PROJECT REPORT

When Is a Restoration Successful? Results from a 45-Year-Old Tallgrass Prairie Restoration

by Stuart K. Allison

A survey of the third oldest tallgrass prairie restoration in the Midwest demonstrates the difficulty of achieving a "complete restoration."

Restoration ecology had its genesis in the 1930s as Midwestern ecologists came to the realization that nearly all the tallgrass prairie in Illinois, Iowa, and Wisconsin had been converted to agricultural or urban land uses (Curtis and Greene 1949, Critical Trends Assessment Project 1994, Smith 1998). While calls for preservation of remaining prairie in Iowa began by 1919 (Smith 1998), the pioneer restoration ecologists of the early 20th century recognized that if extensive areas of tallgrass prairie were going to be part of our future, they would have to begin to restore these historic grasslands.

The first efforts were undertaken at the University of Wisconsin-Madison Arboretum, initially as experimental plots under the direction of biology professor Dr. Norman Fassett, and later under the direction of Dr. Theodore Sperry and Dr. Henry Greene. Dr. Sperry led the restoration activity at Curtis Prairie—a planting effort that involved men from the Civilian Conservation Corps and lasted from 1936 through 1940—while Dr. Greene almost single-handedly planted Greene Prairie between 1943 and 1952 (Blewett and Cottam 1984). Their efforts served as the inspiration for the third tallgrass prairie restoration in the Midwest (Howell and Jordan, 1991) which took place at the Knox College Green Oaks Field Study Center in west-central Illinois.

Green Oaks: A Pioneer Tallgrass Prairie Restoration

In November 1954, two members of the Knox College Biology Department—George Ward and the late Paul Shepard—visited the Arboretum in Madison and toured its prairies. After their visit, they resolved to undertake a tallgrass prairie restoration at Green Oaks (Shepard, *Green Oaks News*, Dec. 7, 1954, Knox College Library Archives). Shepard's goal for the restoration at Green Oaks was similar to that of the prairie restorations at the University of Wisconsin-Madison Arboretum, namely a "complete restoration: the establishment of a group of species in abundances and proportions similar to those in natural communities such that natural processes occur" (Howell and Jordan 1991).

Shepard and Ward began planting the prairie in April 1955 with seeds of 63 plant species that they either collected along railway rights-of-way and pioneer cemeteries or received from the University of Wisconsin Arboretum (Shepard, *Green Oaks News*, April 11, 1955, Knox College Library Archives). The first prairie they

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During the 1950s George Ward (second from the left) and the late Paul Shepard (far right) were members of the Biology Department at Knox College in Galesburg, Illinois. In 1955, they planted the first section of prairie (East Prairie) at Green Oaks. Shepard left Knox College in 1963, having planted East Prairie and started another known as West Prairie. Shepard was later to become famous as the author of several provocative books, including *The Tender Carnivore, Subversive Sciences, Coming Home to the Pleistocene,* and *Nature and Madness.* Also in the photo are Bill Ward (left, the property caretaker, but no relation to George Ward) and Alvah Green (second from right, a local attorney and the property owner at the time George Ward and Shepard starting planting). *Photo courtesy of Stuart K. Allison*

planted became known as East Prairie. Shepard continued and expanded the prairie plantings, initiating another prairie restoration at West Prairie.

In 1963 Shepard left Knox College. He was replaced by Peter Schramm, who was hired in 1965. Schramm maintained the original plantings, expanded the plantings in West Prairie, and began a new prairie restoration at South Prairie in 1966 (Schramm 1992). Schramm treated the restorations in West and South Prairies as a working laboratory in which he tested different restoration techniques and mixtures of plant species. Though he based his restorations on remnant prairies, he felt it might be almost impossible to exactly re-create original prairie so his goal became the establishment of an aesthetically pleasing facsimile of original prairie (Schramm 1992). Schramm completed major plantings in West Prairie by 1973 and in South Prairie by the late 1970s. Even after those plantings were finished, he continued to experiment with transplanting rare prairie plants into established prairie in both West and South Prairies (D. Krohne pers. comm.).

