FLORISTIC COMPOSITION OF A RESTORED TALLGRASS PRAIRIE COMPARED TO A NATIVE TALLGRASS PRAIRIE REMNANT IN SOUTHEAST KANSAS

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An Abstract of the Thesis by
Craig James Corpstein

The Fort Scott National Historic Site (FOSC) restored tallgrass prairie in southeast Kansas was studied in order to (1) analyze its current condition, (2) compare it to a regional native tallgrass prairie, (3) compare four subunits of the FOSC restored prairie, (4) compare it to previous studies, and (5) provide management recommendations. Cover values for plant species were estimated using a systematic random design based on the modified Daubenmire cover scale. Species richness and floristic quality were significantly higher at the native prairie than at FOSC in June and September. *Andropogon gerardii* (big bluestem) was the only dominant species found at both study sites. Summer/fall forbs are the main functional group at FOSC in June, with C_4 grasses becoming dominant by September. The C_4 plant guild was the major functional group at the native prairie in June and September. Species composition and abundances were similar among the four FOSC subunits. Species richness has increased since the FOSC restoration was started in 1979. Differences in species composition and their interaction between study areas indicate that the FOSC restored prairie has not fully recreated the native prairie that was once found in the area around Fort Scott. The elimination of exotic and woody species, along with efforts to increase native species diversity, is needed to maintain the restored prairie and to improve its overall condition.

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CHAPTER I

INTRODUCTION

The tallgrass prairies of North America are a threatened ecosystem. Since the 1830s, decreases in tallgrass prairie area have been as high as 82-99% in some states (Samson & Knopf 1994). Historically, tallgrass prairie once covered 69 million hectares; today, estimates of remaining native tallgrass prairie range from 13% to less than 1% (Risser 1988; Samson *et al*. 2004). Remaining patches of tallgrass prairie are now fragmented and scattered across its former range (Steinauer & Collins 1996). Losses of tallgrass prairie are largely due to agricultural practices, elimination of native grazers, and prolonged fire suppression (Howe 1994; Samson & Knopf 1994).

Due to the substantial losses in prairie habitat, the remaining fragments of tallgrass prairie are now the focus of intense study and conservation efforts (Samson & Knopf 1994). Efforts are now underway to re-establish tallgrass prairie within its former ranges, resulting in restoration attempts ranging from several hundred hectares down to a few dozen hectares. Careful management and monitoring are needed to assess the success of both large and small-scale restorations (McIndoe *et al.* 2008).

A tallgrass prairie restoration began in 1979 at the Fort Scott National Historic Site (FOSC), located in Bourbon County, KS. The last vegetation analysis was performed in 1997 and a new vegetation analysis needs to be performed in order to evaluate the current condition of the restoration. This information regarding the restored tallgrass prairie is needed to determine the appropriate focus and direction of future restoration efforts at FOSC.

The purpose of this study is to describe the condition of the prairie restoration project at FOSC in comparison to a regional reference prairie. The goals are to describe and assess the current condition of the restored prairie at FOSC, to compare its condition to that of a reference remnant prairie, to compare four subunits of the FOSC restoration, to compare its current condition to that of previous studies, and give management recommendations.

CHAPTER II

LITERATURE REVIEW

Great Plains Prairies

The Central portion of North America, extending from Canada to Mexico and from the Rocky Mountains to western Indiana and Wisconsin, is collectively known as the Great Plains. This vast area was once covered in a blanket of native prairie. Prior to European settlement, this expanse of prairie was the largest ecosystem in North America (Samson & Knopf 1994).

There are three main divisions of prairie within the Great Plains (Figure 1). These divisions are a result of the rain shadow effect caused by the Rocky Mountains (Knopf 1994; Samson *et al*. 2004). The western edge of the Great Plains receives little rainfall and is known as the shortgrass prairie region, due to the predominance of low growing vegetative species. The far eastern edge of the Great Plains receives larger amounts of rainfall and can support trees as well as grass and forb species, which grow in excess of three feet, and is known as the tallgrass prairie region. The area between shortgrass and tallgrass prairie receives a moderate amount of rainfall and can support species found in both the shortgrass and tallgrass prairies, along with some trees mainly confined to riparian habitats, and is known as the mixed-grass prairie (Samson & Knopf 1994; Samson *et al*. 2004).

Figure 1. Extent of historical (pre-European) tall-grass, mixed-grass, and short-grass prairies on the North American Great Plains. Source: United States Geological Survey http://www.npwrc.usgs.gov/resource/habitat/grlands/pastpres.htm

Estimated historic ranges indicate that approximately 162 million hectares of the Great Plains was covered in native prairie. Shortgrass prairie covered approximately 18 million hectares, mixed-grass prairie covered 64 million hectares, and tallgrass prairie covered 69 million hectares (Samson & Knopf 1994). Current estimates show a 70% overall loss of prairie across the Great Plains (Samson *et al*. 2004). Short grass prairies have experienced decreases ranging from 20-85%; mixed grass prairies have experienced decreases ranging from 30-99%; and tallgrass prairies have experienced decreases ranging from 82-99% (Samson & Knopf 1994; Samson *et al*. 2004). Estimates of remaining native tallgrass prairie range from 13% to less than 1% (Risser 1988; Samson *et al*. 2004).

