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Monitoring a Savanna Restoration in East-Central Illinois

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ABSTRACT

This study monitored the effects of fire on the vegetation of a savanna restoration site at Forest Glen County Preserve, Vermilion County, Illinois. Pre-burn and post-burn inventories of the vegetation were conducted to determine changes in frequency of herbaceous species and changes in frequency and density of woody species after two successive annual fires. Post-burn survival of several tree species was also measured. Twenty-one herbaceous species exhibited significant changes in frequency after the fires. The shrubs *Rubus allegheniensis* and *Rosa multiflora* decreased significantly, while *Rubus flagellaris* increased significantly following the fires. Seedlings of *Prunus serotina* decreased significantly in frequency and density and saplings of *Prunus serotina* decreased significantly in density following the fires. Individuals ≥ 3 m tall of *Quercus alba*, *Q. imbricaria*, *Q. rubra*, *Q. velutina*, *J. nigra*, *Liriodendron tulipifera* and *Liquidambar styraciflua* were fire resistant, in contrast with individuals of *Quercus macrocarpa* which were fire resistant when > 1 m tall. This study indicates a need to protect several common native oak species from any prescribed burn until they reach at least 3 m in height.

INTRODUCTION

The deep, black soil savannas of Illinois, the vegetation continuum between forest and prairie, were dominated by oaks having between 10-80% canopy cover, with or without a shrub layer, and an herbaceous layer dominated by prairie and forest grasses and forbs (Bray 1960, White and Madany 1978, Anderson and Brown 1983, Nuzzo 1986, Anderson 1991a and 1991b). Savannas were fire and moisture dependent; the presence of fire and/or dry conditions resulted in a shift toward prairie while the absence of fire and presence of moist conditions resulted in a closed canopy forest.

Very little is known about the original savannas of Illinois. Nuzzo (1986) proposed general structures for the vegetation continuum of midwestern savannas. Anderson (1991a) outlined the conditions believed to be necessary for savanna development in presettlement time and the importance of fire frequency in its development and maintenance. Ebinger and McClain (1991) discussed the changes in a savanna community after fire suppression and McClain et al. (1993) described changes in the structure and compositions of a savanna remnant after grazing and fire.

In Illinois, few attempts have been made to restore or re-create savannas. Packard (1991) listed many species that may have been savanna components based on Mead's list (Mead 1846) and discussed some of the steps necessary for restoration. He is involved in several savanna restoration projects in northern Illinois (Breining 1993). Apfelbaum and Haney (1991) studied the restoration of degraded oak savanna remnants in northern Illinois, Indiana, and southern Wisconsin. The Illinois Department of Conservation and the Illinois Chapter of The Nature Conservancy are involved in the Funks Grove Savanna Restoration Project in McLean County (Szafoni et al. 1994). This study was initiated to describe the effects of fire on existing vegetation in an attempt to restore savanna to an area where little original natural savanna vegetation remained.

DESCRIPTION OF THE STUDY AREA

The study area is within the Forest Glen County Preserve, Vermilion County, Illinois (Sec24 T18N R11W), which is owned and managed by the Vermilion County Conservation District (VCCD). The site is 8.4 ha, triangular and on the south-central border of the VCCD property. The west side of the site is adjacent to a prairie restoration site, the south side is bordered by a plowed field, and the northeast side is bordered by a road. Across the road is a playground, beyond that is a mature second growth hardwood forest. The entire area was removed from agricultural production in 1968, and it was allowed to lie fallow until the beginning of the present study. In 1990, the area was in the perennial herb stage of old field succession with pioneer trees and shrubs becoming common in some areas.

Several old fence rows divided the site into four areas; three are approximately equal in size (NW, SW, SE) while the fourth is smaller (NE). The NW area, which generally lacked pioneer trees, had a 0.8-ha area planted to prairie species prior to the present study. The SW area was dominated by the recent growth of weedy tree species, including *Prunus serotina* (black cherry), *Juglans nigra* (black walnut), *Gleditsia triacanthos* (honey locust) and *Sassafras albidum* (sassafras). In the NE area *Quercus alba* (white oak) and *Q. imbricaria* (shingle oak) seedlings and saplings seem to have seeded in from an adjacent fence row or possibly a mature second growth hardwood forest which is in the area. The SE area had a few pioneer trees and a 1-ha wet depression in the middle, created when topsoil was removed for road construction. Two rows of *Liquidambar styraciflua* (sweet gum) and *Liriodendron tulipifera* (tulip tree) were planted on the east edge of this area in 1984.