Now that these restored prairies are maturing, we can ask just how successful they are and whether they are good copies of natural prairies.

The first step in analyzing the success of a restoration is to determine whether the restorationists involved set clear goals before they proceeded with their work. A major problem for all restorationists is that they are attempting to re-create an ecosystem that is no longer present on the site and is known only from historical records. Restorationists often find it difficult to set definite ecological standards for such a restoration because they do not have quantitative data about the historical condition of a site (Westman 1991).

This was certainly the case for the prairie restorations at Green Oaks. Shepard's notes (Knox College Library Archives) indicate that his goal for the restored prairies at Green Oaks was to eventually replicate the prairies that existed at the time of European settlement of Knox County in the 1830s. Schramm continued the restorations with this final goal in mind, although Schramm felt that, due to the lack of historical data, existing prairie remnants had to serve as the model for prairie restoration (Schramm 1992).

I began this study by asking: How successful are the restored prairies at Green Oaks? Because historical data are lacking and Schramm used remnant prairies as his model, I decided to analyze the success of the restorations at Green Oaks by comparing the restored prairies with nearby prairie remnants. The best way to judge the success of the prairie restorations at Green Oaks is by comparing the restored and remnant prairies in terms of the percentage of species present in them that also appear in Mead's (1846) list of prairie plants present at the time of European settlement. Mead listed a total of 297 species occurring in prairies in west-central Illinois, primarily in Hancock County. I found 100 species in the restored prairies at Green Oaks, and 72 of them (72 percent) were listed by Mead. I found 105 species in the remnant prairies, 75 of which (71.4 percent) were listed by Mead. The restored and remnant prairies are about equally composed of plant species known to be present in Illinois prairies at the time of European settlement.

Using remnant prairies as the model for determining the success of prairie restoration is also problematic. Remnant prairies are not static and are likely to have changed during the approximately 170 years since European settlement. Of course, the question we can never answer is whether 72 percent of the species in the remnant prairies would have occurred on Mead's list if they had been sampled 170 years ago at the time Mead began compiling his species list. Taft (1995) feels that prairie remnants in Illinois have survived at random, captured different subsets of the total prairie flora, and thus are probably low in floristic similarity. So it is likely that the prairie remnants I studied would have been somewhat different from the prairies Mead saw. Curtis and Greene (1949) felt that prairie remnants were unlikely to be representative of natural prairie because often the remnants survived because they were on sites that were not as conducive to agriculture as typical prairie. They also thought that the small size of the prairie remnants and their artificial isolation from other prairie patches would lead to species losses, an hypothesis that was confirmed when Leach and Givnish (1996) resampled the prairie remnants Curtis and Greene studied. Leach and Givnish (1996) estimated that prairies lose from 0.5 to 1.0 percent of their plant species per year due to fire suppression and habitat fragmentation.

Methods

Study Sites

My research was conducted at three sites—Green Oaks Field Study Center, Brownlee Cemetery Prairie Nature Preserve, and Spring Grove Cemetery Prairie Nature Preserve (Figure 1). The restored prairies are all located at Knox College's Green Oaks Field Study Center. Green Oaks is a 760-acre field station located 20 miles east of Galesburg in Knox County in west-central Illinois. The field station is located in an area where oak savanna graded into oak-hickory forest at the time of European settlement. The restored prairies are all located on land that was planted with crops such as soybeans and alfalfa, or used as pasture, prior to restoration. They are relatively small, with East Prairie at 5.8 acres, South Prairie at 12.9 acres, and West Prairie at 19 acres. One of the remnant prairies, Lost Meadow, is also located at Green Oaks. Lost Meadow is a small (0.9 acres) prairie-savanna site that is currently surrounded by second growth oak-hickory forest. We don't have a good history of Lost Meadow, but it probably experienced some grazing until the 1930s. After that, Lost Meadow was allowed to lie fallow and was invaded by woody plant species, especially smooth sumac (*Rhus glabra*) and blackberry (*Rubus allegheniensis*). The woody vegetation was cleared by hand in the summer of 1972 and spring burning was initiated in 1973 (D. Krohne pers. comm.). All of the prairies at Green Oaks are mesic prairies that are maintained by burning in the early spring every other year.