The wide-ranging loss of tallgrass prairies is considered by many scientists and ecologists to be the direct result of human activity (Samson & Knopf 1994; Samson *et al*. 2004). Between 1770-1830, European settlers began altering the Great Plains, resulting in tallgrass prairie losses largely due to agricultural practices, extirpation of native grazers, and prolonged fire suppression (Howe 1994; Samson & Knopf 1994; Samson *et al*. 2004).

Agricultural practices have primarily involved the modification of native prairie into other uses, such as crop production. This conversion requires the plowing of prairie sod, which destroys the prairie vegetation (Knopf 1994; Samson & Knopf 1994; Steinauer & Collins 1996). Prairie communities are also affected by the removal of native grazers and the introduction of domestic herbivores, such as cattle. This often leads to overgrazing, which transforms prairies into scrublands (Risser 1988).

Fires have historically been important to the health of the Great Plains. Fires suppress the growth of non-native and woody species, while stimulating the growth of native prairie species (Schramm 1990). Suppressing prairie fires has contributed to the elimination of native grasslands from the landscape; additionally, studies have shown that burned prairies have greater species diversity than unburned prairies (Risser 1988).

The remaining tallgrass prairie is now fragmented and scattered across its former range. Most prairie fragments, also referred to as remnant prairies, are surrounded on all sides by non-prairie landscapes (Steinauer & Collins 1996). This increases the likelihood of invasion by woody and non-native plant species into the remnants, resulting in degradation (Allison 2002; Steinauer & Collins 1996). As these remnants become smaller, occurrences of local extinctions of native plant species increase (Leach & Givnish 1996). Lower genetic diversity of plant species is also a result, which further contributes to the loss of the prairies (Steinauer & Collins 1996; Wilsey *et al*. 2005). This isolation of prairie remnants greatly hinders the ability of native plant species to migrate and become established (Steinauer & Collins 1996; Williams *et al*. 2007). It has been predicted that the combination of reduced migration rates and local extinctions will lower plant species richness within remaining remnants (Wilsey *et al*. 2005).

Fragmentation, reduced remnant sizes, local plant extinctions, and lower plant species diversity have been found to negatively affect the diversity of animal species within the Great Plains. The loss and decline of bison, prairie dogs, and the black-footed ferret are well known; however, reduced diversity and abundance of other mammals, insects, and birds has been documented (Samson & Knopf 1994). In some cases, declines in animal species are not directly related to the loss of grassland habitats. Prairie dogs have experienced an estimated 98% decline since European settlement, which has impacted several other species. Prairie dogs are considered a keystone species, meaning the continued existence of other species depends on them. The ferruginous hawk, mountain plover, burrowing owl, black-footed ferret, and swift fox are all endangered or experiencing significant declines, which are attributed to declines in Prairie dog numbers (Knopf 1994; Samson & Knopf 1994).

Tallgrass Prairie Conservation

Due to the substantial losses of tallgrass prairie, conservation efforts are underway to preserve the remaining tallgrass prairie remnants. Samson and Knopf (1994) proposed some reasons for conserving native prairies. (1) Grasses, which are a vital component of prairies, are a major source of human nourishment, either directly or indirectly. (2) As native prairies are destroyed, the risk of extinction increases not only for plants, but also for other species, which depend on the prairie habitat. (3) Prairies may help with global warming issues, because they are superior carbon sinks. Consequently, efforts focused on conserving North America's remaining tallgrass prairies are gaining support and attention.

Most remaining tallgrass prairie remnants were not initially set-aside with conservation goals in mind (Cully *et al*. 2003). Many were left intact as native hay fields or as future cemeteries or school sites (Herzberg & Pearson 2001). Others survived because of their historical or cultural significance, such as Pipestone National Monument in Minnesota and Wilson's Creek National Battlefield in Missouri (Cully *et al*. 2003). Curtis and Greene (1949) point out that some prairie areas were left intact as railroad right-of-ways or because they were on land not well suited to agricultural purposes, such as steep banks, thin soils, or low grounds. The Flint Hills of Kansas is an area that was not suitable for crop production. This physiographic region is characterized by shallow soils intermixed with hard rock, which wore out the steel plows used by early settlers. The tallgrass prairie of the Flint Hills was, however, suitable for cattle grazing, thus sparing it from destruction (Collins 1985). The Flint Hills contain the largest remaining relatively intact blocks of tallgrass prairie in North America (Ricketts *et al*. 1999).

