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PRAIRIE RECONSTRUCTION IN INDIANA: HISTORICAL HIGHLIGHTS AND OUTCOMES

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ABSTRACT. Prairie reconstruction or restoration in Indiana dates at least to 1987 with a demonstration planting at Butler University in Indianapolis. A brief account of this and other tallgrass prairie reconstruction efforts by the Indiana Department of Natural Resources, Taylor University, Newport Chemical Depot, and The Nature Conservancy during the period of 1990 and early 2000 are described. These projects document the rationale behind reconstructing prairies and changes in practices relating to seed mixes. In order to provide an overview of the status and success of Indiana prairie reconstructions, 23 were sampled via a Floristic Quality Assessment (FQA) protocol during the period 2005–2012. Four native prairies were also sampled for comparison. The results indicate that, thanks to the increased availability of more affordable forb rich seed mixes, recent reconstructions may achieve a much higher floristic quality. In fact, certain FQA metrics for some recent prairie reconstructions rival those of native prairies. Species richness per quadrat, however, is always lower in reconstructed prairies. Furthermore, conservative and even some less conservative species are consistently lacking in reconstructed prairies. A resampling of three sites after a lapse of 4 to 5 years showed steady to increasing FQA metrics. The experience in Indiana suggests that restoring and sustaining a tallgrass prairie landscape is possible to a degree, though the efforts are expensive and intensive. Furthermore, planted prairies, as with native prairies, can be vulnerable to repurposing of land.

Keywords: Prairie reconstruction, prairie restoration, Indiana history, floristic quality assessment, restoration flora

INTRODUCTION

Prairie reconstruction and prairie restoration are relatively young ecological disciplines (Packard & Mutel 1997). Reconstructing a prairie most often seeks to establish a prairie planting on former agricultural land, while prairie restoration more narrowly refers to renewing a remnant natural ecosystem that has been taken over to some degree by another plant community (IPN 2017). In response to the soil losses of the Dust Bowl, Aldo Leopold and Norman Fassett, curator of the University of Wisconsin at Madison Arboretum, transformed 11 ha of abandoned pastureland into the world's first prairie reconstruction in 1934 (Pauly 2008). Although this initial effort used sod transplantation from remnant prairies, John Curtis, then a University of Wisconsin graduate student, encouraged direct sowing of seed (Cottam & Wilson 1966; Wegener et al. 2008) that quickly became the accepted method of prairie reconstruction.

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During the 1950s and 1960s Paul Sheppard, George Ward, and later Peter Schramm at Knox College (northwestern Illinois) further developed prairie reconstruction techniques. Schramm would not only champion the return of fire to the prairies but also left his mark through the number and quality of prairie reconstructions he nurtured (Schramm 1970, 1978; Geer et al. 1997).

Prairie reconstruction comes to Indiana.—Indiana's first prairie reconstruction was planted on land that historically was located in the eastern deciduous forest. In 1987, the Holcomb Research Institute, housed at Butler University, selected a site next to newly developed athletic fields in an attempt to display a low maintenance alternative to turf grass (Rebecca Dolan, interview, August 10, 2010; see Appendix A for list of interviewees). Intended to serve as a prairie demonstration more than an actual reconstruction, the proposed prairie was divided into two sections, tall grass and mixed grass, and was planted using seed from Wisconsin. Although there was some concern about using Wisconsin genotype seed, the Institute had no other option. At this time, no vendors in

Indiana produced local seed and the amount of seed required made hand collection unrealistic (Rebecca Dolan, interview, August 10, 2010).

The first sizeable reconstruction in Indiana was at Stoutsburg Savanna in Jasper County. The site supported a rare black oak sand savanna interrupted by swaths of weedy fallow ground (Tom Post, interview, September 17, 2010). When the Indiana Department of Natural Resources (INDR) decided to restore the site in 1990, they called upon Peter Schramm. By this time, Schramm had become one of the most prolific prairie restorationists in the Midwest, planting 25 prairies a year using regional species and genotypes (Tom Post, interview, September 17, 2010; Schramm 1992).

The goal of the Stoutsburg Savanna was unique in the 1990s. In response to the Conservation Reserve Program in 1985, many farmers had started to plant their highly erodible lands with prairie warm season grasses (Schramm 1992). These plantings had few if any prairie forbs and were isolated from remnant prairies, often by many miles. In contrast, the prairie reconstructions of Stoutsburg Savanna were directly adjacent to existing remnant natural areas for the purpose of providing a buffer between the savanna and neighboring agricultural land.

The prairie reconstruction concept had spread sufficiently by 1993 that the earliest homeowner installations began. The oldest may be a 0.8 ha site planted by Phyllis Schwitzer (north of Bloomington, Monroe County, Indiana). The seed mix, from a Wisconsin source, was rich in tall grasses (*Andropogon gerardii* and *Sorghastrum nutans*), but contained over 15 forb species. The planting continues to thrive, especially thanks to the recent use of grass specific herbicide to reduce the dominance by tall grasses.

In 1993, Avis Industrial with assistance from Taylor University in Upland commissioned their own Schramm planting. Planned by Edwin Squiers and Paul Rothrock of Taylor University and Leland Boren of Avis Industrial Corporation, it was an isolated reconstruction planted for both academic and aesthetic purposes. The interior of the planting was dominated by tall grasses with a few forbs, but the edges of the prairie were planted in a dense forb mix (in excess of 40 species) in hopes that the beauty of the prairie flowers could be seen from passing autos (Rothrock & Squiers 2003). In practice, about ten forb species became strongly established and another 25 have persisted somewhere on the 10 ha site.