Figure 1. Map of Illinois showing the location of the three study sites: Green Oaks Field Study Center (Knox County), Brownlee Cemetery Nature Preserve (Mercer County), and Spring Grove Cemetery Nature Preserve (Warren County).

I also studied two prairie remnants located close to Green Oaks (Figure 1). Brownlee Cemetery Prairie Nature Preserve and Spring Grove Cemetery Prairie Nature Preserve are Illinois Nature Preserves administered by the Illinois Department of Natural Resources. Brownlee and Spring Grove are both small (1.4 acres and 1.1 acres respectively), mesic, black soil prairie remnants. The Brownlee Cemetery was established in 1842 and the Spring Grove Cemetery was established in 1859. Neither was ever cultivated. Both cemetery remnants are surrounded by agricultural land and are maintained by burning sections every other year.

Data Collection

Four times—from June through September 1999—I randomly placed 25-m belt transects within the prairies and then identified all plant species that occurred within one meter of the central transect

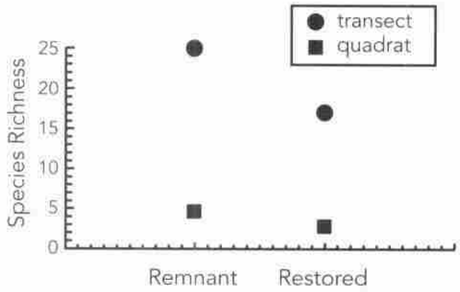

Figure 2. Comparison of mean species richness in quadrats and belt transects on remnant and restored prairies.

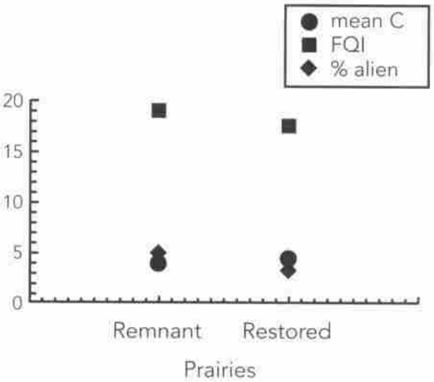

Figure 3. Comparison of mean Coefficient of Conservation (mean C), Floristic Quality Index (FQI), and mean percent of alien species recorded in belt transects on remnant and restored prairies.

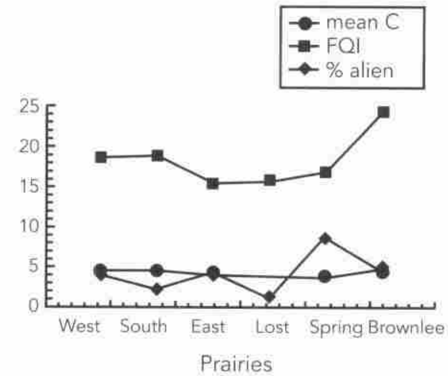

Figure 4. Comparison of mean Coefficient of Conservation (mean C), Floristic Quality Index (FQI), and mean percent of alien species recorded in belt transects on each of the prairies sampled. West, South, and East Prairies are restored, others are remnant prairies.

line. I also placed 0.10-m^2 quadrats at five-meter intervals along each transect line. I used the quadrats to collect data on plant abundance and ground cover by identifying the plants occurring at 25 points on a 0.10-m^2 grid. I placed five belt transects in West and South Prairies, four belt transects in East Prairie, and three belt transects in Lost Meadow, Spring Grove, and Brownlee Prairies. I used fewer transects in the smaller prairies because I did not want to over-sample the small prairies. Using this method, I was able to observe almost the entire sequence of flowering phenology of these prairies.