METHODS AND MATERIALS

A prescribed burn was conducted on the entire site on March 3, 1992 and March 30, 1993. In the falls of 1991 (pre-burn), 1992 (post-burn) and 1993 (post-burn), frequency (%) of herbaceous species were determined using 0.001-ha circular plots located using a stratified random sampling procedure. Eighty-three plots were sampled in 1991, 76 in 1992 and 71 in 1993. Fisher's Exact Test ($p < 0.01$, two-tailed) was used to determine significant changes in the vegetation (Table 1, Schefler 1988). All possible comparisons were made for each species among the samples obtained in the three years (Table 1).

The frequencies (%) and density (no./ha) of the shrubs, woody vines and tree seedlings (< 2.5 cm dbh) and tree saplings (2.5-10.0 cm dbh) were determined using 0.001-ha and

0.01-ha circular plots respectively. Plots were located using a stratified random sampling procedure. For frequency data, 83 plots were sampled in 1991, 30 in 1992 and 71 in 1993. For density data, 50 plots were counted in 1991, 30 in 1992 and 71 in 1993. Fisher's Exact Test ($p < 0.01$, two-tailed) was used to determine significant changes in the frequency data (Table 2). All possible comparisons were made for each species among the samples obtained in the three years. Shrub and woody vine densities were not recorded in 1991. Student's T-test ($p < 0.01$, two-tailed) was used to compare the two-year shrub density data (Table 2, Schefler 1988). One-way ANOVA ($p < 0.01$) and Duncan's Multiple-Range Test were used to compare three year density data (Table 2, Schefler 1988). Total stem counts of shrubs and vines were compared using Student's T-test ($p < 0.01$, two-tailed) and total stem counts of tree seedlings and saplings were compared using one-way ANOVA ($p < 0.01$, Table 2, Schefler 1988).

Tree survival after the first fire (1992) was determined originally using four categories: not top-killed, top-killed not resprouting, top-killed resprouting from the base and top-killed resprouting from the trunk. Data were then categorized into top-killed and not top-killed and two height classes (< 3 m and ≥ 3 m). Fisher's Exact Test ($p < 0.01$, two-tailed) was used to determine if species differed significantly in their ability to survive a burn by comparing the proportion of top-killed and not top-killed stems in the two height classes (Table 3). *Quercus velutina* and *Q. rubra* were combined for analysis because of their low stem counts.

In the spring of 1993, the ages of two height classes were determined. Trees ≥ 3 m tall were aged by counting growth rings on cores taken at 137 cm above the ground with an increment borer. Cross-sections of trees < 3 m tall were made at ground level. Their ages were determined in the laboratory. Five years were added to those ≥ 3 m tall to adjust for the sampling height (Table 4). Plant nomenclature follows Mohlenbrock (1986).

RESULTS AND DISCUSSION

Burns

Dry weather and a moderate fuel load resulted in a hot, intense fire on March 3, 1992. Compared to the 1992 fire, the 1993 fire was not as hot and intense due to heavy spring rains and a reduced fuel load. Consequently, the fire skipped many small wet areas, and the vegetation in general did not burn as completely as in 1992.

Herbaceous Species

A total of 77 herbaceous species were present in the plots (Table 1). *Carex* species were not differentiated. The species with the highest frequencies in 1991, *Solidago canadensis* (99%), *Poa pratensis* (71%), *Cirsium discolor* (70%), *Festuca pratensis* (65%) and *Aster pilosus* (63%), are all species of old fields and disturbed areas. In 1992, these same plants were the most frequent species except the introduced legume, *Trifolium pratense* (87%), had the second highest frequency. In 1993, *Solidago canadensis* (97%) was again the most frequent species; *Desmodium glabellum* (73%) and *Ambrosia artemisiifolia* (56%) increased in frequency, while *Trifolium pratense* (58%), *Cirsium discolor* (56%), *Poa pratensis* (17%) and *Aster pilosus* (31%) all decreased.