In the same year, the United States Army participated in prairie reconstruction in Indiana. Phil Cox, the Natural Resource Administrator at Newport Chemical Depot realized that the Depot property still contained a few remnant prairie species (Greninger 2010; Philip Cox, interview, August 25, 2010). In 1993, he met with John Bacone, IDNR Director of the Division of Nature Preserves, and Roger Hedge, an ecologist with the Indiana Natural Heritage Program. As a result, in 1994 the IDNR drafted a report that encouraged the reconstruction of 770 ha of leased agricultural land within the Depot's boundaries. The Mason and Hanger Corporation, the independent contractor responsible for the Depot, hired Peter Schramm to plant a preliminary 3 ha prairie. During the next 10 years (1994–2005) Schramm and Cox expanded the reconstruction to 135 ha, at a cost of $125,000 for seed and maintenance (Phil Cox, interview, August 25, 2010).

For a time the Newport Chemical Depot Prairie became the largest contiguous prairie reconstruction in Indiana. The Depot's lands, including the prairie, were passed to the Newport Chemical Depot Reuse Authority after the Depot's official close in July of 2010. Although plans call for 51% of the complex to remain as "natural areas and open space" (NECDRA 2010), the fertile soils of the prairie reconstruction, further improved and enriched by a prairie cover, could be leased to local farmers and plowed. Indeed, much of this reconstructed prairie acreage has returned to row crop agriculture.

The role of restoration nurseries.—Before the 1990s, no nurseries in Indiana produced prairie seed. Those concerned with importation of nonnative genotypes were forced to collect seed by hand from the scattered remnant prairies (Tom Post, interview, September 17, 2010; Rebecca Dolan, interview, August 10, 2010). This changed in 1994, when the first of three native plant nurseries began producing local genotype seed in bulk.

J.F. New & Associates, Inc. (now Cardno), a major environmental consulting firm in Indiana, founded in 1989, established its native seed nursery in 1994 that originally focused on wetland mitigation seed (Chris Kline, interview, February 6, 2011). Heartland Restoration Services, founded by Eric Ellingson, likewise initially raised seed for wetland mitigation before expanding its operation in 1997 to include prairie species. A year later, Doug Spence and Kevin Tungesvick followed suit and opened Spence Restoration

Nursery in 1998 (Eric Ummel, interview, February 6, 2011; Kevin Tungesvick, interview, September 17, 2010).

Since the late 1990s, the demand for local seed from the non-restoration community increased rapidly. Residential and commercial landscaping companies, private homeowners, and even golf courses, began requesting local genotype seed (Eric Ummel, interview, February 6, 2011). Cardno, Heartland, and Spence, working collaboratively with the ecological community to educate the public on the importance and benefits of local genotypes, were the major force behind this increased demand for local seed. It became a matter of preserving Indiana—not solely its landscape, but its ecological genetics as well (Alan Galbreth, interview, February 8, 2010).

Reconstruction at Kankakee Sands.—In 1996, The Nature Conservancy (TNC) identified three major natural areas in Newton County, Indiana: Conrad Savanna Nature Preserve (a 327 ha black oak sand savanna owned and managed by TNC and the IDNR), Beaver Lake Nature Preserve (a 260 ha IDNR property initially known as the Beaver Lake Prairie Chicken Refuge), and the Willow Slough Fish and Wildlife Area (a IDNR property approximately 4,050 ha) (National Audubon Society 2011). It was an already established postulate of conservation biology that larger populations were more likely to retain ecological integrity (e.g., Wilcox & Murphy 1985; Menges 1991; Noss & Cooperrider 1994). TNC sought to connect the properties to reduce potential problems associated with fragmentation (Chip O'Leary, interview, September 22, 2010). In 1997, TNC purchased 2900 ha from Prudential Insurance for $11 million (Chip O'Leary, interview, September 22, 2010; Ney & Nichols 2010). It became the largest prairie reconstruction effort in the TNC's history with total IDNR and TNC land holdings exceeding 8500 ha (Lucas 2005; Applied Ecological Services 2011).

The Kankakee Sands Restoration Project, headed by Chip O'Leary, initially used hand-collected seed from local remnant prairies, but they soon realized the project was too large to rely on the amount of native seed available. Committed to using local genotype, the reconstruction project established the Kankakee Sands Seed Nursery, an operation that would eventually grow to a 50 ha complex that could produce enough seed to plant 200 ha per year using 130 different species (Chip O'Leary, interview September 22, 2010; Applied Ecological Services 2011).

During the first three years, Kankakee Sands was planted using the traditional tallgrass-heavy seed mix as seen in the Schramm reconstructions and the Butler University site. However, five years into the project, they used a forb-rich mix with only short grasses and continued this practice for the remainder of the reconstruction. They removed *Andropogon gerardii* and *Sorghastrum nutans* entirely from the new seed mixes (Chip O'Leary, interview, September 22, 2010), a seed mix strategy that has now become routine for better quality reconstruction efforts (Kevin Tungesvick, interview, September 17, 2010).

By the early twenty-first century, prairie reconstruction as a concept was firmly established in Indiana as demonstrated by the increased use of native prairie species by landscape architects and homeowners. However, what has been the level of "success" of the reconstruction efforts to date? And what lessons and strategies can be gleaned from the first generation of prairie reconstruction efforts? Intermittently since 2005, we have sought to visit significant reconstructions and apply a standard assessment protocol. The remainder of this paper, summarizes the Floristic Quality Assessment (FQA) of 19 properties, makes comparisons between these and several extant prairie remnants, and records, to the extent possible, planting and management regimes.

