GREAT LAKES/
PROJECT REPORT

Restoring Historic Plant Communities in the Oak Openings Region of Northwest Ohio

by Scott R. Abella, John F. Jaeger, Denise H. Gehring, Robert G. Jacksy, Karen S. Menard, and Kim A. High

Historic prairie, oak savanna, and oak woodland communities recovered quickly following experimental treatments by the Toledo Metroparks staff.

Before European settlement, a diverse fire-maintained landscape of oak savanna, oak woodland, and wet prairie covered the 100,000-acre Oak Openings ecological region of northwest Ohio and southeastern Michigan (Figure 1). Separated by the densely forested Great Black Swamp (Sampson, 1930; Transeau, 1935; Kaatz, 1955) from the large oak savanna-prairie complex that once covered much of southern Michigan (Jones, 1838; Veatch, 1927; Nuzzo, 1986; Anderson, 1998), the Oak Openings region occupied the deep sands and rolling dunes that were deposited along the western shoreline of Lake Warren—a shallow glacial lake that extended over an area larger than present-day Lake Erie (Atwater, 1818; Moseley, 1928). As glaciers retreated north and Lake Warren dried, sandy beach ridges were exposed to create a landscape unique in Ohio. The rolling beach dunes of the Oak Openings historically supported oak savanna and woodland, while wet prairies grew in interdunal depressions (Sears, 1925; Sears 1926a, b). The oak savannas and woodlands were dominated by sparse overstories of white oak (*Quercus alba*) and black oak (*Q. velutina*) and contained understories with a variety of grasses, sedges, and herbs (Moseley, 1928; Gordon, 1969). Wet prairie occurred as extensive plains or as pockets in lowlands within a matrix of upland savanna. These treeless wet prairies had a water table within three feet of the surface throughout the year and contained a luxuriant growth of mesic grasses, sedges, and herbs (Tryon and Easterly, 1975; Easterly, 1983). Historic savanna and wet prairie burned frequently and intensely (Wells, 1818; Anonymous, 1838), while woodlands occupied landscape positions protected from fire that burned less frequently (Grimm, 1984).

By the late 1800s, human activities including agricultural clearing, logging of oaks, draining of the wet prairies, and fire suppression had altered the historic Oak Openings plant communities (Moseley, 1928). Even a few years of fire suppression dramatically changed the structure of these fire-dependent ecosystems as the cartographer-naturalist A. Bourne (1820) noted, "A young growth of trees, healthy and vigorous soon springs up, far superior to the stunted growth which the frequent fires have scorched, and the barren assumes the appearance of a timbered country." Fire suppression allowed red maple (*Acer rubrum*) and other fire-intolerant species to gradually replace oaks and fire-dependent species. Throughout the 1900s, wet prairie and oak savanna succeeded to forest, groundlayer diversity declined, and remaining natural areas became increasingly fragmented by agricultural clearing and urbanization. By the late 1980s, land managers realized that restoration would be required to

Ecological Restoration, Vol. 19, No. 3, 2001

save the historic plant communities of the Oak Openings.

Restoration in the Oak Openings Preserve

In 1988 Toledo Metroparks began identifying and restoring degraded savanna remnants in the 3,693-acre Oak Openings Preserve by reintroducing fire and removing brush (Brewer and Grigore, 1993). Ten years later, Metroparks received a grant from the U.S. EPA Great Lakes Project Office to continue restoring about 400 acres of historic oak savanna, oak woodland, and wet prairie communities on several degraded sites that had succeeded to forest due to fire suppression. Restoration involved the reintroduction of fire, selective thinning of overstory trees, selective removal of understory brush using cutting and herbicides, and thinning of red maple, sassafras (*Sassafras albidum*), and black cherry (*Prunus serotina*) saplings. In this paper, we report the results of restoration efforts that began in 1998 at three degraded sites that historically supported wet prairie, oak savanna, and oak woodland.

Figure 1. Location of the Oak Openings ecological region and Oak Openings Preserve Metropark. Modified from Moseley, 1928 and Transeau, 1935.