When making comparisons of old surveys and recent prairie surveys in Iowa, Wilsey *et al*. (2005) found evidence for "substantial amounts of extinction" due to the fragmentation of the original tallgrass prairie ecosystem (Wilsey *et al*. 2005). They also found that "even tiny remnants continued to support a large number of native species" (Wilsey *et al*. 2005). Based on these findings, Wilsey *et al*. (2005) suggest that conservation efforts should focus on protecting many different prairie types instead of a few large remnants. They explain that even within the tallgrass prairie region, prairies can vary greatly depending on soil composition and geographic region. Protecting only a few large prairies may not conserve all the species diversity found across the differing prairie types (Wilsey *et al*. 2005). Their findings were supported by results from a study, which looked at 25 tallgrass prairie sites across Central North America. Sampling revealed that some small patches of tallgrass prairie "can support a near-full complement of native species," indicating that small fragments should receive conservation attention (Cully *et al*. 2003).

Samson *et al*. (2004) believe that conservation efforts should be focused on preserving what remains of the shortgrass and mixed-grass prairies. They argue that losses to the tallgrass region are too great and "the opportunity to recover or restore that ecosystem on any meaningful spatial scale has been lost" (Samson *et al*. 2004). They believe that remnant reserves and restorations are all that can be hoped for in the tallgrass prairie region.

Because so little tallgrass prairie remains, restoration efforts have begun throughout the tallgrass prairie region. Conservation organizations, universities, and landowners have initiated restorations ranging in size from only a few hectares to several hundred hectares (McIndoe *et al*. 2008). Most tallgrass prairie restorations take place on land that had previously been converted for agricultural use (Allison 2004; Foster *et al*. 2007; Kindscher & Tieszen 1998). A common goal of prairie restoration is to reestablish the native plant species found in remnant prairies (Camill *et al*. 2004). These restorations are important from a conservation viewpoint because they can serve as "steppingstones" for prairie plant species migration between remaining native prairie remnants (Williams *et al*. 2007). Piper *et al*. (2007) also point out that large C_4 grasses, typical of tallgrass restorations, can contribute to soil organic matter, provide erosion control, and offer habitat for ground-nesting birds. In addition, more diverse plant communities could feature higher diversities of arthropods and small vertebrates, improve soil quality, increase stability, and exclude invasive exotic species (Piper *et al*. 2007).

The Society of Ecological Restoration International (SER) published a primer on ecological restoration in 2004. SER defines ecological restoration as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed"

(SER 2004). The SER Primer elaborates on this definition by describing ecological restoration as an intentional activity designed to aid in the recovery of an ecosystem that has been harmed, either directly or indirectly, by human activities. SER further explains, "restoration attempts to return an ecosystem to its historic trajectory" (SER 2004). However, SER does concede that the restored ecosystem may not be able to return to its former state. Nevertheless, SER maintains that ecological restoration is beneficial to the health and integrity of damaged ecosystems (SER 2004).

Allison (2004) argues that we do not have enough information on pre-settlement native prairies to know what historical trajectory the land may have develop into if European settlers had never arrived. Allison uses the example of Illinois tallgrass prairies becoming oak-hickory forests in the absence of fires, which were often set by Native Americans. The question presents itself as to whether tallgrass prairie is in fact the historic trajectory of a landscape that had been manipulated by humans long before the arrival of European settlers.

The SER Primer (2004) lists nine attributes of restored ecosystems. These attributes are designed to serve as a basis for deciding if a restoration has been accomplished. The nine attributes of a restored ecosystem include: (1) an assemblage of species that occur in the reference ecosystem; (2) primarily indigenous species that are located within the restoration; (3) essential functional groups that are present to ensure continued development and/or stability of the restoration; (4) restoration populations, which are capable of reproduction; (5) restoration, which functions normally without dysfunction; (6) restoration that is integrated into the larger landscape; (7) possible threats from the surrounding landscape that have been eliminated or reduced as much as possible; (8) restoration, which is resilient and can endure local environmental stress events; and (9) restoration that can persist indefinitely under existing environmental conditions and is self-sustaining to the same degree as its reference ecosystem (SER 2004). SER does point out that "The full expression of all these attributes is not essential to demonstrate restoration. Instead, it is only necessary for these attributes to demonstrate an appropriate trajectory of ecosystem development towards the intended goals or reference" (SER 2004).

The reference ecosystem is intended to serve as a model for planning a restoration. SER (2004) suggests assembling a reference from multiple sources in order to capture the range of developmental possibilities for the future restoration. Sources can include nearby remnant ecosystems, written ecological descriptions of the site prior to alteration, descriptions of similar intact ecosystems, species lists, historical and recent photographs, herbarium and museum specimens, historical accounts, and paleoecological evidence. A reference site is typically selected for its range of biodiversity.