METHODS

Twenty-seven prairies (Table 1) were selected for quality sampling across Indiana, including four remnant prairies: Hoosier Prairie, Biesecker Prairie, German Methodist Cemetery, and Smith Cemetery (a degraded remnant recovering from a history of mowing). Reconstructions were located in five of Indiana's ten terrestrial natural regions (Table 1, Homoya et al. 1985), but most were from the Grand Prairie and Central Till Plain Natural Regions. Aside from the prairie reconstructions at Butler University and Christy Woods, the reconstructions utilized land that had experienced recent row crop agriculture. Twelve sites were sampled during July and August of 2005 to 2007. Eight sites were sampled in July and August of 2010, in addition to resampling three previously sampled sites. A final two sites were sampled in 2011 and 2012 (Fig. 1; Table 2).

A total of 39 transects were sampled across all the prairies (Table 2). Twelve sites were sampled using multiple transects based upon site area and

Table 1.—Site characteristics for prairie sampled. With the exception of sites at Butler University and Christy Woods, the reconstructions had recent history of row crop agriculture. Reconstructions marked # buffer adjacent oak savanna. Natural Regions (Homoya et al. 1985) with sample sites were: CTP = Central Till Plain; GP = Grand Prairie; NL = Northern Lakes; NW = Northwestern Moraine; SL = Southwest Lowlands. Those indicated with * were in regions that historically supported extensive oak savanna and prairie communities. The date of planting for certain sites is indicated by a range. This may be a result of uncertainty of the exact year of planting as efforts occurred over several years. Seed mix type refers to the dominance of tall grasses compared to the content of forbs. Due to the mixed nature of seeding at some sites, these labels are approximate.

Site Characteristics				
Site transect	Type	Natural region	Date of planting	Seed mix type
Avis Prairie	Reconstruction	CTP	1993	Tall grass heavy
Biesecker Prairie	Remnant	NM*	NA	NA
Butler University Prairie	Reconstruction	CTP	1987	Tall grass heavy
Christy Woods Prairie	Reconstruction	CTP	1996/extension in 2001	High forbs
Cooper Farm Prairie	Reconstruction	CTP	2002/2003	High forbs
Fisher Oak Savanna	Reconstruction #	GP*	2005	High forbs
German Methodist	Remnant	NM*	NA	NA
Goose Pond 1	Reconstruction	SL	2002	Tall grass heavy
Goose Pond 2	Reconstruction	SL	2002	Tall grass heavy
Hoosier Prairie South Block	Remnant	NM*	NA	NA
Kankakee Sands Dry	Reconstruction	GP*	1999–2003	High forbs
Kankakee Sands Mesic	Reconstruction	GP*	1999–2003	High forbs
Loblolly Prairie	Reconstruction	CTP	1997	Tall grass heavy
Ludwig Prairie	Reconstruction	NL	east in 2000/ west in 2003	High forbs
Merry Lea–Luckey Prairie	Reconstruction	NL	2004	High forbs
Merry Lea–REA Prairie	Reconstruction	NL	2006	High forbs
Newport Chemical Depot	Reconstruction	GP*	post-2000	High forbs
Prairie Border	Reconstruction #	GP*	2005	Tall grass heavy
Prophetstown State Park Bluestem	Reconstruction	CTP-GP*	1998	Tall grass heavy
Prophetstown State Park Farm	Reconstruction	CTP-GP*	2000	Tall grass heavy
Red Tail Nature Preserve	Reconstruction	CTP	1999	Tall grass heavy
Ritchey Woods	Reconstruction	CTP	2001	Tall grass heavy
Smith Cemetery	Remnant (mowing stopped in 1981)	GP*	NA	NA
Stoutsburg Savanna	Reconstruction #	GP*	1991–1995	Tall grass heavy
Taltree Arboretum	Reconstruction	NW*	2000	High forbs
Wapihani Nature Preserve	Reconstruction	CTP	2006	Tall grass heavy
Weiler-Leopold Nature Reserve	Reconstruction	CTP-GP*	1999	Tall grass heavy

notable floristic differences present. In placing transects, areas were selected that seemed representative of overall site quality while avoiding edges and areas unsuitable for successful seedling establishment. Given the scale of the Kankakee Sands project two older plantings were selected that represented distinct moisture regimes. Aside from several urban sites (Ritchey Woods and Wapihani Nature Preserve), each of the reconstructions has had a regular fire management program. For most sites, twenty 0.25 m^2 quadrats, spaced 5 m apart, were sampled along linear 100 m transects. Small sites required parallel 50 m transects. GPS coordinates were recorded for the start and end of transects. For Avis Prairie, data from previous studies (Rothrock & Squiers 2003) were used. These quadrats were from random points along several 15 m transects. For Newport Chemical Depot, direct physical sampling was not possible. Instead a series of high resolution photographs were studied, each of which imaged an area of about 1 m^2 (see below).

Species and their cover were recorded for each quadrat. The Floristic Quality Assessment Com-

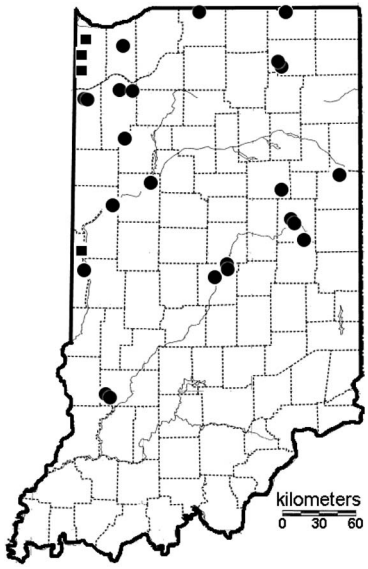

Figure 1.—Map showing locations of remnant prairies (square symbols) and reconstructed prairies (round symbols) used in this study.