Before the 1998 restoration activities, we established 20 x 25 m measurement plots with six 1-m^2 subplots within each of the three degraded sites. The savanna and woodland restoration sites contained four measurement plots each, and the wet prairie restoration site contained three measurement plots. In 1998 we implemented spring and fall burning regimes in all three degraded communities. In addition to removing brush, we also cleared the entire overstory of red maple, sassafras and other non-oak species from the wet prairie restoration site (Figure 2). We removed non-oaks, partially thinned overstory oaks and removed brush at the savanna restoration site. We did nothing to the overstory or brush in the woodland site.

In 1998, we inventoried the plots twice before restoration and then inventoried the plots twice each year after restoration in 1999 and 2000. We recorded the percent cover of the groundlayer by species in subplots and determined the species and diameter at breast height (DBH) of overstory trees greater than 1 cm DBH in the measurement plots. We used one-tailed paired *t* tests to test our hypotheses that native species would increase and exotic species decrease from pre-restoration to post-restoration levels within each community. To compare groundlayer composition and percent cover among restoration community types, we used one-way analyses of variance with Fisher's least significant difference for mean separation. Percent data not meeting the assumption of homogeneity of variance were analyzed on a transformed scale as arcsin ($\sqrt{\pi}$). We compared groundlayer community composition between years and among communities with Jaccard's index of community similarity. Jaccard's index is based on species presence/ absence and is calculated as C / (A + B – C), where C = number of common species, A = total species in community A and B = total species in community B.

Results

We found that native groundlayer species richness in the savanna increased after restoration (Table 1). Although not statistically significant, there was also a trend for greater native species richness in the wet prairie and woodland communities following restoration treatments. Native species richness differed among communities following restoration with the savanna community containing the most native species and the woodland the least. Exotic species richness did not change following restoration in any community, although the woodland community contained fewer exotic species than the wet prairie in both 1998 and 2000.

After the 1998 restoration activities, the percent native herb cover increased in the wet prairie community, and shrub and tree seedling cover increased in the woodland (Table 2). We found few differences between 1998 and 2000 in percent cover of individual species and species groups in the three communities (Table 3). There were a few exceptions, however. For example, goldenrod (*Solidago* spp.) increased in the wet prairie following restoration, while blueberry (*Vaccinium* spp.) and other shrubs tended to increase in the woodland. In the savanna, species such as big bluestem (*Andropogon gerardi*), sweetfern (*Comptonia peregrina*), western sunflower (*Helianthus occidentalis*) and puccoon (*Lithospermum* spp.) tended to increase following restoration. In 2000 we also found new occurrences of Canada frostweed (*Helianthemum bicknellii*), Indiangrass (*Sorghastrum nutans*) and bushclover (*Lespedeza capitata*) in the savanna. We also found, based on the results of Jaccard's index, that overall species composition was dissimilar in the wet prairie before and after restoration, while the species composition of the woodland changed very little (Table 4).

Implications for Restoration

Oak Woodland

We found that the significant changes in the wet prairie and savanna communities were highlighted by shifts in species composition and cover. Meanwhile, the composition of the woodland remained relatively the same, although the total percent cover of native species did increase. This increase in total native cover in the woodland was due primarily to increases in tree seedlings of black cherry and white oak as well as increases in shrubs, such as witch hazel (*Hamamelis virginiana*) and blueberry. Earlier studies of Oak Opening woodlands (Sears, 1926b; Moseley, 1928) indicate that they were historically dominated by shrubs. Our reintroduction of burning likely stimulated the growth of understory seedlings and shrubs, although we suspect that long-term burning will probably depress the growth of tree seedlings and saplings that have accumulated due to fire suppression. While woodlands in the Oak Openings historically burned less frequently than savanna or wet prairie (Brewer and Grigore, 1993), our results suggest that periodic burning is important to maintain the shrub structure characteristic of presettlement woodlands.