The Curtis Prairie restoration at the University of Wisconsin-Madison Arboretum is frequently cited as being the first prairie restoration project (Cottam 1987; Sperry 1994). First proposed in the early 1930s by Norman Fasssett and Aldo Leopold, the idea behind the project was to restore the area to pre-European settlement conditions. Beginning in 1934, members of the Civilian Conservation Corp (CCC), under the supervision of Theodore Sperry, began transplanting native prairie sod and seed from nearby remnants into a 25 hectare abandoned field. The work of transplanting and seeding continued through 1941, with no additional seeding being performed again until 1950 (Blewett & Cottam 1984; Sperry 1994). The prairie was named Curtis Prairie in honor of John Curtis, who directed much of the early research on the restoration, including the first three vegetation surveys in 1946, 1951, and 1956 (Cottam & Wilson 1966). A second prairie restoration was also started at the University of Wisconsin-Madison Arboretum. Henry Greene developed a 20-hectare restoration and carried out most of the work single-handedly between 1942 and 1952. The prairie was later named the Greene Prairie in honor of his work (Cottam 1987).

The efforts of these men inspired a third prairie restoration in 1955 at the Knox College Green Oaks Field Study Center in West-Central Illinois (Allison 2002). George Ward and Paul Shepard, both from the Knox College Biology Department, began the restoration by planting 63 species from seed. Shepard, and his successor Peter Schramm, expanded the restoration three more times in subsequent years. The goal of this restoration was to re-create the original Illinois prairie prior to European settlement in the 1830s (Allison 2002; Allison 2004). Since these initial restorations, numerous other prairie restoration projects, both public and private, have been started throughout the Midwest.

Limitations of Tallgrass Restoration

Research involving tallgrass prairie restorations are demonstrating that restorations do not achieve the levels of native plant diversity found in remnant prairies. Polley *et al*. (2005) examined patterns of plant species diversity in remnant and restored tallgrass prairies in Texas. Their findings showed greater species diversity in remnant than in restored prairies. Remnants showed a greater partitioning of resources than restored prairies. Species evenness was also greater in remnant than restored prairies.

Martin *et al*. (2005) assessed the success of the largest prairie restoration project in the United States in comparison with three remnant prairies. Located in Iowa, the Neil Smith National Wildlife Refuge has approximately 1200 ha of restored tallgrass prairie. They conclude that even this large restoration “was unable to restore fully all aspects of species diversity” (Martin *et al*. 2005). They believe the lack of success may be attributed to difficulties in restoring spatial patterns of species richness and diversity (Martin *et al*. 2005).

In an Illinois tallgrass restoration study, Sluis (2002) found a decrease in plant species richness over time. The restored prairie was dominated by a few native species, which excluded other species; however, nearby remnant prairies did not reflect the same levels of dominance and exclusion. Richness was also greater in the remnant prairies than the restoration. Sluis (2002) concludes, “Our understanding of the maintenance of species richness and mechanisms causing species patterns is not sufficient to allow the re-creation of patterns of species found in remnant grassland communities.”

Allison (2002) used three nearby remnants and Mead’s 1846 species list of Illinois prairie plants as a reference when determining the success of a 45-year-old tallgrass prairie restoration. Allison (2002) studied the Green Oaks restoration in Illinois, and concluded that the restoration has not been successful in achieving the original goal of re-creating pre-settlement tallgrass prairie. Allison (2002) believes one possible reason for this lack of restoration success is due to insufficient information regarding all of the species present in the pre-European settlement prairie. Incomplete species lists also limit our knowledge of how species would have interacted and the relative abundances of species. Allison (2002) points out that using remnant prairies as models for assessing restoration success can be problematic because remnant prairies are not static. There remains the possibility that remnants have changed since pre-settlement times, approximately 170 years ago. Notable changes include the loss of animals associated with tallgrass prairies, changes in fire regimens, and the small, isolated nature of most tallgrass remnants (Allison 2004). However, others at Knox College do regard the restoration as successful, mainly because the Green Oaks restoration is attractive and provides visitors with the sensory experience of a prairie (Allison 2002).

The possibility that remnant plant species composition has changed since pre-settlement times was examined when Wilsey *et al*. (2005) looked at current plant species richness in Iowa tallgrass prairie remnants. Twenty-two remnants were studied and compared to Greene's 1907 plant surveys of the entire state and statewide herbarium specimens, collected by Cratty, curator of the University of Iowa Ada Hayden Herbarium from 1918-1933, between 1870 and 1933. Wilsey *et al*. (2005) found 491 native species within the 22 remnants surveyed. This was much lower than the 806 species Greene found in 1907, or the 897 species Cratty collected.