Data Analysis

I compared the restored and remnant prairies by examining species richness (the number of species) that occurred in the transects and quadrats. I also made comparisons using the Coefficient of Conservatism (Taft and others 1997) a system of analysis that describes and quantifies the tendency of a plant species to be resistant to disturbance and the fidelity of that species to undisturbed, original native habitat. The Coefficient of Conservatism is scored using an 11-point scale with a score of zero indicating the plant is weedy and found in any habitat (common milkweed [*Asclepias syriaca*] is a good example in Illinois) and a score of ten indicating the plant is susceptible to disturbance and is found only in original, native habitat (tall or prairie cinquefoil [*Potentilla arguta*] in Illinois).

I calculated mean conservatism values for each transect or quadrat sample. The mean conservatism values can then be multiplied by the square root of species richness to arrive at the Floristic Quality Index (FQI), a measure that combines conservatism with number of species in a sample. I calculated mean conservatism and FQI both with and without alien species and obtained the same result for both metrics regardless of whether I included alien species or not. In this paper all mean conservatism and FQI scores that I report have been calculated exclusive of alien species.

I used Minitab for Windows, version 12.1, for all statistical analyses. I compared the type of prairie (restored or remnant) or individual prairies using ANOVA followed by Tukey's multiple comparison test.

Results

I found a total of 134 plant species in the prairies, but the species were not evenly distributed among the prairies (Table 1). Species richness was significantly greater along transects in remnant prairies when compared to transects through restored prairies ($F = 18.35$; $df = 1, 89$; $p < 0.001$) (Figure 2). Species richness as measured in quadrats was also significantly higher in remnant prairies than in restored prairies ($F = 47.77$; $df = 1, 449$; $p < 0.001$) (Figure 2).

My analysis also indicated that the mean Coefficient of Conservatism was significantly higher in restored prairies than in remnant prairies ($F = 7.65$; $df = 1, 89$; $p = 0.007$) (Figure 3). This result surprised me, so I decided to look more closely at the data by performing an ANOVA that examined mean conservatism on a per prairie basis. I found that the mean conservatism was significantly different among the prairies ($F = 10.6$; $df = 5, 89$; $p < 0.001$). A Tukey's multiple comparison test revealed that Brownlee, West, and South Prairies had significantly higher mean conservatism (Figure 4), and thus contain more plant species typical of undisturbed, original prairie than do Lost Meadow, Spring Grove, and East Prairies.

I found no significant difference in FQI between the two types of prairie, restored and remnant ($F = 1.17$; $df = 1, 89$; $p = 0.283$) (Figure 3). I was also surprised by this result because I had expected the remnant prairies to have greater FQI than the restored prairies. However, FQI was significantly different among the individual prairies ($F = 5.99$; $df = 5, 89$; $p < 0.001$). Brownlee Prairie had a significantly higher FQI than did any of the other prairies indicating that Brownlee possessed both a higher number of species and more conservative species than any of the other prairies (Figure 4).

Table 1. List of plant species found in the restored and remnant prairies during this study. An X indicates that a plant species is found in a particular prairie. Coefficient of Conservatism (C.C.) is taken from Taft and others 1997. An asterisk by a species name indicates that species is one listed as planted at Green Oaks by Schramm (1992). Nomenclature based on Mohlenbrock 1986.