After analyzing the results of this study and 12 years of burning in similar woodlands in other parts of the Oak Openings Preserve, we believe that groundlayer diversity in this community is below historic levels. The groundlayer in these woodlands is being inhibited by low levels of light from dense overstories and thick litter layers that have accumulated from more than a century of fire suppression (Goldberg and Werner, 1983; Facelli and Pickett, 1991; Leach and Givnish, 1999). This is a situation where re-establishing the historic burn regime will not correct the problem. Instead, we recommend 1) thinning the overstory to 40-50 trees per acre to decrease the annual litter fall (Bray and Gorham, 1964) and 2) implementing a long-term, periodic burn regime (one burn every two to five years) to thin the surface organic litter layers (Phillips and others, 2000). With increased light penetration and reduced litter layers, we believe that the woodland could support a diverse groundlayer while continuing to support a characteristic understory structure dominated by shrubs and sedges.

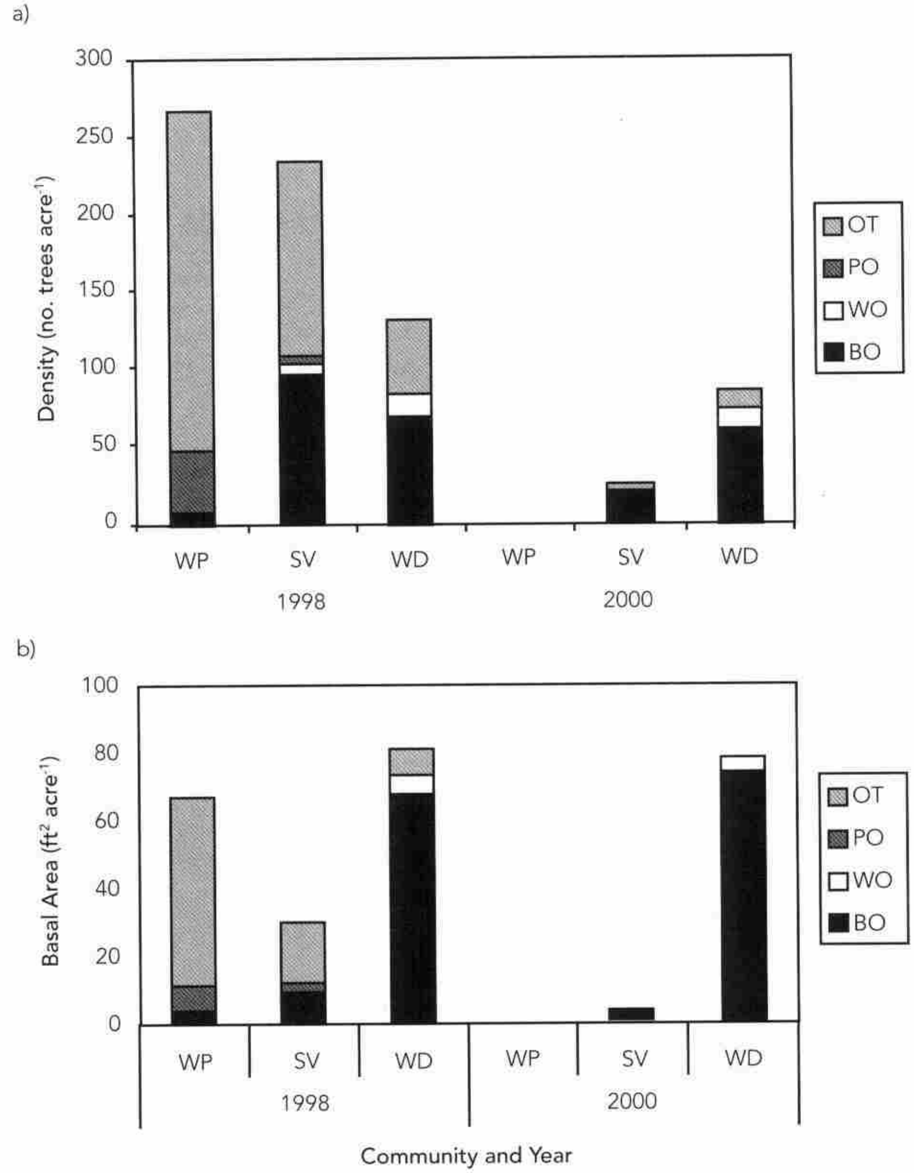

Figure 2. Mean density (a) and basal area (b) by species of communities in 1998 prior to restoration and in 2000 following restoration. Species abbreviations are as follows: BO = black oak, WO = white oak, PO = pin oak, OT = other (primarily black cherry, sassafras, and red maple). Community abbreviations are as follows: WP = wet prairie, SV = savanna, WD = woodland.