Kansas Tallgrass Prairie Research

Many Kansas studies involving tallgrass prairies have been surveys of natural areas, conducted by members of the Kansas Biological Survey at the University of Kansas. The purpose of these studies was to survey remaining high quality natural areas and identify habitat that might harbor rare species (Kindscher *et al*. 2005). Inventories of Cherokee, Anderson, Linn, Douglas, Johnson, Leavenworth, Miami, and Wyandotte Counties have been performed, as well as studies focusing on the Marias des Cygnes National Wildlife Refuge in Linn County, and Fort Riley Military Reservation in Geary and Riley Counties (Loring *et al*. 2005; Kindscher *et al*. 2009; Kindscher *et al*. 2005; Kindscher *et al*. 2008; Freeman & Delisle 2004). These studies did not make comparisons with prairie restorations.

Other Kansas studies have focused exclusively on tallgrass prairie restorations. Piper *et al*. (2007) established a tallgrass prairie restoration on former agriculture land, located east of Bethal College in North Newton, KS. The purpose of this restoration was to "examine the rate of establishment and diversity of grassland restorations" (Piper *et al*. 2007). After a six-year study, they concluded that establishment of minimally species-rich prairie communities could be enhanced by increasing the number of native plant species in the initial seed mixture (Piper *et al*. 2007). In another re-seeding experiment, Dickson & Busby (2009) began a restoration on 6.1 hectares of land located near Lawrence in northeast Kansas. They found that forb species establishment increased when initial seed mixtures contained more forbs and fewer grasses (Dickson & Busby 2009). These results are consistent with findings by McCain *et al*. (2010), in which increases in forb species richness, evenness, and diversity followed the removal of dominant grass species, particularly *Andropogon gerardii* (big bluestem). This study was performed on a 3.2-hectare tallgrass restoration located at the Konza Prairie Research Natural Area, located near Manhattan, KS (McCain *et al*. 2010).

Research comparing restored tallgrass prairies and native tallgrass prairies in Kansas are limited. The few studies, which make comparisons, have been performed in northeast Kansas. Jog *et al*. (2006) compared 104 privately owned grasslands in Douglas, Jefferson, and Leavenworth Counties. They compared warm-season hay meadows, warm-season pastures, cool-season planted hay fields, cool-season planted pastures, and Conservation Reserve Program (CRP) fields. At least 20 grasslands of each type were sampled and compared using a floristic quality assessment index (FQI) to characterize plant communities. Higher FQI values indicate greater prairie quality. Of the different grassland types sampled, warm-season hay meadows, warm-season hay pastures, and CRP fields had the highest FQI values, with averages of 32, 21, and 13 respectively (Jog *et al*. 2006). These results are consistent with other studies in which native prairies had greater species diversity than restored prairies.

In another northeast Kansas study, Kindscher and Tieszen (1998) looked at floristic and soil organic matter changes in two prairie restorations in comparison to adjacent remnants. Even though the restored and remnant prairies had the same soil type, local climate, and pre-European settlement vegetation, results indicate that the restored prairies are dissimilar to remnants in terms of plant species composition. This study is unique in that the restored and remnants prairies are bordering each other; however, this still did not seem to facilitate the establishment of native species into the restored prairies. Kindscher and Tieszen (1998) speculate that perhaps the restorations are reaching alternative stable states. They conclude that establishing highly diverse tallgrass restorations using only a few warm-season native grasses will occur only over long periods of time, perhaps centuries.

History of Fort Scott

Fort Scott was established in 1842 on the Fort Leavenworth-Fort Gibson Military Road, in present day Bourbon County, Kansas. The fort was situated on a bluff overlooking the Marmaton River to the North. Fort Scott served as one of a network of outposts designed to protect western settlers and Indians along the "Permanent Indian Frontier" (Olivia 1984). As the fort was constructed, all prairies were eliminated from the immediate area (Bacon 1992; Stubbendieck &Wilson 1986).

Once the frontier boundary had moved farther west of Fort Scott, authorities in Washington D.C. had no further need for the fort. Construction at Fort Scott was halted in 1850, and in 1853, the fort was abandoned. The remaining fort buildings were sold at public auction in 1855 (Utley 1991). Fort structures and the adjacent land were converted to residential and business uses. Additional homes were built, and the town of Fort Scott began to take shape in and around the abandoned military post (Figure 2) (Bacon 1992).

In the 1950s and 60s a movement to preserve and restore Fort Scott began (Bacon 1992; FOSC General Management Plan 1993). The site became an affiliated area of the National Park Service on August 31, 1965, and eventually was donated to the National Park Service by the City of Fort Scott. Fort Scott National Historic Site was authorized by Public Law 95-484 on October 19, 1978, "to commemorate the significant role played by Fort Scott in the opening of the west, as well as the civil war and strife in the state of Kansas that preceded it...." (FOSC General Management Plan 1993).