Latin Name	Common Name	C.C.	West	South	East	Lost	Spring	Brownlee
Achillea millifolium	common yarrow	0 - alien	X	X	X			
Alopecurus carolinianus	foxtail	0						X
Ambrosia artemisiifolia	common ragweed	0	X	X	X			X
Ambrosia trifida	giant ragweed	0					X	X
**Amorpha canescens*	leadplant	8		X				X
**Andropogon gerardii*	big bluestem	5	X	X	X	X	X	X
Apocynum androsaemifolium	spreading dogbane	6				X		
Apocynum cannabinum	dogbane	2	X	X	X		X	X
Asclepias purpurascens	purple milkweed	7		X		X	X	
Asclepias syriaca	common milkweed	0	X	X	X	X	X	X
**Asclepias tuberosa*	butterfly milkweed	5	X					X
Aster simplex	panicled aster	3	X	X	X	X	X	X
Astragalus canadensis	Canada milk vetch	7					X	X
**Baptisia lactea*	white wild indigo	6	X	X	X	X		X
Bidens frondosa	beggarticks	1	X					
Bidens spp.	sticktight			X				
Bromus inermis	smooth brome	0 - alien			X		X	X
Calystegia sepium	hedge bindweed	1					X	X
Campanula americana	tall bellflower	4			X			
Carex bicknelli	Bicknell's sedge	8	X	X	X	X	X	X
Castelleja coccinea	Indian paintbrush	8				X		
Ceanothus americana	New Jersey tea	8				X		X
Cirsium discolor	pasture thistle	3				X		
Cirsium pumilum	prairie thistle	7		X		X	X	X
Cirsium vulgare	bull thistle	0 - alien		X			X	X
Cleome hassleriana	spiderflower	0 - alien	X			X		
Convolvulus arvensis	field bindweed	0 - alien	X	X			X	X
**Coreopsis palmata*	stiff-leaved coreopsis	6	X	X				X
Coreopsis tripteris	tall coreopsis	4	X	X		X		
Coronilla varia	crown vetch	0 - alien					X	X
Cuscuta compacta	compact dodder	10				X		
Dactylis glomerata	orchard grass	0 - alien			X			
**Dalea candida*	white prairie clover	9	X	X	X			X
**Dalea purpurea*	purple prairie clover	8	X	X				X
**Desmodium canadense*	showy tick trefoil	5	X	X	X	X	X	X
Desmodium canescens	hoary tick trefoil	4	X	X	X	X	X	X
Desmodium glutinosum	pointed-leaved tick trefoil	3				X		
**Desmodium illinoense*	Illinois tick trefoil	5				X	X	X
Dracocephalum parviflorum	American dragonhead	0 - alien						X
**Echinacea pallida*	pale purple coneflower	7	X	X	X		X	X
Elymus canadensis	Canada wild rye	4	X	X	X			X
Equisetum arvense	horsetail	0					X	X
Equisetum hymale	scouring rush	2						X
Erigeron annus	daisy fleabane	1	X	X	X	X		X
**Eryngium yuccifolium*	rattlesnake master	7	X	X	X		X	X
Eupatorium serotinum	late-flowering throughwort	1		X				
Euphorbia corollata	flowering spurge	3	X		X	X	X	X
Euthamia graminifolia	lance-leaved goldenrod	3		X				X
Fragaria virginiana	wild strawberry	2				X		
Gentiana andrewsii	bottle gentian	7				X		
Gentiana saponaria	creamy soapwort gentian	9			X	X		
Glyceria striata	fowl manna grass	4	X					X
Helianthus divaricatus	woodland sunflower	5				X		
Helianthus giganteus	tall sunflower	9	X	X	X		X	X
Helianthus grosseserratus	sawtooth sunflower	2	X	X	X		X	X
Helianthus hirsutus	stiff-haired sunflower	5	X	X	X	X	X	X
Helianthus mollis	hairy sunflower	7	X		X			X
Helianthus tuberosus	Jerusalem artichoke	3					X	X
Heliopsis helianthoides	oxeye	4						X
Hypericum perforatum	common St. John's wort	0 - alien	X	X	X			
Hypericum pyramidatum	great St. John's wort	8		X	X			
Ipomoea pandurata	wild potato vine	2					X	
Juncus interior	inland rush	3	X	X	X	X		X
Lactuca canadensis	wild lettuce	1		X		X	X	
**Lespedeza capitata*	round-headed bush clover	4	X	X	X	X	X	X
**Liatris pycnostachya*	prairie blazing star	6		X				X
Liatris spp.	blazing star		X	X	X		X	X
Lobelia inflata	Indian tobacco	4				X		
Lobelia spicata	pale spike lobelia	4	X			X		
Lysimacha quadrifolia	whorled loosestrife	9						X
Melilotus alba	white sweet clover	0 - alien	X		X		X	
Melilotus sp.	sweet clover	0 - alien	X	X			X	X
**Monarda fistulosa*	wild bergamot	4	X	X	X	X	X	X
Morus rubra	red mulberry	4	X					
Muhlenbergia mexicana	leafy satin grass	4	X			X		
Muhlenbergia sp.	muhly grass							X
Nepeta cataria	catnip	0 - alien					X	
Oenothera biennis	common evening primrose	1					X	
Panicum dichotomiflorum	kneegrass	0				X		
**Panicum virgatum*	switchgrass	4	X	X	X	X	X	X
**Parthenium integrifolium*	wild quinine	8	X	X				
Pastinaca sativa	wild parsnip	0 - alien			X			X
**Penstemon digitalis*	foxglove beardstongue	4			X			
Phalaris arundiancea	reed canary grass	0 - alien					X	
Phleum pratense	timothy	0 - alien			X			
Plantago lanecolata	English plantain	0 - alien		X				
Polygonatum commutatum	Solomon's seal	4						X
Polygonum pensylvanicum	Pennsylvania smartweed	1		X				
Polygonum scandeus	climbing false buckwheat	2			X			