Wet Prairie

In contrast to the woodland, the wet prairie is undergoing a dramatic shift in species composition following restoration. Despite these compositional changes, several characteristic Oak Openings wet prairie species such as big bluestem, swamp milkweed (*Asclepias incarnata*), wild bergamot (*Monarda fistulosa*), dense blazing star (*Liatris spicata*), cardinal flower (*Lobelia cardinalis*) and Virginia mountain mint (*Pycnanthemum virginianum*) are lacking in this restored community (Tryon and Easterly, 1975). In addition, goldenrod has increased dramatically and is forming a monoculture that is suppressing other species.

Another concern is the altered hydrology of the site. The wet prairie site occupies hydric soils (Stone and others, 1980) in a depression between dune ridges, but ditching has lowered the water table below this depression. Blocking the ditches would partially restore the hydrology and, when combined with an annual or biannual intense burning regime and interseeding of prairie species, could reduce the goldenrod monoculture and encourage growth of a lush groundlayer of grasses, sedges, and forbs characteristic of Oak Openings wet prairie (Riddell, 1835 in Sears, 1926a; Moseley, 1928; Tryon and Easterly, 1975). Nonetheless, restoring this wet prairie will take more time than either the savanna or woodland.

Table 1. Mean species richness of native and exotic groundlayer species by community type before restoration (1998) and after restoration (2000).† Means represent the total number of species occurring during two sampling events each year in six 1-m² subplots within each 0.05-ha plot averaged for each community. Means within a row not followed by the same letter differ significantly at $P < 0.05$.‡ Paired means preceded by an asterisk (*) differ significantly at $P < 0.05$ between years within a community.§

	Wet Prairie		Savanna		Woodland		
	Mean	SE+	Mean	SE	Mean	SE	Year
Native richness	19.7 ab	2.3	*24.0 a	2.4	14.5 b	1.9	1998
	20.3 b	1.9	*26.5 a	1.5	15.3 c	1.3	2000
Exotic richness	3.3 a	1.2	2.3 ab	0.8	0.5 b	0.3	1998
	4.0 a	1.5	1.5 ab	0.9	0.5 b	0.3	2000

† Native and exotic species classified according to Voss 1972, 1985, 1996 and USDA-NRCS, 1999.
‡ One-way analysis of variance with Fisheris least significant difference for mean separation
§ One-tailed paired t tests
+ Standard error of the mean

Table 2. Mean percent cover of native groundlayer life forms,† total native groundlayer, and exotic species by community type before restoration (1998) and after restoration (2000).‡ Means within a row not followed by the same letter differ significantly at $P < 0.05$.§ Paired means for each life form preceded by an asterisk (*) differ significantly at $P < 0.05$ between years within a community.+

	Wet Prairie		Savanna		Woodland		
	Mean	SE+	Mean	SE	Mean	SE	Year
% grass cover	5.1 ab	4.4	15.3 a	8.0	0.2 b	0.1	1998
	4.9 b	2.3	18.4 a	6.3	0.3 b	0.2	2000
% herb cover	* 9.5 a	2.4	7.7 ab	2.9	0.8 b	0.5	1998
	*12.2 a	2.4	8.0 a	3.0	1.0 b	0.3	2000
% sedge cover	*13.9 a	1.5	5.8 a	1.8	10.3 a	3.9	1998
	*8.4 a	2.5	4.7 a	1.5	12.0 a	4.8	2000
% seedling cover	9.2 a	6.7	9.3 a	2.6	*11.7 a	1.3	1998
	7.1 a	6.0	6.7 a	2.8	*18.1 a	2.0	2000
% shrub cover	5.1 a	1.0	11.4 a	5.1	14.9 a	7.3	1998
	8.8 a	0.7	12.4 a	3.4	20.4 a	7.3	2000
% fern cover††	—	—	5.3 a	2.2	5.4 a	2.8	1998
	—	—	4.1 a	1.0	5.2 a	2.9	2000
% vine cover	0.2 a	0.1	0.9 a	0.5	0.1 a	0.1	1998
	0.1 a	0.1	1.2 a	0.6	0.1 a	0.1	2000
% total native cover	42.9 a	2.5	55.6 a	6.2	*43.4 a	7.9	1998
	41.6 a	3.3	55.4 a	1.4	*57.0 a	7.8	2000
% exotic cover	5.4 a	2.5	1.2 b	1.0	0.1 b	0.1	1998
	1.7 a	0.9	0.8 a	0.8	0.1 a	0.1	2000

