2
Eupatorium rugosum	5	0.22	2.1	0	0.00	0.0	4	0.15	1.9
Euthenia gramnifolia	0	0.00	0.0	6	0.23	1.6	0	0.00	0.0
Hieracium florentinum	3	0.10	1.1	0	0.00	0.0	0	0.00	0.0
Lespedeza virginica	0	0.00	0.0	10	0.35	2.8	0	0.00	0.0
Panicum anceps	3	0.20	1.6	26	0.98	9.6	4	0.20	2.2
Phleum pretense	0	0.00	0.0	0	0.00	0.0	7	0.35	3.8
Poa compressa	0	0.00	0.0	4	0.13	1.2	0	0.00	0.0
Poa pretense	7	0.32	3.0	0	0.00	0.0	0	0.00	0.0
Potentilla simplex	6	0.22	2.3	4	0.23	2.3	21	0.88	10.6
Pycnanthemum verticillatum	10	0.47	4.3	28	1.28	10.0	19	0.82	9.6
*Rhus copallinum**	18	0.68	7.0	0	0.00	0.0	6	0.20	2.6
*Rubus allegheniensis**	0	0.00	0.0	3	0.12	1.2	0	0.00	0.0
*Rubus flagellaris**	24	0.97	9.7	10	0.35	2.1	16	0.65	7.8
*Sassafras albidum**	3	0.10	1.1	13	0.50	4.3	10	0.40	4.8
*Smilax gluaca**	0	0.00	0.0	13	0.52	4.4	0	0.00	0.0
Solidago canadensis	0	0.00	0.0	0	0.00	0.0	11	0.62	6.4
Solidago juncea	31	1.35	12.9	58	3.37	26.3	12	0.47	5.7
Solidago nemoralis	8	0.27	3.0	0	0.00	0.0	8	0.30	3.8
*Spirea tomentosa**	0	0.00	0.0	3	0.10	0.9	0	0.00	0.0
Trifolium agrarium	0	0.00	0.0	3	0.10	0.9	4	0.13	1.8
Trifolium pretense	3	0.10	1.1	0	0.00	0.0	9	0.32	4.1
Trifolium repens	4	0.13	1.5	0	0.00	0.0	0	0.00	0.0
Vernonia gigantea	0	0.00	0.0	4	0.13	1.0	3	0.10	1.4
Total			100.0			100.0			100.0

out of 60 (77%) subplots and an average cover of 2.62. One sedge species, *Carex bushii*, was observed in three subplots (5%) and an importance value of 1.1%. Two species of *Trifolium* were also observed in the ground layer.

Rubus flagellaris and *Rhus copallinum* were the dominant woody species occurring in the ground layer with importance values of 9.7% and 7.0%. *Rubus flagellaris* occurred in 24 out of 60 (40%) sub-plots and had an average cover of 0.97. *Sassafras albidum* was observed in 3 out of 60 (5%) of the subplots and had a 1.1 % importance value.

Eighteen species were observed in at least 5% of the herbaceous subplots of Area 26 (Table 3). *Solidago juncea* occurred in 58 of the 60 subplots (94%) and had the highest importance value (26.3). *Andropogon virginicus* occurred in 33 subplots (55%) and had an importance value of 11.8%. *Pycnanthemum verticillatum* and *Panicum anceps* had importance values of 10.0% and 9.7%, respectively.

Smilax gluaca was the most dominant woody species in the ground layer of Area 26, occurring in 13 subplots (21%) with an importance value of 4.4%. *Sassafras albidum* and *Rubus flagellaris* had importance values of 4.3% and 2.1%. *Rubus allegheniensis* was also observed in three subplots (5%) and had an importance value of 1.2%.

There were 21 species sampled in >5% of the ground layer of Area 26 during the summer of 2001 (Table 3). *Andropogon virginucus*, *Potentilla simplex*, and *Pycnanthemum verticulatum* were the dominant herbaceous species. *Achillea millifolium* and two species of goldenrod (*Solidago*) also had importance values >5.0.

Rubus flagellaris was the most frequent woody species but occurred in only 27% of the plots. *Rhus copallinum*, the most frequent woody species in 2000, was observed in 10% of the plots. *Sassafras albidum* was the only other woody plant observed in the ground layer of Area 26.

DISCUSSION

Ground layer.—The species composition of the ground layer in these areas is unique for Midwestern U.S. grasslands. Typical tallgrass prairies in the Midwestern U.S. are dominated by big bluestem (*Andropogon gerardii*), Indian grass (*Schizachyrium scoparium*), and switchgrass (*Panicum virgatum*) (Sims & Risser 2000). None of these traditional species occur in the grassland areas monitored in Big Oaks NWR. The most common grass species at Big Oaks NWR are *Andropogon virginicus*, *Dathonia spicata*, *Panicum anceps*, and *Phleum pretense*.

