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EFFECTS OF A PRESCRIBED BURN ON TREE- AND HERB-LAYER VEGETATION IN A POST OAK *(QUERCUS STELLATA)* DOMINATED FLATWOODS

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ABSTRACT: Post oak flatwoods are an unusual plant community type dominated by even-aged and uniformly sized post oaks *(Quercus stellata)* growing along level terraces of the Ohio River. Historical evidence exists that fire may play a role in the maintenance of the open canopy and poorly-developed understory characteristic of this community type (Dolan and Menges, 1989). The results of summer vegetation surveys taken yearly from 1989 to 1992 in a post oak flatwoods in southwestern Indiana that was subjected to a prescribed bum in the spring of 1989 are reported in this paper. The objective of the study was to determine the effects of the burn on tree- and herb-layer vegetation. The fire killed or top-killed more than half the trees but did not markedly shift the rank order of species importance values. Mortality was greatest among small tree species, such as winged elm and shingle-bark oak, and least among post oak. Composition of the herb-layer did not change greatly following the fire, but several new species were found that did not occur in unburned control plots. The results indicate that fire contributes to the unusual species composition and community structure of post oak flatwoods.

KEYWORDS: Plant community types, post oak flatwoods, prescribed burn.

INTRODUCTION

Historical evidence suggests that fire may play a role in the maintenance of post oak flatwoods, a rare and little-studied forest type (Dolan and Menges, 1989), as it does in post oak savannas where cessation of fire and overgrazing have contributed to the invasion of shrubs and non-native grasses (Scifres, 1982). Post oak *(Quercus stellata)* dominated flatwoods are forests of even-aged and uniformly-sized trees found along level alluvial lacustrine terraces of the Ohio River in southern Indiana and Illinois. They are associated with the McGary silt loam soil type, which has nearly impervious subsoil layers (often a fragipan) that result in ponding in small depressions in the spring and very dry conditions in the summer. The tree layer is dominated by slow-growing post oaks and hickories. These communities lack a well-developed shrub layer. The herbaceous layer is dominated by grasses, sedges, and mosses.

The effects of a prescribed burn on herb- and tree-layer vegetation in a post oak flatwoods community in southwestern Indiana are reported in this paper. The goal of the study was to document tree mortality and to measure the effects of fire on species composition three years following the burn.

Table 1. Mortality and resprouting of tree species following the 1989 prescribed burn.

Species	Pre-Burn No. of Trees	Percent Alive (Live Crowns)	Percent Alive (Resprouting)	Percent Dead
Carya spp.	58	46.6	15.5	37.9
Quercus stellata	51	68.6	5.9	25.5
Q. falcata pagoda	21	47.6	28.6	23.8
Q. imbricaria	17	41.2	29.4	29.4
Q. rubra	17	29.4	23.5	47.1
Ulmus alata	15	33.1	20.2	46.7
U. americana	7	14.2	42.9	42.9
Quercus alba	5	40.0	20.0	40.0
Fraxinus americana	4	-	-	100.0
Nyssa sylvatica	3	33.3	33.3	33.3
Quercus marilandica	3	-	-	100.0
Q. palustris	2	100.0	-	-
Fraxinus sp.	2	100.0	-	-
Liquidambar styraciflua	1	-	100.0	-

MATERIALS AND METHODS

The study was conducted at the Indiana Department of Natural Resources Division of Nature Preserves' 120 acre Post Oak Barrens Nature Preserve (POB) in Spencer County, Indiana (38°06'N, 87°01'W). The vegetation and environment at the site are described in detail in Dolan and Menges (1989).

The current study utilized a permanently marked, 32-point 8 x 4 rectangle of grid points located 25 m apart that was established in 1986 during the initial vegetation survey work at POB. Data from the previous vegetation study (collected in June 1986) were analyzed using two-way indicator species analysis (TWINSPAN; Gauch and Whittaker, 1981) calculated using PC-ORD software (McCune, 1991) to identify plots containing similar herbaceous vegetation. Using this information, the 8 x 4 center point grid system was divided in half geographically, yielding 15 and 17 grid points within the southern and northern portions, respectively. Each half contained vegetation similar to the other. The area containing the southern 15 points was not burned and was used to track changes in species composition in the absence of fire.

The area containing the northern 17 points was subjected to a prescribed burn in April 1989. This burn was conducted in the spring because a fire-crew was available to work at this remote site and because buds were dormant and the leaf litter was dry at this time. A fast-burning surface fire developed with average flame lengths of 50 cm. Dried leaves on top of the litter were burned, but lower sections of the litter remained moist, and the fire did not burn these layers (Chris Maron, pers. comm.).