† Life forms follow Radford and others, 1968.
‡ Data not meeting the assumption of homogeneity of variance was analyzed on a transformed scale as arcsin ((().
§ One-way analysis of variance with Fisheris least significant difference for mean separation
+ One-tailed paired t tests
# Standard error of the mean
†† No ferns were recorded in wet prairie restoration plots.

Savanna

We were surprised that native species richness increased in the restored savanna after only three years. We hypothesize that these new species emerged from the seed bank after stimulation by burning or were transported to the site from nearby areas. With continued burning, selective brush removal and interseeding of absent or reduced species, we expect that groundlayer diversity and grass cover will continue to increase in the savanna while bracken fern (*Pteridium aquilinum*), tree seedlings and brush more characteristic of forest and woodland will decrease.

The percent cover of wild lupine (*Lupinus perennis*) at the savanna site did not change following restoration treatments. Wild lupine is the larval food source for several rare savanna butterflies—Persius dusky wing (*Erynnis persius*), frosted elfin (*Incisalia irus*), and Karner blue (*Lycaeides melissa samuelis*)—that in Ohio are restricted to the Oak Openings ecological region (Shuey and others, 1987). Grigore and Tramer (1996) found that burned lupine plants in the Oak Openings grew larger and produced more seed than unburned lupine, but burning increased seed and seedling mortality. These results suggest that long-term burning will favor lupine at sites where it is already present in significant densities, but intense annual or biannual burns may inhibit lupine from establishing new populations. We believe that an irregular burning regime (varying time of year and frequency) will enhance lupine over the long-term at the savanna restoration site and will more closely mimic a presettlement burning regime.

Restoration Plan

With a diverse mixture of prairie species from the midwestern prairie region

(Weaver and Fitzpatrick, 1934) and disjunct species outside their normal range (Thompson, 1939), the Oak Openings ecological region is still highly diverse despite severe losses of sites to urban sprawl and degradation of remnants by fire suppression. For example, Lucas County, in the heart of the Oak Openings region, still supports 163 state rare plants, 23 more than the next highest county in Ohio (Ohio Division of Natural Areas and Preserves, 2000). Several rare savanna insects, including antennal-waving wasps (*Tachysphex pechumani*) and a previously undescribed moth (*Aethes patricia*), persist in the Oak Openings region despite severe reduction of habitat (Kurczewski, 1998; Metzler, 1999). After more than 150 years of fire suppression and fragmentation in the Oak Openings, the future health of these and other rare species is dependent on continued historic ecosystem restoration.

Our results demonstrate that within three years controlled burning, overstory thinning, and other restoration treatments began to increase native species diversity and restore historic structure in three degraded Oak Openings communities. Moreover, they imply that restoration treatments should be continued to restore structure, groundlayer species, and natural disturbances characteristic of historic Oak Openings (White, 1983; Packard and Mutel, 1997).

In addition there are other concerns that must be addressed to ensure the sustainability of these restored communities. First, we must aggressively identify and control infestations of exotic species, such as spotted knapweed (*Centaurea maculosa*), as part of the restoration process (Abella and MacDonald, 2000). Second, conservation organizations must purchase key remaining remnant areas throughout the Oak Openings or they will be lost to residential and other land uses. Restoration, combined with key land purchases, has a central role in the future ecological health of the northwest Ohio Oak Openings region in an increasingly urbanizing landscape.