One reason why these areas do not contain typical tallgrass species may be attributed to soil conditions. Numerous studies have described the vegetation patterns of tallgrass prairies based on the underlying substrate (Nelson & Anderson 1983; Nelson 1985; Umbanhowar 1992; Robertson et al. 1997). Tallgrass species occur in areas with dry, nonacidic, dolomite limestone substrate. The substrate underlying the grassland areas at Big Oaks NWR is classified as Alfisols primarily Cobbsfork-Avonburg and Cincinnati-Rossmoyne soil associations (McWilliams 1985). The Avonburg series is described as having slow permeability and typically poorly-drained soils (McWilliams 1985). These soils also have strongly to very strongly acidic top layers. These soil associations have topsoil pH values as low as 4.0 (McWilliams 1985). These low pH levels are not conducive to most tallgrass prairie species.

Andropogon virginicus was the most abundant herbaceous species in the ground layer. This species should continue to be dominant in these grasslands because it is well suited to grow in poorly-drained acidic soils like those at Big Oaks NWR (Lewis & Harshberger 1976). This species is dependant on periodic disturbance to maintain its abundance. Fire kills the top-growth portion of the plant, but meristems survive springtime burns (Hughes et al. 1991). New shoots have been observed growing from these meristems four days after a fire (Hughes et al. 1991).

The second most common herbaceous species was *Solidago juncea*. The growth of *Solidago juncea*, like most *Solidago* species, is generally enhanced by fire. New shoots grow from the underground rhizomes immediately following a burn. *Solidago* species respond favorably to spring burns by increasing in stem density with each subsequent burn (Medve 1984). If the current fire regime is maintained, both *Solidago juncea and Solidago canadensis* should continue to maintain or increase in dominance in these grassland areas.

One species of particular interest, *Rhexia mariana* var. *mariana*, was observed in Area

16. However, it occurred in less than 5% of the ground layer subplots and was not included in the quantitative analysis. *Rhexia mariana* var. *mariana* is listed as a state-endangered plant in Indiana. This species thrives in wet, acid grasslands; and benefits from frequent disturbances (Craine 2002). The frequent burns in Area 16 may be promoting this species. We observed a reduction in the occurrence of this species in subsequent years.

Overstory.—No tree species occurred in the overstory of all three study areas. Furthermore, tree species had a clumped distribution, occurring in only 8 of the 60 (13%) permanent plots. Typically, overstory trees were located along streams and in depressional areas where increased moisture and reduced fuel loads may prevent prescribed burns from having an impact. Because these trees occur in isolated depressional areas they may not have serious negative impact on grassland habitat quality. If the goal of management continues to be the removal of overstory trees then mechanical elimination may be necessary.

The two dominant species in the overstory layer of the three study areas, *Nyssa sylvatica* and *Liquidamber styraciflua*, are relatively fire resistant and readily sprout new shoots (Miller 1990). Even when aboveground portions of young trees are killed by fire, they typically survive and spread by root sprouting. These species, along with *Sassafras albidum*, will continue to be present in these plots as evidenced by their occurrence in both the ground and the understory layers.

Understory.—Many of the species occurring in the understory in these areas have been identified as fire-tolerant and thrive in fire-managed areas. Keely (1992) defined those shrubs that sprout the first season after a fire as fire recruiter species. These fire recruiter species can increase in abundance as a result of prescribed burns from either root sprouts or seedling sprouts.

Rhus copallinum was the dominant species in this layer. Density estimates for the three areas ranged from 416 stems/ha to 3791 stems/ha in 2001, suggesting that past burns may not be controlling this species. Although prescribed burns kill the above ground portion of *Rhus copallinum*, fire also stimulates root sprouting (Evans 1983). Species abundance increases as a result of increased stem production following a fire. In Tennessee, the density of *Rhus copallinum* in burn plots increased 50–88% (Deselm et al. 1991). Several standing dead stems of this species were observed in the grasslands at Big Oaks NWR, and multiple living sprouts were noted at the base of many of these dead stems. If this species is chosen for removal or density reduction, then other management practices may be necessary to control this species. Sampling this layer in subsequent years should provide more evidence of burn effects.

Other fire-resistant woody species also occurred in the understory layer. Both *Liquidamber styraciflua* and *Sassafras albidum* occurred in the understory of all three areas. Fire can reduce the above ground portion of these species, but only hot summer fires are effective in killing their root stalks (Chen et al. 1975). Both species readily sprout from the root portion after winter or spring burns. The spring burns at Big Oaks NWR should reduce standing individuals, but roots sprouts will appear in subsequent years. In fact, *Sassafras albidum* was observed in the ground layer of all three areas.

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