Data on herb-layer species were gathered from all 32 grid points during the four summers following the April 1989 burn. Cover estimates were made for each species of vascular plant (stems 1 cm dbh), moss, and lichen within 10 m^2 circular plots (1.79 m radius) centered on the grid points. Cover was estimated in equal angular (arcsine square root) classes (1-7%, 8-25%, 26-50%, 51-75%, 76-93%, 94-100%; Dolan and

Menges, 1989). Species nomenclature follows Gleason and Cronquist (1991). Hickory species *(Carya laciniosa, C. ovata,* and *C. tomentosa)* are grouped together because many apparent hybrids were seen and the species are especially difficult to distinguish in the seedling and sapling stage. Young oaks that could not be identified to species were likewise lumped as *Quercus* spp.

The tree layer vegetation was compared before and after the burn by utilizing the 1986 survey as pre-burn data and resampling the trees three years post-burn in 1992. The data gathered were the species name and diameter at breast height (dbh) for all stems larger than 1 cm within circular plots 5.64 m in radius (100 m^2) centered on each grid point. Stem sprouts from the same individual were added together to yield total dbh.

Community structure and diversity measurements were calculated for the tree- and herb-layer data using PC-ORD software (McCune, 1991). Surveys of the tree-layer vegetation were conducted in the summers of 1986 and 1992. Surveys of the herb-layer vegetation were conducted each summer from 1986 to 1992. Pre-burn herb-layer diversity data from the 1988 survey, the survey conducted the summer prior to the burn, were compared to post-burn surveys to identify any vegetational changes occurring following the burn.

RESULTS

Tree-Layer Mortality and Resprouting on Burned Plots. Less than half (39.6%) of the trees survived the fire with live crowns; 37.6% of the trees were dead (no evidence of resprouting) three years after the bum. *Quercus stellata, Q. pagoda,* and *Q. imbricaria* had the lowest levels of mortality, while *Fraxinus americana, Ulmus alata, U. americana, Quercus rubra,* and *Q. marilandica* were among the highest (Table 1). Seventeen point five percent (17.5%) of the trees were resprouting from the base. *Quercus pagoda, Q. imbricaria,* and *Ulmus americana* had the largest numbers of resprouts. Hickories (*Carya* spp.) were more common than post oak in terms of total number of stems and had intermediate levels, relative to the other species, of morality and resprouting after the fire. Mortality on control plots over the period was 12.0%.

Tree-Layer Stand Structure and Diversity on Burned Plots. Three years following the burn, stem density in burned plots had decreased by 66.5 %, and basal area had decreased by 7.8% (Table 2). The importance value (IV = mean of relative frequency, relative density, and relative basal area; range = 0 - 100%) of *Quercus stellata* increased 10% between pre- and post-burn sampling. This increase is due to a decrease in IV for all other species except for modest increases in *Quercus pagoda* and *Q. palustris.* Rank order of species by importance value did not change following the burn with the exception of a rise in rank of *Q. palustris.* Species richness was lower on plots following the burn (Table 3), but there were no significant differences in evenness or Shannon-Weaver diversity before and after the burn.

Herb-Layer Composition and Cover for Burned and Unburned Plots. No significant changes in richness or diversity in the herb-layer plots were noted following the burn, but an increase in evenness in species distribution (Table 4) was apparent. The three measures did not change significantly on the unburned plots over the four-year time period.

Table 2. Tree species composition before and after a prescribed burn in 1989.

Species	Pre-Burn (1986)			Post-Burn (1992)		
	Density (Trees/ha)	Basal Area (m^2/ha)	IV* (%)	Density (Trees/ha)	Basal Area (m^2/ha)	IV* (%)
Quercus stellata	340	18.5	41	200	16.9	51
Carya spp.	387	0.5	16	87	0.4	14
Quercus falcata pagoda	140	0.5	9	60	0.5	10
Q. imbricaria	113	0.3	7	33	0.2	6
Q. rubra	113	0.8	7	20	0.7	5
Ulmus alata	100	-	5	20	-	2
Quercus palustris	13	2.2	4	13	2.4	7
Ulmus americana	47	-	3	7	-	1
Quercus alba	33	0.1	3	13	0.1	3
Nyssa sylvatica	20	-	1	7	-	1
Quercus marilandica	20	-	1	-	-	-
Fraxinus americana	27	-	12	-	-	-
Fraxinus sp.	13	-	1	-	-	-
Liquidambar styraciflua	7	-	1	-	-	-
All species	1373	23.2	100	460	21.4	100

*Importance value = mean of relative density, relative basal area, and relative frequency.