Table 3. Mean percent cover of selected species and species groups in 2000 following restoration by community type. Means for each species preceded by an asterisk (*) differ significantly at $P < 0.05$ between pre- (1998) and post-restoration (2000) levels within a community.† Plant life form‡ follows the scientific name in parenthesis.§

Scientific Name+	Common Name	Wet Prairie Mean#	Wet Prairie SE††	Savanna Mean	Savanna SE	Woodland Mean	Woodland SE
Acer rubrum (s)	red maple	0.2	0.1	—	—	0.2	0.1
Andropogon gerardii (g)	big bluestem	—	—	2.6	2.6	—	—
Andropogon scoparius (g)	little bluestem	—	—	10.3	7.9	—	—
Carex spp. (d)	sedge	*8.4	2.5	4.7	1.5	12.0	4.8
Comptonia peregrina (b)	sweet fern	0.7	0.7	2.1	1.3	—	—
Euphorbia corollata (h)	flowering spurge	0.1	0.0	0.2	0.1	—	—
Fragaria spp. (h)	strawberry	0.1	0.1	0.2	0.1	—	—
Gaylussacia baccata (b)	huckleberry	—	—	0.9	0.9	2.6	2.2
Hamamelis virginiana (s)	witch hazel	—	—	—	—	4.2	3.3
Helianthemum bicknellii (h)	Canada frostweed	—	—	0.3	0.3	—	—
Helianthus occidentalis (h)	western sunflower	—	—	0.9	0.8	Tr	0.0
Koeleria macrantha (g)	Junegrass	—	—	0.2	0.2	—	—
Krigia virginica (h)	dwarf dandelion	—	—	Tr	0.0	0.1	0.1
Lespedeza capitata (h)	bush clover	0.1	0.1	Tr	0.0	Tr	0.0
Liatris spp. (h)	blazing star	Tr	0.0	0.3	0.2	—	—
Lithospermum spp. (h)	puccoon	—	—	1.1	0.7	—	—
Lupinus perennis (h)	wild lupine	—	—	1.5	1.5	—	—
Oxalis spp. (h)	wood sorrel	0.2	0.2	Tr	0.0	—	—
Panicum clandestinum (g)	deertongue	2.4	1.5	Tr	0.0	—	—
Panicum spp. (g)	panic grass	2.6	1.2	3.2	1.2	0.3	0.2
Panicum virgatum (g)	switchgrass	—	—	1.0	1.0	—	—
Polygala polygama (h)	racemed milkwort	0.3	0.3	Tr	0.0	Tr	0.0
Polygonatum biflorum (h)	smooth Solomon-seal	—	—	0.1	0.0	0.2	0.1
Potentilla simplex (h)	common cinquefoil	1.2	1.2	0.2	0.1	0.1	0.0
Prunus serotina (s)	black cherry	1.3	1.0	0.4	0.2	2.1	1.1
Pteridium aquilinum (f)	bracken fern	—	—	4.1	1.0	5.2	2.9
Quercus alba (s)	white oak	Tr	0.0	Tr	0.0	2.7	1.6
Quercus velutina (s)	black oak	2.5	1.8	3.1	1.1	5.4	1.2
Rhus copallina (b)	winged sumac	0.5	0.5	0.8	0.8	—	—
Rosa carolina (b)	pasture rose	0.1	0.1	0.9	0.3	0.6	0.4
Rubus spp. (b)	raspberry/blackberry	6.3	0.6	3.2	1.6	2.8	1.6
Sassafras albidum (s)	sassafras	3.1	3.0	1.4	1.3	3.5	2.3
Smilax spp. (v)	greenbrier	Tr	0.0	0.6	0.5	0.1	0.1
Solidago spp. (h)	goldenrod	*9.5	3.5	2.5	1.5	0.3	0.3
Sorghastrum nutans (g)	Indian grass	—	—	0.1	0.1	—	—
Vaccinium spp. (b)	blueberry	—	—	4.2	4.2	14.3	7.1

† One-tailed paired t tests
‡ Life forms follow Radford and others, 1968.
§ b = shrub, d = sedge, f = fern, g = grass, h = herb, s = tree seedling, v = vine
+ Nomenclature follows Voss 1972, 1985, 1996.
# — = species not present, Tr = trace (rounds to zero)
†† Standard error of the mean

Table 4. Jaccard's community similarity coefficients for the Oak Openings restoration communities by community type pre- (1998) and post-restoration (2000).