Of the 68 species sampled between 1991 and 1992, eight significantly increased while three significantly decreased (Table 1). Seventy-seven species were sampled between 1991 and 1993. Seven of these species significantly increased and seven significantly decreased (Table 1). Seventy-seven species were also sampled between 1992 and 1993, of which five significantly increased and five significantly decreased (Table 1). *Trifolium pratense* and *Dichanthelium acuminatum* significantly increased between 1991 and 1992, and then significantly decreased in 1993 (Table 1).

Four legumes, both native and introduced, increased after the fires. Anderson and Schwegman (1971, 1991) and Anderson and Van Valkenburg (1977) all obtained similar results, with increases in legume frequency after burns in barren communities in southern Illinois. Many of the species that increased in frequency are native prairie species that are adapted to fire. Most are perennials but *Ambrosia artemisiifolia* is a native annual well-adapted to colonizing disturbed habitats such as bare soil that is common after fires (Anderson and Van Valkenburg 1977 and Anderson and Schwegman 1991). Most of the species that increased are not considered high quality prairie or savanna species.

Of the species that decreased in frequency, four are introduced: *Achillea millefolium*, *Dactylis glomerata*, *Dianthus armeria* and *Poa pratensis*. The others that decreased are native, open forest or disturbed habitat species that probably are also not well-adapted to fire. The reason for the decrease in frequency of the native prairie species (*Aster pilosus*, *Oenothera biennis*, *Solidago nemoralis)* is not known although some prairie species do decline following fire. Anderson and Van Valkenburg (1977) recorded a similar decrease in *Solidago nemoralis* after a prescribed burn on a barren in southern Illinois.

Woody Species

The shrub *Rubus allegheniensis* had the highest frequency all three years followed by *Rosa multiflora* (Table 2). Both species decreased in frequency the third year of the study. *Rubus flagellaris* increased in frequency both years; Anderson and Van Valkenburg (1977) recorded an increase in this species after a prescribed burn on a barren in southern Illinois. This increase may have been stimulated by the fires. Except for *Rosa multiflora* and *Elaeagnus umbellata*, all are native species that probably were components of the savanna shrub layer (Ebinger 1986 and 1987). The decrease in total stems between years was not statistically significant.

Seedlings of 20 tree species were present on the site; most are native forest species. *Prunus serotina* was the most frequently encountered species in all three years and it had the highest density in pre-burn data of 1991. *Juglans nigra* ranked second in frequency and density in 1991 followed by *Sassafras albidum*. *Prunus serotina* significantly decreased in density between 1992 and 1993. It is not fire resistant, probably accounting for much of this decrease. *Sassafras albidum* increased due largely to sprouting in 1992 and then decreased in 1993. This species commonly forms root sprouts after fires. Anderson and Van Valkenburg (1977) also recorded a large increase in *Sassafras albidum* sprouts after a single fire on a barren community in southern Illinois. Much of the increased density was probably a result of this ability to root sprout, while the subsequent decrease may have been due to a decline in stem vigor after the second fire. *Malus ioensis*, a savanna component, was fairly important on the site in 1991 and 1992, but showed a major decline after two fires. Few oak seedlings were encountered during the study, though occasional individuals of *Quercus alba*, *Q. imbricaria*, *Q. macrocarpa*, *Q. velutina* and *Q.*

rubra were found. Total seedling density varied from 2520 individuals in 1991 to 2701 in 1992, to 703 in 1993. The increase between 1991 and 1992 was due to the large increase in the number of stems of *Sassafras albidum* and a doubling of the stems of *Malus ioensis*. The decrease between 1992 and 1993 was the result of a major decrease in the stems of all species. Anderson and Schwegman (1991) recorded a similar decrease in stems after prescribed fire on a barren community in southern Illinois.