Table 3. Plot-level diversity measures of tree-layer species composition in control and burned plots pre- and post-burn.

	N	Richness	Evenness	H′*
Unburned plots - Pre-burn (1986)	17	4.7	0.277	0.444
Unburned plots - Post-burn (1992)	17	5.2	0.277	0.483
Burned plots - Pre-burn (1986)	15	5.3**	0.319	0.561
Burned plots - Post-burn (1992)	15	2.8**	0.367	0.383

* H′ = Relativized Shannon-Weaver Index.

** Significantly different at $p < 0.001$ based on paired t-test.

Danthonia spicata was the most frequently encountered species in the herb-layer both before and after the bum (Table 5), followed by *Polytrichum ohioense, Quercus* spp. seedlings, *Toxicodendron radicans,* and *Eleocharis tenuis* var. *verrucosa.* Seedlings of *Diospyros virginiana* and the grass, *Agrostis perennans,* were not found on burned plots prior to the bum, but in 1992, both were present in 3 of the 15 burned plots. *Potentilla simplex* and seedlings of *Prunus serotina* and *Quercus imbricaria* were completely eliminated from burned plots and had not reappeared in 1992.

Of the prominent non-vascular plants present, *Polytrichum ohioense* was more fire-tolerant than *Leucobryum glaucum,* suffering a 20% drop in frequency but maintaining the same average cover class three years following the burn as it had before the burn (Table 5). *Leucobryum glaucum* decreased by half in both

Table 4. Plot-level diversity measures of herb-layer species composition in control and burned plots pre- and post-burn.

	N	Richness	Evenness	H′*
Unburned plots - Pre-burn (1988)	17	7.5	0.962	1.877
Unburned plots - Post-burn (1992)	17	7.8	0.964	1.883
Burned plots - Pre-burn (1988)	15	7.1	0.938**	1.818
Burned plots - Post-burn (1992)	15	8.1	0.961**	1.979

* H′ =Relativized Shannon-Weaver Index.
**Significantly different at p <0.01 based on paired t-test.

measures. *Cladonia strepsilis,* a lichen, was killed by the fire and had not reestablished in 1992.

Over the three growing seasons following the burn, nine new species were found in the burned plots (Table 6). *Erechtites hieracifolia* (commonly called fire weed) was present in great abundance (average cover class = 0.4) in the first summer after the fire, was present as a few small individuals the second summer (average cover class = 0.07), and was not present in 1991. The grasses, *Panicum dichotomum, P. lanuginosum,* and *Agrostis perennans,* were found following the burn, along with *Rhus glabra.* On unburned plots, 5 new species were found during the 4-year survey period. Two of these, *Panicum lanuginosum* and *Agrostis perennans,* were also found on burned plots.

DISCUSSION

The tree data show that the prescribed burn did contribute to the characteristic open understory of post oak flatwoods (Aldrich and Homoya, 1984) by killing and reducing the density of smaller understory trees, such as winged elm *(Ulmus alata).* A secondary effect was an increase in the importance value of the community indicator species, *Quercus stellata,* with no change in the overall rank order of the other tree species present.

Post oak is reportedly a slow-growing tree, often overtopped by other species and intolerant of competition and shade, but able to persist and become dominant on poor sites due to its drought resistance (Fowells, 1965). At POB, environmental features such as low water and nutrient availability, coupled with occasional fire (Aldrich and Homoya, 1984; Dolan and Menges, 1989) appear to keep succession in check, keeping mid-successional oaks dominant.

No evidence exists at POB for replacement of oak with more mesic species, a phenomenon found in other oak forest types in the northeast and central United States where shade-tolerant, mesic species such as sugar maple dominate the understory (Abrams, 1992). Abrams (1992) has stated that "stable late successional oak forests are probably limited to areas at the western extent of the eastern deciduous forest biome or to very xeric, nutrient poor sites further east." As examples, he cites post oak forests derived from savanna in Oklahoma and blackjack oak forests on extremely xeric upland sites in Illinois. Nowacki, *et al.* (1990) support the notion that oak dominated communities are more stable on

Table 5. A comparison of frequency and average cover class of herb-layer vegetation in 15 plots before and after the burn. All species with 10% overall frequency or greater before or after the burn are included.