Comparison‡	1998	2000	1998/2000
WP:SV	0.37	0.37	X
WP:WD	0.26	0.26	X
SV:WD	0.32	0.25	X
WP:WP	X	X	0.49
SV:SV	X	X	0.60
WD:WD	X	X	0.67

A Jaccard coefficient > 0.5 indicates community similarity, whereas a coefficient < 0.5 indicates dissimilarity. Jaccard coefficients range from 0 when no species occur in both communities to 1, when all species occur in both communities (complete similarity).
‡ WP = wet prairie, SV = savanna, WD = woodland

Acknowledgments

Restoration in Oak Openings Preserve was supported in part by U.S. EPA grant GL985592-01-0. We are grateful to Michelle Grigore for her efforts during the grant process and Gary Horn and Joe Croy for providing administrative support. We thank Mark St. Mary, Ted Witham, Jerald Jankowski, Thomas Duvendack, Heather Norris, Mark Plessner, Kathryn Nelson, Jenny Finfera, Monique Mendieta and Sarah McCallum for providing invaluable assistance in the field with restoration work for this project. We also thank Neil MacDonald for providing helpful comments on a preliminary draft of this paper.

References

Abella, S.R. and Neil W. MacDonald. 2000. Intense burns may reduce spotted knapweed germination. *Ecological Restoration* 18:203-205.

Anderson, R.C. 1998. Overview of midwestern oak savanna. *Transactions of the Wisconsin Academy of Sciences, Arts and Letters* 86:1-18.

Anonymous. 1838. Prairies of Ohio. *American Journal of Science* 33:230-236.

Atwater, C. 1818. On the prairies and barrens of the West. *American Journal of Science* 1:116-125.

Bourne, A. 1820. On the prairies and barrens of the West. *American Journal of Science* 2:30-34.

Bray, J.R. and E. Gorham. 1964. Litter production in forests of the world. *Advances in Ecological Research* 2:101-157.

Brewer, L.G. and M.T. Grigore. 1993. Restoring oak savannas in northwest Ohio – monitoring the progress. *In* Proceedings of the 1993 Midwest Oak Savanna Conference, Chicago, Illinois (available at http://www.epa.gov/glnpo/oak/).

Easterly, N.W. 1983. Endangered and threatened plant species of Schwamberger Preserve, Lucas County, Ohio. *Ohio Journal of Science* 83:97-102.

Facelli, J.M. and S.T.A. Pickett. 1991. Plant litter: its dynamics and effects on plant community structure. *Botanical Review* 57:1-32.

Goldberg, D.E. and P.A. Werner. 1983. The effects of size of opening in vegetation and litter cover on seedling establishment of goldenrods (*Solidago* spp.). *Oecologia* 60:149-155.

Gordon, R.B. 1969. The natural vegetation of Ohio in pioneer days. *Bulletin of the Ohio Biological Survey* (New Series) 3(2):1-113.

Grigore, M.T. and E.J. Tramer. 1996. The short-term effect of fire on *Lupinus perennis* (L.). *Natural Areas Journal* 16:41-48.

Grimm, E.C. 1984. Fire and other factors controlling the Big Woods vegetation of Minnesota in the mid-nineteenth century. *Ecological Monographs* 54:291-311.

Jones, G. 1838. Some observations in Holland, connected with our prairie region. *American Journal of Science* 33:226-230.

Kaatz, M.R. 1955. The Black Swamp: A study in historical geography. *Annals of the Association of American Geographers* 45:1-35.