puter Program, Version 1.0, was used to calculate mean C values (MC) and native species richness (NR) (Wilhelm & Masters 2000). FQA methodology was originally developed for the Chicago Region, as a standardized, repeatable means of evaluating the quality of a natural area (Swink & Wilhelm 1994), but has found success in evaluation of constructed ecosystems (McIndoe et al. 2008, DeBoer et al. 2011). Care, however, must be taken to consider both MC and NR and to watch for anomalous situations. Metrics were calculated on both transect and quadrat levels. Transect level metrics are based upon the overall checklist of species observed in the 20 sampled quadrats. Quadrat level metrics are the result of calculating FQA metrics for each quadrat and then calculating their mean. As a result, quadrat level analyses are weighted by species frequency. Since Newport Chemical FQA relied upon a slightly larger quadrat size and static images, comparisons will of necessity be tentative, e.g., metrics involving species richness are more tentative than MC and quadrat level more tentative than transect level.

MC and NR were graphed individually from highest to lowest to illustrate the gradient of quality among the sites. The sites were classified using four quality categories: 1) high remnant quality, 2) degraded remnant quality/high quality reconstruction, 3) low quality reconstruction, and 4) poor quality reconstruction. High remnant quality benchmarks were based upon transects from native prairies that lacked obvious degradation (Biesecker, Hoosier, and German Methodist Cemetery). The low quality reconstructions benchmarks were based upon comparison with old field transects (Rothrock et al. 2011). A third benchmark line (that delineates moderate and high quality reconstructions) was positioned midway between the other two lines.

Transects from three prairie reconstructions with high FQA metrics were sampled twice over a 5-year period. These sites included Kankakee Sands, Fisher Oak Savanna, and Ludwig Prairie. The two-tailed t-test was used to determine whether significant changes occurred over that time interval.

RESULTS AND DISCUSSION

The floristic quality of Indiana restored prairies is broad, ranging from conditions similar to an old field (e.g., Ritchey Woods), at the low end, to displaying attributes of a remnant native prairie (e.g., Fisher Oak Savanna). The majority of reconstructions contain ten species, what might be called a tall grass prairie reconstruction flora. The species include grasses such as *Andropogon gerardii, Elymus canadensis, Schizachyrium scoparium,* and *Sorghastrum nutans* and forbs such as *Eryngium yuccifolium, Monarda fistulosa, Parthenium integrifolium, Ratibida pinnata, Rudbeckia hirta,* and *Solidago rigida. Silphium* spp. (such as *S. laciniatum*), *Coreopsis tripteris,* and *Symphyotrichum novae-angliae* are also common. The reconstruction flora of more recent installations, such as Fisher Oak Savanna, has little *Andropogon gerardii* and instead may be dominated by grasses such as *Elymus canadensis, E. virginicus,* and *Schizachyrium scoparium*. The reconstruction flora includes some species with high C-values such as *Coreopsis tripteris, Eryngium yuccifolium, Parthenium integrifolium,* and *Silphium* spp. At the same time reconstructed prairies lack a suite of conservative species seen at our reference sites – *Amorpha canescens, Ceanothus americanus, Comandra umbellata, Lithospermum canescens,* and, with few exceptions, *Symphyotrichum oolentangiense*. Surprisingly even some less conservative species (e.g., *Euphorbia corollata* and *Rosa carolina*) were not observed in any of the reconstructions.

Sites with the highest FQA metrics, transect MC in particular, include Fisher Oak Savanna, Kankakee Sands, and Merry Lea. Newport

Table 2.—GPS coordinates recorded for the sites sampled and the year(s) in which the sites were sampled. Those marked with * were later approximated using Google Earth 7.1.5.1557.