Figure 2. 1950s aerial view shows the extent of urban development at the old fort site. At this time the former fort parade ground served as the town square for the city of Fort Scott. Source: National Park Service.

Fort Scott National Historic Site comprises 6.75 hectares (16.69) acres and consists of 20 principal historic structures (11 original, 9 reconstructed), a parade ground, approximately five acres of restored tallgrass prairie, a museum collection and an unknown quantity of archeological resources. FOSC is the only unit of the National Park System representing a 1840s military installation. The historic structures have been restored and reconstructed to depict the original 1842-53 appearance (FOSC General Management Plan 1993).

Interpretation efforts at FOSC are designed to "promote public awareness and understanding of Fort Scott and its role in the opening of the West from 1842-1853, during the 1854-1860 period of strife in Kansas, through the 1861-1865 Civil War period, and during the railroad development years of 1867-1873" (FOSC General Management Plan 1993). In order to accomplish this several management objectives have been established for the preservation, restoration, protection, and interpretation of the site's cultural resources. One of the management objectives described in the FOSC General Management Plan (1993) is, "to restore and cultivate the native vegetation which provides the historic setting for the primary historic restoration and interpretive period 1842 to 1853."

Native vegetation around Fort Scott is characteristic of the tallgrass prairie region. No written accounts describing specific species are available from the 1840s; however, early accounts indicate that forbs appeared to be abundant in the prairie surrounding Fort Scott. Inspector General Colonel George Croghan in 1844 wrote that some of the fort buildings "shut out of view the most magnificent prairie of the country" (Bacon 1992). In 1852, Fort Scott Assistant Surgeon Joseph K. Barnes wrote that "The immediate site of the post is a flat spur of high prairie, this plateau opens out rapidly to the South in a beautifully undulating prairie." Barnes further elaborated on the vegetation as having "an almost entire exclusion of the grasses; the latter being the character of much of this section of the country" (Bacon 1992). A letter written at Fort Scott in 1843 by Charlotte Swords, wife of Captain Swards, describes how she gathered "all the pretty flowers we see and try to become botanists, the flowers here far surpass those of [Fort] Leavenworth in fragrance" (Bacon 1992).

History of Fort Scott Restored Tallgrass Prairie

Prairie restoration work at FOSC began in 1979 by planting a mixture of grasses and forbs over a 2.02-hectare area. The acreage restored has been sectioned into three units (Figure 3). Unit A is located at the northeast side of the site behind the remaining Officer's Quarters (HS-1, HS-2, HS-4). There is a mowed path winding through Unit A so visitors can walk through and experience the prairie. Unit B is the area at the East/Southeast end of the site behind the Infantry Barracks (HS-6). A shaded picnic area in the center of the unit separates Unit B into two smaller areas called B1 and B2, although it is treated as one unit. Unit C is located at the south end of the site. A brick path from the parking lot to the parade grounds separates Units B and C. Units A and B were seeded in the spring of 1979 with 13 species, using a combination of hand broadcasting and seed drilling. Soil was first prepared with a disk and harrow. The grass mixture included *Andropogon gerardii* (big bluestem) 16%, *Schizachyrium scoparius* (little bluestem) 50%, *Bouteloua curtipendula* (sideoats grama grass) 12%, *Panicum*