Kurczewski, F.E. 1998. Distribution, status, evaluation, and recommendations for the protection of *Tachysphex pechumani* Krombein, the antennal-waving wasp. *Natural Areas Journal* 18:242-254.

Leach, M.K. and T.J. Givnish. 1999. Gradients in the composition, structure, and diversity of remnant oak savannas in southern Wisconsin. *Ecological Monographs* 69:353-374.

Metzler, E.H. 1999. Two new species of Cochylini (Lepidoptera: Tortricidae: Tortricinae) from the eastern United States. *Great Lakes Entomologist* 32:185-197.

Moseley, E.L. 1928. Flora of the Oak Openings. *Proceedings of the Ohio Academy of Science*, Volume 8, Special Paper No. 20:79-134.

Nuzzo, V.A. 1986. Extent and status of Midwest oak savanna: Presettlement and 1985. *Natural Areas Journal* 6:6-36.

Ohio Division of Natural Areas and Preserves. 2000. Rare native Ohio plants: 2000-01 status list. Ohio Department of Natural Resources, Columbus, Ohio (available at http://www.dnr.state.oh.us/odnr/dnap/heritage/hertage2.html).

Packard, S. and C.F. Mutel, eds. 1997. *The tallgrass restoration handbook*. Washington, D.C.: Island Press.

Phillips, D.H., J.E. Foss, E.R. Buckner, R.M. Evans and E.A. FitzPatrick. 2000. Response of surface horizons in an oak forest to prescribed burning. *Soil Science Society of America Journal* 64:754-760.

Riddell, J.L. 1835. *A synopsis of the flora of the western states*. Cincinnati: E. Deming.

Sampson, H.C. 1930. Succession in the swamp forest formation in northern Ohio. *Ohio Journal of Science* 30:340-357.

Sears, P.B. 1925. The natural vegetation of Ohio I. A map of the virgin forest. *Ohio Journal of Science* 25:139-149.

__. 1926a. The natural vegetation of Ohio II. The prairies. *Ohio Journal of Science* 26:128-146.

__. 1926b. The natural vegetation of Ohio III. Plant succession. *Ohio Journal of Science* 26:213-231.

Shuey, J.A., J.V. Calhoun and D.C. Iftner. 1987. Butterflies that are endangered, threatened, and of special concern in Ohio. *Ohio Journal of Science* 87:98-106.

Stone, K.L., E.H. McConoughey, G.D. Bottrell and D.J. Crowner. 1980. Soil Survey of Lucas County, Ohio. U.S. Department of Agriculture, Soil Conservation Service. Washington, D.C.: U.S. Government Printing Office.

Thompson, I. 1939. Geographical affinities of the flora of Ohio. *American Midland Naturalist* 21:730-751.

Transeau, E.N. 1935. The prairie peninsula. *Ecology* 16:423-437.

Tryon, C.A. and N.W. Easterly. 1975. Plant communities of the Irwin Prairie and adjacent wooded areas. *Castanea* 40:201-212.

U.S. Department of Agriculture, Natural Resources Conservation Service. 1999. The PLANTS database (http://plants.usda.gov/plants). National Plant Data Center, Baton Rouge, LA 70874-4490 USA.

Veatch, J.O. 1927. The dry prairies of Michigan. *Papers of the Michigan Academy of Science, Arts, and Letters* 8:269-278.

Weaver, J.E. and T.J. Fitzpatrick. 1934. The prairie. *Ecological Monographs* 4:111-295.

Wells, R.W. 1818. On the origin of prairies. *American Journal of Science* 1:331-337.

White, A.S. 1983. The effects of thirteen years of annual prescribed burning on a *Quercus ellipsoidalis* community in Minnesota. *Ecology* 64:1081-1085.

Scott R. Abella is a graduate student in the Department of Forest Resources, Clemson University, Clemson, SC 29634-0331, 864/653-3618, ras@clemson.edu;

John F. Jaeger, Denise H. Gehring, Robert G. Jacksy, Karen S. Menard, and Kim A. High are with Metroparks of the Toledo Area, 5100 W. Central Avenue, Toledo, OH 43615, 419/535-3058.