Latin Name	Common Name	C.C.	West	South	East	Lost	Spring	Brownlee
**Potentilla arguta*	tall cinquefoil	10		X				X
Potentilla simplex	common cinquefoil	3		X				
Prunus serotina	wild cherry	1		X	X			X
**Pycnanthemum tenuifolium*	narrow-leaved mountain mint	4	X	X	X	X	X	X
Quercus macrocarpa	bur oak	5			X			
Quercus spp.	oak					X		
**Ratibida pinnata*	gray-headed coneflower	4	X	X	X		X	X
Rhus glabra	smooth sumac	1	X		X	X	X	X
Robinia pseudoacacia	black locust	0 - alien			X			
Rosa carolina	pasture rose	4				X		X
Rubus allegheniensis	blackberry	2	X	X	X	X	X	X
**Rudbeckia hirta*	black-eyed susan	2	X	X	X	X	X	
Rudbeckia lacinata	green-headed coneflower	3	X				X	X
Rudbeckia subtomentosa	sweet coneflower	5			X			
Ruellia humilis	hairy ruellia	3	X					
Rumex crispus	curly dock	0 - alien			X			X
**Schizachyrium scoparius*	little bluestem	5	X	X	X	X	X	X
Scirpus atrovirens	dark green rush	4		X				
Scirpus hattatorianus	early dark green rush	5		X				
**Silphium integrifolium*	rosinweed	5	X	X	X		X	X
**Silphium laciniatum*	compass plant	5	X	X	X		X	X
**Silphium terebinthinaceum*	prairie dock	4	X	X	X			X
Solidago altissima	tall goldenrod	1	X	X	X	X	X	X
Solidago canadensis	Canada goldenrod	1					X	
Solidago gigantea	late goldenrod	3	X	X	X	X	X	X
Solidago juncea	early goldenrod	4	X	X	X	X	X	
**Solidago rigida*	stiff goldenrod	4	X	X				X
**Solidago speciosa*	showy goldenrod	7	X	X	X			X
**Sorghastrum nutans*	Indiangrass	4	X	X	X	X	X	X
Sphenopholis obtusata var. major	slender wedge grass	5	X	X	X	X		
Stachys aspera	hyssop-leaved hedge nettle	9		X				
Stachys tenuifolia var. hispida	rough hedge nettle	5					X	X
Teucrium canadense	germander	3				X		
Thalictrum dioicum	early meadowrue	5		X				
Thalictrum revolutum	waxy meadowrue	5	X					
Toxicodendron radicans	poison ivy	1					X	
**Tradescantia ohiensis*	spiderwort	3	X	X	X	X	X	X
Ulmus rubra	slippery elm	3	X		X	X	X	X
Ulmus thomasii	rock elm	3					X	
Verbena hastata	blue vervain	3	X					
Verbena urticifolia	white vervain	3		X				X
Vernonia arkansana	Ozark ironweed	10	X					
Vernonia gigantea	tall ironweed	4	X	X	X	X	X	X
**Veronicastrum virginicum*	Culver's root	6	X	X	X			
Vitis spp.	wild grape			X	X			X