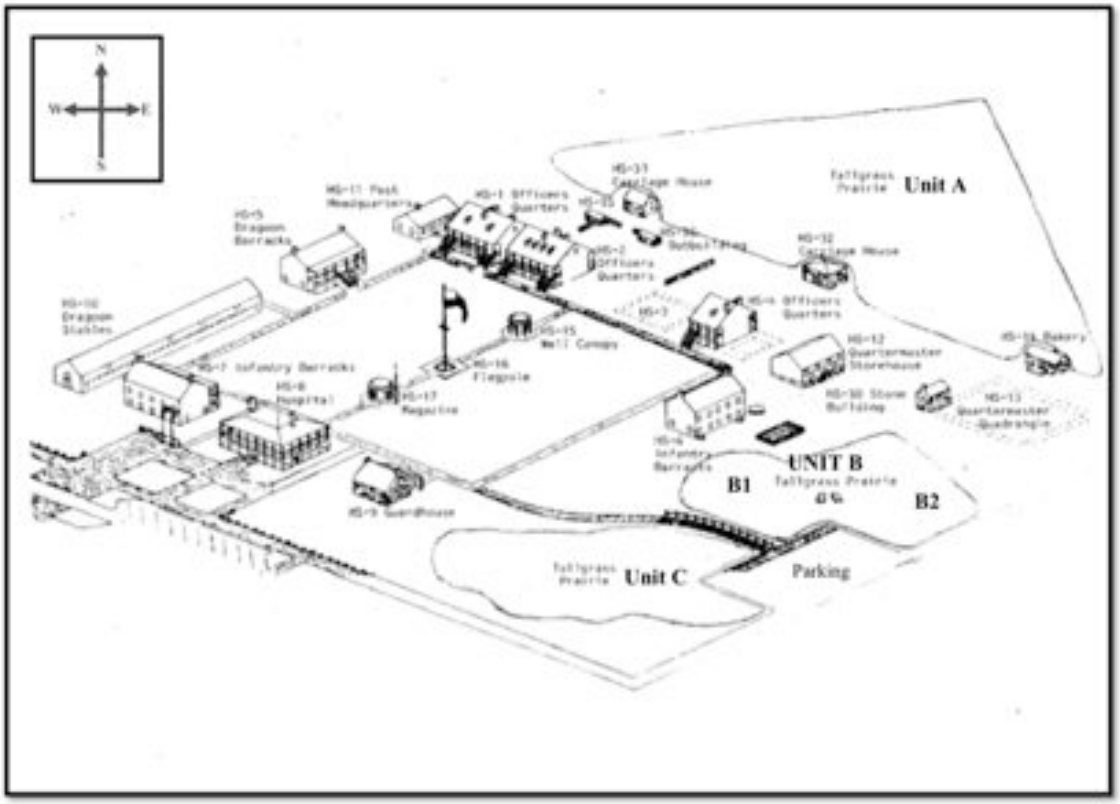

Figure 3. Fort Scott National Historic Site showing location of prairie Units A, B, and C. Source: National Park Service.

virgatum (switchgrass) 8%, and *Sorghastrum nutans* (Indian grass) 14%. The forb mixture included *Amorpha canescens* (leadplant) 10%, *Helianthus maximilianii* (Maximillian sunflower) 5%, *Liatris aspera* (tall gayfeather) 11%, *Dalea purpurea* (purple prairie clover) 14%, *Ratibida pinnata* (grayhead prairie coneflower) 30%, *Rudbeckia hirta* (blackeyed susan) 10%, *Salvia azurea* (blue sage) 10%, and *Silphium laciniatum* (compass plant) 10% (Stubbendieck &Wilson 1986). Kelley Collins (2011), Chief of Interpretation and Resource Management at FOSC stated there is no information on file regarding the rationale behind the original seed mixture.

Additional seeding of Units A and B was accomplished in April 1984, May 1985, and September 1986. Unit C was established during the April 1984 seeding and included eight species. Seeding was performed using a seed drill and hand broadcasting. Reseedings included: *Bouteloua gracilis* (blue gramma grass), Indian grass, little bluestem, big bluestem, grayhead prairie coneflower, upright coneflower (species unknown), blue sage, and *Echinacea angustifolia* (purple prairie coneflower). The seed mixture and the source of the seeds used in all three plantings are unknown (Knoblauch & Jackson 1986).

A variety of prairie management activities has been practiced since the original restoration (Appendix 1). Vegetation surveys have been conducted on the Fort Scott grounds during the past 32 years. These surveys vary in their intensity and duration. James Jackson, Missouri Southern State University and Timothy Vinyard, George Washington National Monument, conducted a walk-through study of all units on December 1, 1983. They concluded, without sampling, that the vegetation resembled a mixed grass prairie. They also concluded that the restoration consisting of mixed grass prairie was appropriate to the site and that seeding methods and practices previously conducted should be continued to further establish the prairie as mixed grass (Knoblauch & Jackson 1986).

Jackson returned with Kurt Knoblauch, Missouri Southern State University, to conduct a vegetative survey of the restored prairie in May 1985. The 1985 survey used transects and quadrats in order to obtain vegetation estimates. Jackson and Knoblauch (1986) wrote a report (unpublished), which is located in the FOSC library, in which they present their findings. This report includes discussion of the methods and procedures used and management suggestions.

Methods included placing 25x50 cm quadrats along transects extending West to East. A list–count method was used to tabulate species and numbers present. Transects were spaced 10 meters apart with quadrats spaced every 10 meters along transects. At FOSC, 36 plots were sampled using these methods from May 20-24, 1985. Thirty-two plots were sampled as comparative examples of native prairie at the Little Osage Prairie from June 11-18, 1985.

The Little Osage Prairie is a 32.4-hectare (80 acre) remnant of upland tallgrass prairie located about four miles south of Nevada in Vernon County MO, approximately 25 miles east of Fort Scott (SW ¼, sec. 34, T35N, R31 W). The Missouri Department of Conservation manages the Little Osage Prairie, which is owned by The Nature Conservancy. The soil composition of the Little Osage Prairie is of the Barco-Barden-Coweta association, "consisting of shallow to deep, gently sloping to strongly sloping (2-14%), well drained to moderately well drained soils that have a surface layer of fine sandy loan to silt loam and a subsoil of loam to silty clay-loam; on uplands." Bedrock found under the Little Osage Prairie is composed of sandstone resting on top of shale (Preston 1977).