GPS Coordinates and Years of Sampling			
Site transect	Beginning	Ending	Year
Avis Prairie Block 2 *	40.453N 85.492W		2005
Avis Prairie Block 3 *	40.453N 85.493W		2005
Biesecker Prairie	41.42039N 87.46778W	41.41982N 87.46866W	2010
Butler University Prairie	39.83990N 86.17533W	39.83966N 86.17641W	2010
Christy Woods Prairie	40.19804N 85.41582W	40.19928N 85.41643W	2010
Christy Woods Prairie (cont.)	40.19917N 85.41572W	40.19917N 85.41573W	2010
Cooper Farm Prairie	40.22729N 85.45512W	40.22812N 85.45506W	2010
Fisher Oak Savanna North	40.84314N 87.04276W	40.84299N 87.04390W	2006/2010
Fisher Oak Savanna South	40.84243N 87.04327W	40.84240N 87.04440W	2006/2010
German Methodist Cemetery	41.34874N 87.46850W	41.34862N 87.46794W	2005
Goose Pond 1	38.96503N 87.14607W	38.96600N 87.14626W	2010
Goose Pond 2	38.99817N 87.20781W	38.99725N 87.20766W	2010
Hoosier Prairie South Block *	41.52171N 87.45315W		2006
Kankakee Sands Dry East	41.08863N 87.41570W	41.08777N 87.41559W	2005/2010
Kankakee Sands Dry West	41.08801N 87.41685W	41.08717N 87.41678W	2005/2010
Kankakee Sands Mesic North	41.10273N 87.43069W	41.10268N 87.43177W	2005/2010
Kankakee Sands Mesic South	41.10203N 87.43051W	41.10189N 87.43163W	2005/2010
Loblolly Prairie *	40.55694N 85.03167W		2010
Ludwig Prairie East	41.74434N 85.88902W	41.74429N 85.89018W	2005/2010
Ludwig Prairie West	41.74441N 85.89138W	41.74435N 85.89250W	2005/2010
Merry Lea–Luckey Prairie North	41.32916N 85.52903W	41.32995N 85.52924W	2010
Merry Lea–Luckey Prairie South	41.32845N 85.52938W	41.32771N 85.52876W	2010
Merry Lea–REA Prairie	41.33854N 85.54662W	41.33722N 85.54645W	2010
Newport Chemical 1 *	39.844N 87.466W	39.844N 87.467W	2011
Newport Chemical 2 *	39.832N 87.475W	39.833N 87.475W	2011
Prairie Border East	41.17798N 86.96605W	41.17706N 86.96598W	2005
Prairie Border West	41.17797N 86.96762W	41.17712N 86.96753W	2005
Prophetstown State Park Bluestem	40.50898N 86.81464W	40.50944N 86.81464W	2007
Prophetstown SP Bluestem (cont.)	40.50865N 86.81448W	40.50906N 86.81445W	2007
Prophetstown State Park Farm	40.49953N 86.82057W	40.49955N 86.83061W	2007
Red Tail Nature Preserve East	40.09871N 85.30035W	40.09961N 85.30055W	2005
Red Tail Nature Preserve West	40.09898N 85.30173W	40.09983N 85.30190W	2005
Ritchey Woods near Entry	39.93880N 86.03394W	39.93966N 86.03403W	2007
Ritchey Woods near Parking Lot	39.93871N 86.03511W	39.93955N 86.03533W	2007
Smith Cemetery	40.02636N 87.45115W	40.02634N 87.45167W	2005
Smith Cemetery (cont.)	40.02633N 87.45109W	40.02619N 87.45165W	2005
Stoutsburg Savanna East	41.17368N 87.09058W	41.17371N 87.09153W	2005
Stoutsburg Savanna West	41.17348N 87.09562W	41.17344N 87.09675W	2005
Taltree Arboretum 1	41.44415N 87.14970W	41.44330N 87.14957W	2012
Taltree Arboretum 2	41.44038N 87.14742W	41.44043N 87.14854W	2012
Wapihani Nature Preserve	39.95360N 86.06495W	39.95352N 86.06386W	2010
Weiler-Leopold Nature Reserve	40.35889N 87.11625W	40.35825N 87.11710W	2010

Chemical Depot is also among these high quality reconstruction sites. MC [native + non-native species] for these sites ranged from 3.9 to 5.2 (Fig. 2), similar or perhaps even slightly exceeding that of three native prairies. Sites with a high quadrat level MC (Fig. 3) include those listed above as well as Taltree Arboretum and Ludwig Prairie. Their quadrat MC ranged from 4.2 to 5.2; all were planted since 2000. Their seed mixes were rich in forb species and deleted or minimized the content of aggressive tall grass species such as *Andropogon gerardii,* a strategy shown to enhance species diversity in prairie plantings (Dickson & Busby 2009). The grass species abundant in some of these mixes, *Elymus canadensis*, acts as a

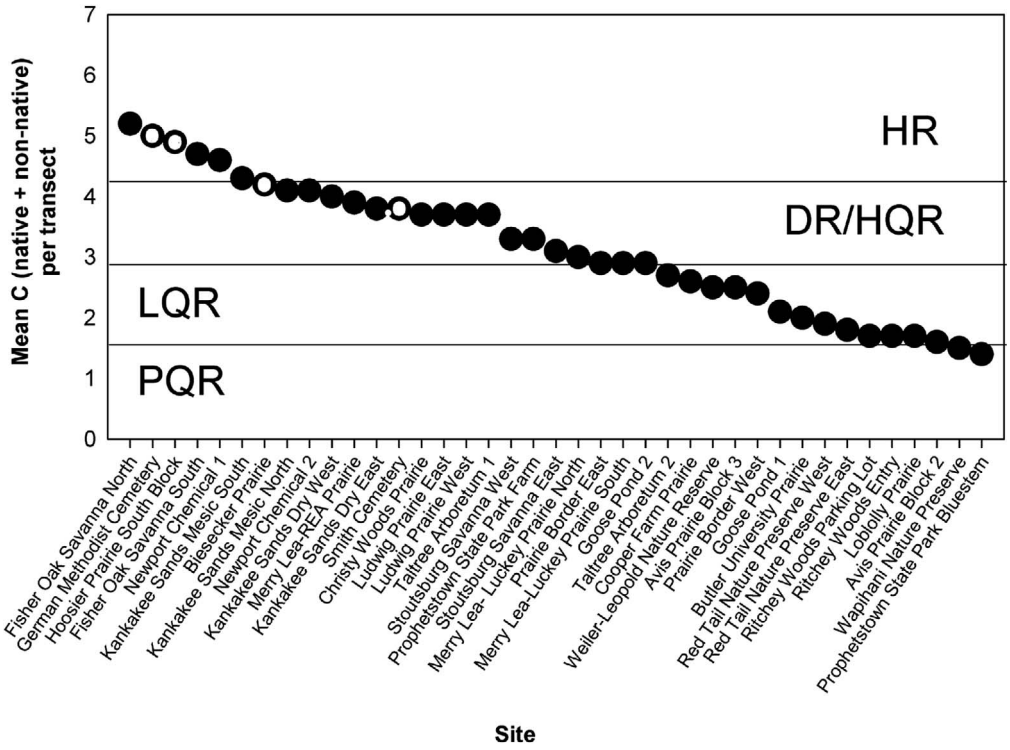

Figure 2.—Transect level mean C (MC) for four remnant prairies (open circles) and 35 transects in reconstructed prairies (solid circles) in Indiana. Prairies with high remnant quality had a transect MC $\geq$ 4.2. The reconstructed prairie at Fisher Oak Savanna and a portion of Newport Chemical Depot and Kankakee Sands (mesic) attained these levels. HR = high remnant quality, DR/HQR = degraded remnant/high quality reconstruction, LQR = low quality reconstruction, and PQR = poor quality reconstruction.