Because the results of comparisons examining mean Coefficient of Conservatism and FQI surprised me, I decided to test whether the two types of prairie differed in the percentage of alien species present among all species along the transects. There was no significant difference in percentage of alien species between restored and remnant prairies ($F = 2.23$; $df = 1, 89$; $p = 0.139$) (Figure 3). Individual prairies differed significantly in terms of percentage of alien species ($F = 4.74$; $df = 5, 89$; $p = 0.001$) with Spring Grove Prairie having significantly more alien species than West, South, and Lost Meadow Prairies (Figure 4). Brownlee and East Prairies were intermediate in the percentage of alien species and did not differ significantly from any other prairies.

Discussion

I expected to find that the remnant prairies would have higher species richness, mean plant conservatism, and floristic quality indices than the restored prairies. While it is clear from the results that the restored prairies are different from the remnant prairies, those differences did not always match my initial expectations. I suspect that the differences are probably due to the history of the remnants and the method of planting the restored prairies (Table 2). The restored prairies, for example, have relatively high mean conservatism and FQI because Shepard and Schramm chose to plant species typical of high quality native prairies (Schramm 1992). Meanwhile the remnant prairies differ in their past history. Brownlee Cemetery Prairie and Spring Grove Cemetery Prairie were protected from human disturbance in the mid-1800s, while Lost Meadow has experienced various types of land use and management. All of the remnant prairies, and especially Lost Meadow and Spring Grove, have many weedy or disturbance-resistant native species. Brownlee and Spring Grove, which are surrounded by agricultural land, have several alien species as well. Thus it seems that the small, isolated prairie remnants have been subject to invasion by alien species and weedy natives or else those species are well suited for long-term survival in the remnants. The restored prairies, which were established using conservative native prairie plants, have relatively fewer of the weedy, invasive species (Table 1).

One of the most striking differences between the restored and remnant prairies is the tendency of the restored prairies to have a patchy distribution of species, with plants often grouped into a mosaic of single-species patches. In contrast, plant species in the remnants occur in a more highly intermingled distribution with several species occupying a small area. This was most clearly shown in the comparison of species richness in quadrats, where, even at the small scale of $0.10\ m^2$, the remnant prairies had significantly greater species richness than did the restored prairies (Figure 2). This patchy distribution pattern of plants in prairie restorations has been observed in other restorations, including the Curtis and Greene prairies (Cottam and Wilson 1966, Blewett and Cottam 1984). The patchy distribution is almost certainly the result of the original pattern of planting the restoration. Schramm (1992) advocates planting in a mosaic pattern and notes that "what you plant is what you get." The question then arises: For how many years will the original planting pattern determine the distribution of plants in a restored prairie? The answer is apparently for many years. When Sperry resampled Curtis Prairie in 1990 (54 years after the initial planting), he could still find patches dominated by the species first planted at that location (Sperry 1994).

Table 2. A comparison of species richness, number of alien species, mean Coefficient of Conservatism, and Floristic Quality Index (FQI) calculated based on all the samples collected in each prairie.

Prairie Name	Type of Prairie	Species Richness	Number of Alien Species	Mean Conservatism	FQI
Brownlee	Remnant	76	11	4.22	34.02
Lost Meadow	Remnant	50	2	3.89	26.99
Spring Grove	Remnant	54	9	3.69	24.74
East	Restored	63	11	4.23	30.51
South	Restored	69	9	4.65	36.02
West	Restored	64	6	4.29	32.69

Problems in Judging Restoration Success

Several problems arise when restorationists attempt to determine the success of prairie restoration projects. Some problems are unique to a site, such as Green Oaks, but others are more general and probably apply to all prairie restorations. I will consider those unique to Green Oaks first and then discuss more general problems.