Of the twelve tree sapling species encountered, *Prunus serotina* had the highest frequency and density in all three years of the study, and was the only species to show significant differences among years (Table 2). The decreases in frequency and density of this species were probably caused by fires. Of the remaining saplings (11 species), all had extremely low frequencies and densities. From a high of 216 stems per ha in 1991, sapling density decreased to less than a quarter of that number in 1992 and 1993 (Table 2). In most instances these decreases could be directly attributed to fires, as many dead stems were observed after the fires (Anderson and Schwegman 1991).

Tree Survival and Age

Because the savanna restoration site had not been burned since being removed from agricultural production in 1968, it was possible to measure the effects of fire on eight tree species. Due to the lack of prairie grasses the fuel load was less than that of a mature prairie. The results indicate that most individuals ≥ 3 m tall were not top-killed, surviving the fire with minimal damage (Table 3). In contrast, individuals < 3 m tall usually were top-killed, the majority resprouting from the base or trunk. The difference in fire resistance by height class was statistically significant for all eight tree species (Table 3). *Quercus macrocarpa* appeared to be the most fire resistant: five individuals less than 1 m tall were top-killed while taller individuals survived with little or no damage.

The average ages for individuals 2-3 m tall were: *Quercus alba*, 11.5 years old; *Q. imbricaria*, 7.3 years; and *Q. macrocarpa*, 13.0 years (Table 4). Individuals 5 to 7 m tall were not adversely affected by the fire and were between 17 and 19 years of age (Table 4). This indicates that oaks used in savanna restoration should be protected from fires until they are more than 3 m tall and 8 to 12 years old.

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LITERATURE CITED

Anderson, R. C. 1991a. Savanna concepts revisited. *BioScience* 41:371.

Anderson, R. C. 1991b. Presettlement forests of Illinois. pp. 9-19 in G. V. Burger, J. E. Ebinger and G. S. Wilhelm, eds. Proceedings of the oak woods management workshop. Eastern Illinois University, Charleston, Ill.

Anderson, R. C. and L. E. Brown. 1983. Comparative effects of fire on trees in a midwestern savannah and an adjacent forest. *Bull. Torrey Bot. Cl.* 110:87-90.

Anderson, R. C. and J. E. Schwegman. 1971. The response of southern Illinois barren vegetation to prescribed burning. *Trans. Ill. St. Acad. Sci.* 64:287-291.

Anderson, R. C. and J. E. Schwegman. 1991. Twenty years of vegetational change on a southern Illinois barren. *Nat. Areas J.* 11:100-107.

Anderson, R. C. and C. Van Valkenburg. 1977. Response of a southern Illinois grassland community to burning. *Trans. Ill. St. Acad. Sci.* 69:399-414.

Apfelbaum, S. I. and A. W. Haney. 1991. Management of degraded oak savanna remnants in the upper midwest: preliminary results from three years of study. pp. 81-89 in G. V. Burger, J. E. Ebinger and G. S. Wilhelm, eds. Proceedings of the oak woods management workshop. Eastern Illinois University, Charleston, Ill.

Bray, J. R. 1960. The composition of savanna vegetation in Wisconsin. *Ecology*. 41:721-732.

Breining, G. 1993. The case of the missing ecosystem. *Nature Conservancy*. 43:10-15.

Ebinger, J. E. 1986. Presettlement vegetation of Douglas County, Illinois. *Erigenia*. 7:15-22.

Ebinger, J. E. 1987. Presettlement vegetation of Coles County, Illinois. *Trans. Ill. St. Acad. Sci*. 80:15-24.

Ebinger, J. E. and W. E. McClain. 1991. Forest succession in the prairie peninsula of Illinois. *Ill. Nat. Hist. Survey Bull.* 34:375-381.

McClain, W. E., M. A. Jenkins, S. E. Jenkins, and J. E. Ebinger. 1993. Changes in the woody vegetation of a bur oak savanna remnant in central Illinois. *Nat. Areas J.* 13:108-114.

Mead, S. B. 1846. Catalogue of plants growing spontaneously in the state of Illinois, the principal part near Augusta, Hancock County. *Prairie Farmer* 6:35-36, 60, 93, 119-122.

Mohlenbrock, R. H. 1986. *Guide to the Vascular Flora of Illinois*. Southern Illinois University Press, Carbondale, Ill. 507 pp.

Nuzzo, V. A. 1986. Extent and status of midwest oak savanna: Presettlement and 1985. *Nat. Area. J.* 6:6-36.