"nurse" species and gradually diminishes in abundance over the first five years of prairie development.

Another strategy that contributed to the high performance of some recent reconstructions is to purge the seed bank of agricultural weeds. Before planting Fisher Oak Savanna the land was prepared using Round-up Ready™ soybeans and applications of glyphosate (Sue Ulrich, interview, August 24, 2010).

Sites with very low MC [transect level, native + non-native] include Prophetstown State Park, Avis Prairie, and Loblolly Prairie, in addition to Ritchey Woods (Fig. 2). These sites have MC ranging from 1.4 to 1.7. Quadrat level results included the same list of sites and the western portion of the Red Tail Conservancy Prairie (Fig. 3). The sites with low FQA metrics frequently shared two attributes. First is their being located on Indiana's Central Till Plain (CTP) outside of the historic prairie and oak savanna region (Table 1). It is difficult to ascertain the importance of location, but one should note that the CTP region tends to have finer silt-clay soils, and soils devoid of prairie mycorrhizae, that may be less conducive to support diverse prairie species. But probably of much greater importance is that these poor to low quality reconstruction sites were planted during the 1990s and, while they support dense cover of native prairie species, they are dominated by tall grasses *Andropogon gerardii*, *Panicum virgatum*, and/or *Sorghastrum nutans*. The interspecific competition with tall grasses reduces forb density at the quadrat level and the resulting MC. Several sites, though, have low MC due to the presence of non-native species (Red Tail Prairie) or an abundance of early successional old field species (Ritchey Woods).

Over time plantings with dominant tall grasses experience a decline in forb species richness (McIndoe et al. 2008), further exacerbating the low species richness of seed mixes used for planting of early reconstructions (or reconstructions with a limited budget). Reconstructions

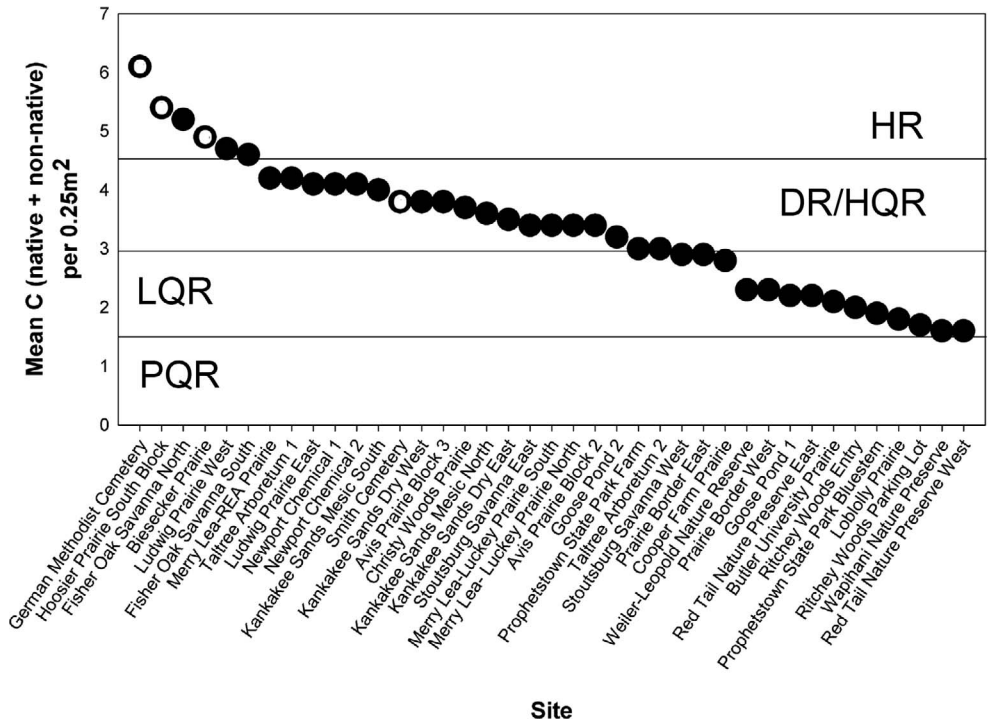

Figure 3.—Quadrat level mean C (MC) for four remnant prairies (open circles) and 35 transects in reconstructed prairies (solid circles) in Indiana. Quadrats were 0.25 m^2 in size. Prairies with high remnant quality had a quadrat MC $\geq$ 4.5. The reconstructed prairie at Fisher Oak Savanna and a portion of Ludwig Prairie attained these levels. HR = high remnant quality, DR/HQR = degraded remnant/high quality reconstruction, LQR = low quality reconstruction, and PQR = poor quality reconstruction.

from the 1990s typically had native species richness (NR) of 2 to 6 species per 0.25 m^2 quadrat and 8 to 24 species per transect (Figs. 4 & 5). Portions of Avis Prairie have particularly low NR since local genotype seed, at the time, had to be hand collected and was costly for large scale plantings. Looking to the future, then, the concern is how to introduce more forbs into these older reconstructions, a question that has become a focus of on-going research (Menges 2008).