Species	Pre-Burn (1988) % Freq.	Pre-Burn (1988) Ave. Cover Class	Post-Burn (1992) % Freq.	Post-Burn (1992) Ave. Cover Class
Danthonia spicata	80.0	1.3	73.7	1.7
*Polytrichum ohioense**	60.0	0.9	40.0	0.9
Quercus spp.	53.3	1.1	60.0	1.3
Toxicodendron radicans	46.7	1.2	40.0	1.3
Eleocharis tenuis var. verrucosa	33.3	0.5	46.7	1.0
*Leucobryum glaucum**	33.3	0.4	13.3	0.2
Potentilla simplex	16.6	0.6	0.0	0.0
Carex laxiflora	26.6	0.3	20.0	0.3
Luzula echinata	20.0	0.2	13.3	0.1
Parthenocissus quinquefolia	20.0	0.5	26.7	0.5
Viola sagittata	20.0	0.3	6.7	0.1
Quercus imbricaria	20.0	0.3	0.0	0.0
Lysimachia lanceolata	20.0	0.4	20.0	0.3
Panicum depauperatum	13.3	0.1	33.3	0.5
*Cladonia strepsilis**	13.3	0.1	0.0	0.0
Carya spp.	13.3	00.3	46.7	1.2
Porteranthus stipulatus	13.3	0.1	33.3	0.5
Carex caroliniana	6.7	0.1	53.3	0.9
Crataegus sp.	0.1	0.1	20.0	0.2
Diospyros virginiana	0.2	0.3	33.3	0.3
Agrostis perennans	0.0	0.0	33.0	0.5

* Non-vascular plant.

xeric sites. The relative stability of these communities is attributed to the ability of upland oaks to resist fire (presumed to have been fairly frequent historically) and drought (through a combination of morphological and physiological adaptations) and the ability to survive on nutrient-poor soils (Abrams, 1992).

Following the fire at POB, subtle shifts occurred in the composition of the vegetation as indicated by a significant decrease in richness in the tree-layer (Table 3) and an increase in evenness in the herb-layer (Table 4) in the absence of significant changes in Shannon-Weaver diversity index values. The presence of *Erechtites hieracifolia* (fire weed) at the site for the first time following the burn (Table 6) indicates that the prescribed burn was sufficiently intense to induce fire-related changes in the vegetation at the site. This annual plant is often found in burned-over woodlands (Deam, 1940). Whether the seeds of fire weed were dispersed into the site or were present in the soil is not known. Also appearing after the burn was the potentially unfavorable species *Rhus glabra,* whose clonal spread can shade out other native species. *Rhus glabra* presents a management problem as a woody invader of glades and hill prairies in Illinois (Hutchinson, 1990) and presumably has the potential to become problematic at POB. *Agrostis perennans,* as the name implies, is a perennial grass of woodlands, often occurring

Table 6. New species appearing in the herb-layer following the 1989 prescribed burn. The year of first observation is in parentheses following the species name. Species were observed in surveys each subsequent year unless indicated.

Burned Plots	Unburned Control Plots
Erechtites hieracifolia (1989, not present in 1991 or 1992)	*Acer negundo* (1990)
Parietaria pensylvanica (1989)	*Agrostis perennans* (1991)
Phytolacca americana (1989)	*Heuchera* sp. (1991)
Urtica sp. (1989)	*Viola* sp. (1991)
Heuchera sp. (1989)	*Panicum lanuginosum* (1991)
Panicum dichotomum (1990)	
Panicum lanuginosum (1990)	
Agrostis perennans (1991)	
Rhus glabra (1991)	

on damp soils but sometimes found in dry open woods and adjacent fields (Voss, 1972). It was not encountered at POB in woods or barrens prior to the burn (Dolan and Menges, 1989) and was not seen in previous surveys of adjacent post oak flatwoods (Aldrich and Homoya, 1984). The non-habitat specialist, *Phytolacca americana,* also appeared following the burn but was not recorded in unburned areas.

CONCLUSIONS

Frequency estimates for presettlement fires in fire-adapted communities of eastern North America range from yearly for prairies (Abrams, 1992), to every 4.3 years for post oak savannas in Missouri (Guyette and Cutter, 1991), to 50-100 years for oak forests in the Midwest and eastern United States (Abrams, 1992). Evidence collected at POB based on fire scars detected in tree-ring analysis and on interviews with long-time residents of the area indicate a historical fire frequency of about one fire every 30 years (Dolan and Menges, 1989). The prescribed burn described here killed understory trees but had little impact on plot-level diversity three years following the fire. The reduced competition resulting from fire may be beneficial to the growth of post oak. These benefits may outweigh the slight risks of opening the site to new species such as *Rhus glabra,* a shrub that has the potential to out-compete shade-intolerant post oak seedlings.

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