Packard, S. 1991. Rediscovering the tallgrass savanna of Illinois. pp. 55-66 in G. V. Burger, J. E. Ebinger and G. S. Wilhelm, eds. Proceedings of the oak woods management workshop. Eastern Illinois University, Charleston, Ill.

Schefler, W. C. 1988. *Statistics: Concepts and Applications*. The Benjamin/Cummings Publishing Co., Inc., Reading, Mass. 590 pp.

Szafoni, R. E., R. L. Phipps and F. M. Harty. 1994. Large, open-grown trees as indicators of presettlement savanna. *Nat. Areas J.* 14:107-112.

White, J. and M. H. Madany. 1978. Classification of natural communities in Illinois. Pp. 309-405 in J. White, ed., Illinois Natural Areas Inventory Technical Report, Vol. 1: Survey methods and results. Illinois Natural Areas Inventory, Urbana, Ill. xix+426p.

Table 1. Pre-burn (1991, n = 83) and post-burn (1992, n = 76; 1993, n = 71) frequency (%)of herbaceous species at the savanna restoration site, Forest Glen Preserve, Vermilion County, Illinois. Species with a frequency of less than 5% are not included.

	Frequency (%)		
Species	**1991**	**1992**	**1993**
Significant increase in frequency			
Agalinis tenuifolia (Vahl) Raf.	0	*21	+34
Ambrosia artemisiifolia L.	0	*26	+~56
Apocynum cannabinum L.	0	0	+~11
Asclepias syriaca L.	4	1	~14
Cassia fasciculata Michx.	0	*14	+~35
Carex ssp.	4	*33	15
Desmodium glabellum (Michx.) DC.	1	*30	+~73
Euthamia graminifolia (L.) Salisb.	1	*12	8
Lespedeza virginica (L.) Britt.	0	8	+18
Solidago juncea Ait.	1	*36	+31
Sorghastrum nutans (L.) Nash	14	*32	21
Significant decrease in frequency			
Achillea millefolium L.	10	17	+~0
Aster pilosus Willd.	63	74	+~31
Dactylis glomerata L.	17	*0	+3
Dianthus armeria L.	8	*0	0
Geum canadense Jacq.	24	17	+~0
Oenothera biennis L.	36	*0	+3
Poa pratensis L.	71	66	+~17
Solidago nemoralis Ait.	40	50	+~17
Significant increase followed by significant decrease			
Dichanthelium acuminatum (Sw.) Gould & Clark	7	*32	~6
Trifolium pratense L.	19	*87	+~58
Species exhibiting no significant changes			
Andropogon gerardii Vitman	4	5	10
Andropogon virginicus L.	6	12	8
Antennaria plantaginifolia (L.) Richardson	7	8	0
Aristida oligantha Michx.	5	8	7
Asclepias verticillata L.	0	0	7
Baptisia lactea (Raf.) Thieret.	11	4	11
Cirsium discolor (Muhl.) Spreng.	70	62	56
Daucus carota L.	49	49	55
Desmodium sessilifolium (Torr.) Torr. & Gray	0	0	6
Elymus canadensis L.	8	9	8
Elymus hystrix L.	19	16	17
Eupatorium serotinum Michx.	20	9	17
Festuca pratensis Huds.	65	63	69
Fragaria virginiana Duchesne	29	22	20
Helianthus mollis Lam.	12	13	17
Hypericum punctatum Lam.	7	0	0
Lespedeza capitata Michx.	8	11	8
Melilotus alba Medic.	8	4	8
Pastinaca sativa L.	7	4	4
Phleum pratense L.	48	54	59
Potentilla simplex Michx.	0	7	1
Pycnanthemum tenuifolium Schrad.	6	8	1
Ratibida pinnata (Vent.) Barnh.	5	4	7
Rudbeckia hirta L.	7	1	0
Schizachyrium scoparium (Michx.) Nash	8	9	10
Solidago canadensis L.	99	97	97
Vernonia gigantea (Walt.) Trel.	5	4	1

* = significant difference between 1991 and 1992
+ = significant difference between 1991 and 1993
~ = significant difference between 1992 and 1993

Table 2. Pre-burn (1991, n = 50) and post-burn (1992, n = 30; 1993, n = 71) frequency (%) and density (no./ha) for shrubs, vines, tree seedlings and saplings at the savanna restoration site, Forest Glen Preserve, Vermilion County, Illinois.