If early prairie reconstructions are characterized by lower NR, the more recent efforts do have the highest observed (Fig. 4 & 5). For example, Kankakee Sands and Fisher Oak Savanna as well as portions of Taltree Arboretum, all planted since 2000, have a range of 36 to 44 native species per transect (Fig. 4) and a mean of 8 to 9.4 species per 0.25 m^2 (Fig. 5). However, species richness of the three least disturbed native prairies is notably higher at both scales. These native prairies ranged from 46 to 61 species per transect; they had a mean of 10 to 12.3 species per 0.25 m^2 quadrat.

Peter Schramm installed prairies in Indiana over the period from 1992 to about 2005. His plantings include Stoutsburg Savanna, Avis Prairie, Newport Chemical Depot, and Taltree Arboretum. The seed mix for early plantings included a generous amount of tall grasses. In part this was due to the belief that tall grasses were needed to out compete non-prairie species as well the expense and difficulty of acquiring hand gathered forb seed. The floristic quality of his more recent plantings is clearly higher. Taltree Arboretum (planted in 1996–2000) has 8.5 species per quadrat and 4.2 MC, compared to 5.9 species and 3.4 MC for the best transect at Stoutsburg Savanna. Another recent Schramm planting was at Newport Chemical. The FQA for this site, as noted in the Methods, had to be estimated from photos since physical sampling was not possible. With this limitation in mind, though, this site apparently had a higher MC, especially at the transect level (MC native + non-native = 4.1–4.7), than his earlier efforts (MC = 3.1–3.3).

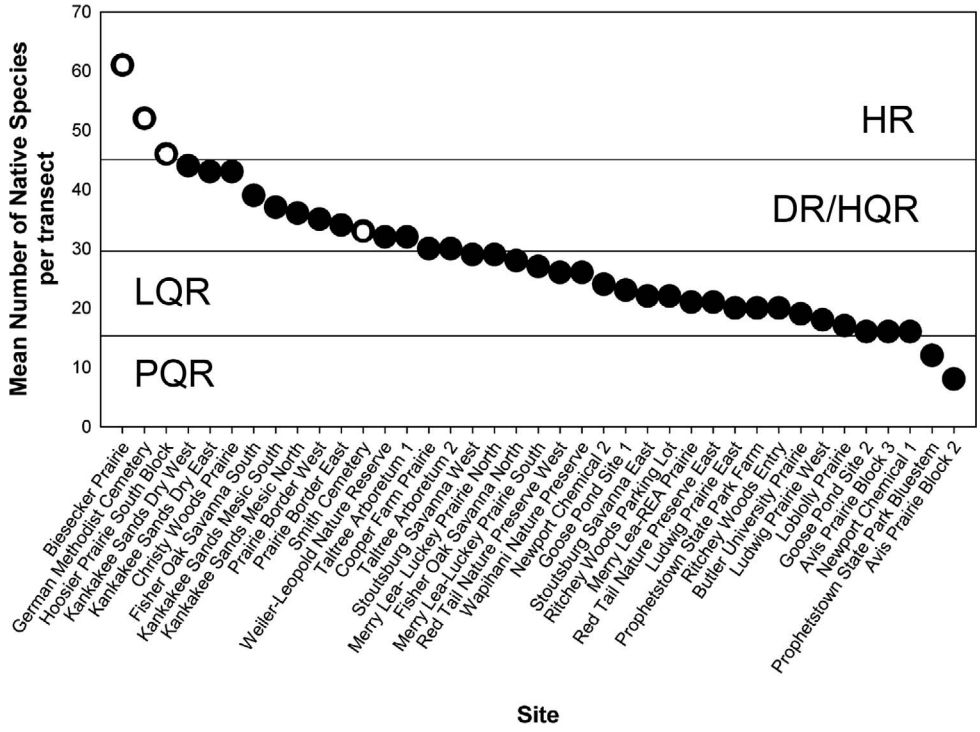

Figure 4.—Transect level native species richness (NR) for four remnant prairies (open circles) and 35 transects in reconstructed prairies (solid circles) in Indiana. Prairies with high remnant quality had 46 or more species per transect. High quality reconstructed prairies reached to 44 species per transect. HR = high remnant quality, DR/HQR = degraded remnant/high quality reconstruction, LQR = low quality reconstruction, and PQR = poor quality reconstruction.

Change in site quality over time.—Three of the higher quality reconstructed prairies were sampled twice over a 4- to 5-year period, in order to evaluate the sustainability of floristic quality. Transects at Kankakee Sands and Fisher Oak Savanna not only performed at relatively high quality for reconstructions, but also maintained their quality as measured by quadrat MC on both transect and quadrat levels.

Fisher Oak Savanna transects and Kankakee Sands Dry transects showed no significant change in quadrat MC ($p > 0.05$) (Table 3). On the other hand, both Kankakee Sands Mesic transects actually showed improvement of quality. In five years, the mean C value for the Mesic North transect increased from 3.10 ± 0.80 to 3.60 ± 0.80 ($p = 0.034$). Kankakee Sands Mesic South increased similarly from 3.50 ± 0.70 to 4.0 ± 0.5 ($p = 0.022$).

Ludwig Prairie, which performed only at a low level in the initial sampling, showed an increase in quality over a five year period (Table 3). At the time of the first sampling Ludwig prairie was 3–5 years of age. The east field, planted in 2000, increased from 3.40 ± 1.00 at the quadrat level to 4.10 ± 0.90 ($p = 0.028$). The west field, planted in 2003, similarly increased in mean C values from 2.90 ± 0.70 to 4.70 ± 0.60 ($p < 0.001$).