One of the most difficult aspects of judging the success of prairie restoration at Green Oaks is that the planting records for the Green Oaks restorations are rather poor. This is especially obvious when one compares the meticulous records of planting history that exist for the Curtis and Greene prairies to the scanty records for Green Oaks. Without good records, it is difficult to determine whether the plants in the restored prairies are the result of the original plantings or whether the species have colonized on their own. We know that Shepard and Ward planted seeds of 63 prairie species in 1955 (Shepard, *Green Oaks News*, April 11, 1955, Knox College Library Archives), but there is no record of the identity of those 63 species. I have searched the Knox College Library Archives several times and have never been able to find a written list of what was planted that spring. Schramm (1992) provides a list of 48 species he planted during prairie restoration at Green Oaks. I found 30 of those species (marked with an asterisk in the species list in Table 1) during my sampling. The remaining 18 species that Schramm planted either have died out or are rare enough that I missed them during sampling.

A major problem for all restorationists is that they are attempting to re-create an ecosystem that is no longer present on the site and is known only from historical records.

The small size of both restored prairies and remnant prairies points to the problem of scale (Noss 1992). The pre-European settlement prairies were large, continuous ecosystems. Remnant and restored prairies usually exist as small islands that are isolated from other such islands and surrounded by dissimilar habitat. They are vulnerable to invasion from species typical of other ecosystems, often forest species and weedy alien species. Their small size means they experience a different physical environment than did the original prairies and this may have considerable effect on their ecology (Janzen 1986). For example prairies bordered by woodlands are more subject to shading and are somewhat buffered from winds (Kline and Howell 1987).

In the end, remnant prairies and pre-settlement species lists provide us with clues about original native prairie but we will never know exactly what those prairies were like. We will never know the identity of all the species present in original prairies and we will never know the relative abundances and interactions of those species. Remnant prairies have changed in the last 170 years and it is likely that the original prairies would have changed in that time, even without the influence of settlers and modern agriculture (Howell and Jordan 1991). Thus we have chosen an extremely daunting task if our goal in restoring prairies is to achieve grassland ecosystems that are similar to original native prairies in structure and function. However, if our goal in prairie restoration is to develop self-sustaining prairies that support native prairie flora and fauna, then we probably can achieve success. And in doing so, we will be restoring an ecosystem to our landscape that would otherwise continue to dwindle away.

Conclusions

At this time, the prairie restorations at Green Oaks have not been successful in achieving the planners' original goal of re-creating pre-settlement tallgrass prairie. Ultimately, it seems unlikely that such a goal can be achieved because the restored prairies are dynamic and constantly changing. Schramm (pers. comm.) reports that some plant species in the restored prairies at Green Oaks change their locations from year to year. He says this is especially true of a species such as hairy sunflower (*Helianthus mollis*), which is allelopathic and tends to kill nearby competing plants. Given the fact that some plant species move around the prairie, it is surprising that the restored prairies still retain a mosaic distribution of species when compared to the intermingled pattern of species distribution in remnant prairies. It may be that it will take many years of such plant movements before the original planting pattern is broken and a more natural and intermingled species distribution arises.

We also must not forget that restoration goals have to be set in terms of human values as well as ecology (Westman 1991). Although the prairie restorations at Green Oaks have not met the original ecological goal of re-creating original prairie, the Knox College community tends to regard the prairies as a great success. The prairies are attractive and provide at least a small-scale sensory experience of pre-settlement prairies. Every year many members of the campus community take part in burning the prairies at Green Oaks and for many of them the prairie fires are one of the high points of the year. The nickname for the athletic teams at Knox is the Prairie Fire, and many members of the community take great pride in the heritage of a college established on the prairie (Calkins 1989). While our restored prairies may not exactly match the original prairie, they do provide a model of the original landscape—a model that is valuable if only because these sites are pleasing to the senses and provide a good introduction to what prairies were once like.

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