Species	Frequency (%) 1991	1992	1993	Density (no./ha) 1991	1992	1993	Fcal	p
Shrubs and Vines								
Rubus allegheniensis Porter	66	*93	~56	---	14467	3197		
Rosa multiflora Thunb.	30	40	~15	---	700	310		
Rubus flagellaris Willd.	0	10	+32	---	1000	1211		
Toxicodendron radicans (L.) Kuntze	8	10	20	---	433	---		
Rubus occidentalis L.	8	5	8	---	---	592		
Elaeagnus umbellata Thunb.	4	0	0	[1]40a	0a	0a	2.028	0.1340
Others (3 species)	1	3	3	---	67	28		
Totals			---	16667	5338		0.3770	
Tree Seedlings								
Prunus serotina Ehrh.	30	33	+13	1380a	667b	211b	7.97	0.0005
Juglans nigra L.	13	0	6	420a	0b	56b	4.93	0.0081
Sassafras albidum (Nutt.) Nees	13	27	10	160a	1700a	338a	2.75	0.0660
Malus ioensis (Wood) Britt.	7	13	1	120a	267a	14a	1.14	0.3202
Gleditsia triacanthos L.	5	0	1	160a	0a	28a	1.24	0.2889
Quercus imbricaria Michx.	2	0	3	40a	0a	28a	1.01	0.3644
Others (14 species)	12	7	2	240	67	28		
Totals			2520a	2701a	703a	3.37	0.0361	
Tree Saplings								
Prunus serotina Ehrh.	24	13	13	172a	17b	25b	8.58	0.0003
Juglans nigra L.	4	0	3	8a	0a	3a	1.53	0.2183
Sassafras albidum (Nutt.) Nees	5	10	6	8a	10a	13a	0.83	0.4344
Malus ioensis (Wood) Britt.	1	0	0	4a	0a	0a	0.99	0.3696
Quercus alba L.	4	0	0	6a	0a	0a	3.08	0.0477
Quercus imbricaria Michx.	1	0	0	2a	0a	0a	0.99	0.3696
Others (6 species)	7	10	0	16	16	0		
Totals			216a	43b	41b	10.11	0.0001	

* = significant difference between 1991 and 1992
+ = significant difference between 1991 and 1993
~ = significant difference between 1992 and 1993
[1] significant differences between densities were noted by using different lower case letters

Table 3. The number of trees top-killed by height classes (m) for the dominant tree species at the savanna restoration site, Forest Glen Preserve, Vermilion County, Illinois.

	Height Classes (m)	Not Top-killed	Top-killed
Quercus alba L. *	< 3	2	8
	≥ *3*	*25*	*1*
Quercus imbricaria Michx. *	< 3	7	86
	≥ 3	80	11
Quercus macrocarpa Michx. *	< 3	7	5
	≥3	27	0
Quercus velutina Lam. and	< 3	2	6
Q. rubra L. *	≥3	24	1
Juglans nigra L. *	< 3	58	204
	≥ 3	93	2
Liriodendron tulipifera L. *	< 3	20	12
	≥ 3	48	1
Liquidambar styraciflua L. *	< 3	3	15
	≥ 3	37	1

* = significant difference between height classes

Table 4: Tree age (years), diameter at breast height (cm), basal diameter (cm) and tree height (m) of three species of trees at the savanna restoration site, Forest Glen Preserve, Vermilion County, Illinois.

	Number of Individuals	Tree Height (m)	Ave DBH (cm)	Ave. Basal Diameter (cm)	Ave. Age (years)
Quercus alba L.	2	< 3	---	4.25	11.5
	7	5-7	11.9	---	17.3
Quercus imbricaria	3	< 3	---	2.4	7.3
Michx.	5	5-7	12.7	---	18.2
Quercus macrocarpa	2	< 3	---	3.6	13.0
Michx.	7	5-7	15.8	---	19.0