Conclusion.—In comparison to the FQA of remnant native prairies and old fields, Indiana prairie reconstructions encompassed a broad quality spectrum: from near remnant quality to low and poor quality. The highest quality transects were clearly those planted since 2000 indicating that important lessons have been learned through our early prairie reconstruction pioneers. The MC of about half of transects sampled fell into the high quality reconstruction level and about 30% also had excellent NR per transect. Thus, human effort over the past 35 years has produced some noteworthy reconstructed prairies. These results should be encouraging news as we seek to rebuild ecosystem function. At the same time,

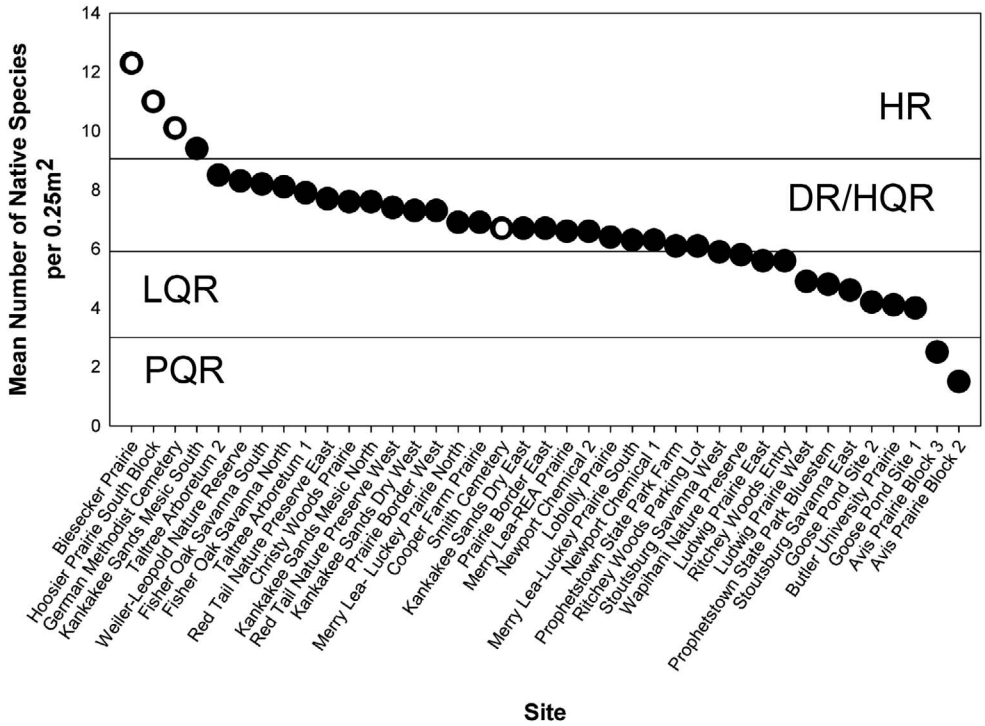

Figure 5.—Quadrat level native species richness (NR) for four remnant prairies (open circles) and 35 transects in reconstructed prairies (solid circles) in Indiana. Quadrats were 0.25 m^2 in size. Prairies with high remnant quality had 10 or more species per quadrat, a level achieved by only one reconstructed prairie. HR = high remnant quality, DR/HQR = degraded remnant/high quality reconstruction, LQR = low quality reconstruction, and PQR = poor quality reconstruction.

Table 3.—Two-tailed t-test results comparing 2005-6 to 2010 mean C. Transects were from Fisher Oak Savanna, Kankakee Sands, and Ludwig Prairies. * means significant at 95% confidence; ** means significant at 99% confidence; df = degrees of freedom.

Fisher Oak Savanna					
Site transect	Mean C 2006	Mean C 2010	t-value	df	*P*-value
Fisher Oak – North	4.80 ± 1.40	5.20 ± 0.80	1.13	38	0.266
Fisher Oak – South	4.30 ± 1.40	4.60 ± 0.90	1.00	38	0.326
Kankakee Sands Transects					
Site transect	Mean C 2005	Mean C 2010	t-value	df	*P*-value
Dry East	3.90 ± 1.10	3.50 ± 1.00	0.98	38	0.333
Dry West	3.40 ± 1.10	3.80 ± 1.10	0.98	38	0.332
Mesic North	3.10 ± 0.80	3.60 ± 0.80	2.20	38	0.034*
Mesic South	3.50 ± 0.70	4.00 ± 0.50	2.38	38	0.022*
Ludwig Prairie Transects					
Site transect	Mean C 2005	Mean C 2010	t-value	df	*P*-value
East	3.40 ± 1.00	4.10 ± 0.90	2.29	38	0.028*
West	2.90 ± 0.70	4.70 ± 0.80	7.53	38	0.000**

what is not regained needs communicating as well. Old-growth grasslands, as described by Veldman et al. (2015), have a mature species composition, endemic species of plants and animals, and high small scale species richness lacking in restored ecosystems. Our floristic assessment supports their observation even for projects that were intense and well-funded.

APPENDIX A.—List of cited interviewees and their positions. A more detailed history of Indiana prairie conservation and reconstruction efforts and additional interviewees is available through the corresponding author or at Pruitt (2011).

Phillip Cox
Former Natural Resources Administrator
Newport Chemical Depot
Vermillion County, IN

Rebecca Dolan
Friesner Herbarium Director
Butler University
Indianapolis, IN

Alan Galbreth
Associate Executive Director
Indiana Crop Improvement Association
Lafayette, IN

Chris Kline
Central Region Director
JFNew
Walkerton, IN

Chip O'Leary
Kankakee Sands Project Director
The Nature Conservancy
Newton County, IN

Tom Post
Northwest Region Ecologist
The Division of Nature Preserves
Medaryville, IN

Kevin Tungesvick
Restoration Ecologist
Spence Restoration Nursery
Muncie, IN

Sue Ulrich
Former President
NICHES Land Trust
West Lafayette, IN

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