Jackson and Knoblauch (1986) believed this was an adequate sampling effort based upon a species area curve; however, the species area curve graph was not included with their report. Percent relative frequency, percent relative density, percent relative cover, and importance values were calculated for both sample sites. Sorensen's coefficient of community similarity was used to compare the Little Osage Prairie to the FOSC restored prairie. The coefficient of similarity between the two prairies was 37.3% (Knoblauch & Jackson 1986). The report does not mention whether voucher specimens were collected.

Knoblauch and Jackson (1986) explained that they chose the Little Osage Prairie to provide a native example of tallgrass prairie to use as a comparison for the FOSC restored prairie, because of similar soil type, drainage, exposure, and relatively close location to the FOSC restored prairie.

Ronald Briggs, District Conservationist with the Natural Resources Conservation Service, evaluated the restored prairie on October 20, 1988. Briggs concluded that Unit C appeared to be improving in range condition, while Units A and B showed a decline in range condition. He found grasses dominated in all the units with forbs making up less than 10%. Briggs recommended removing non-native species, implementing prescribed burns, and mowing and/or annual haying to improve the condition of the restored prairie (Briggs 1988).

In September 1993, the restored prairie underwent another vegetative analysis. National Park Service Biological Science Technician, Kathy Gifford, conducted sampling

(Gifford 1993). Gifford established a baseline along the longest and straightest border for each prairie unit. Running perpendicular to each baseline, eight evenly spaced transects were then established. Along each transect a 1 x ½ meter quadrat was placed every five meters for estimating foliar cover. The first quadrat was randomly placed within the first five meters of each transect. Quadrat placement on either side of transects was determined by flipping a coin. A modified Daubenmire cover value scale was used for estimating foliar cover.

Gifford's data were used to determine frequency, relative frequency, mean cover, relative cover, and importance values. Sorensen's coefficient of community similarity was calculated using Gifford's results, the 1985 species list of the Little Osage Prairie, and the species list from the 1985 Knoblauch and Jackson survey. Gifford reported a 33% similarity between the 1993 Gifford survey and the 1985 Little Osage Prairie and a 58% similarity between the 1993 Gifford survey and the 1985 Knoblauch and Jackson survey (Gifford 1993). Gifford's survey results are on file at FOSC. It is unknown if voucher specimens were collected.

A notable management activity occurred in the summer of 1995 when 0.58 hectares (1.43 acres) of native prairie sod were transplanted into Unit A. The sod transplants came from a donor prairie five miles south of FOSC, which was scheduled for destruction due to road construction activities. The soil associations at the donor prairie were the same as those found at FOSC. The average size of sod sections was 12" x 12" x 9". This sod transplant increased the number of native species at FOSC (Compton 1995).

National Park Service Biological Science Technician, Dennis Compton, performed a vegetation survey of Units A and B in 1997 (Compton 1996-1997).

Compton's survey data was used to find the frequency, relative frequency, and relative density of vegetation found in prairie units A and B. A survey of unit C was not performed. Compton established baselines in the same location as Gifford and then ran transects spaced 10 meters apart perpendicular from the baselines. Quadrats, measuring 1 x ½ meter were placed along transects every 10 meters. A coin was flipped to determine which side of transects to place each quadrat. Compton estimated foliar cover using a modified Daubenmire cover value scale. A community similarity comparison was not performed. Compton found 100 taxa with 68 species being non-native. Voucher specimens were not collected (Compton 1996-1997).

CHAPTER III

METHODS AND MATERIALS

Location of Study Sites

The study areas were in Bourbon County, Kansas. Bourbon County is located in southeast KS, within the Osage Cuestas physiographic region (Figure 4). The climate of southeast KS is humid with an average annual rainfall of 40 inches; 75% of this annual rainfall occurs between April and September. The annual mean temperature of southeast KS is 14°C (58°F), with extremes of over 38°C (100°F) to under sub-zero. Air temperatures may fluctuate as much as twenty degrees in one day. Prevailing winds are mainly from the South, expect between December and March when winds come from the North or Northwest (Collins 1985). The dominant native grass species in southeast KS are *Andropogon gerardii* (big bluestem) and *Sorghastrum nutans* (Indian grass). Other native species include: *Amorpha canescens, Dalea candida, Dalea purpuea, Psoralidium tenuiflorum, Schizachyrium scoparium,* and *Scleria triglomerata* (Lauver *et al*. 1999).

Restored Tallgrass Prairie

The restored tallgrass prairie site is located in the town of Fort Scott, KS as part of the Fort Scott National Historic Site (FOSC) (lat 37°50'N, long 94°42'W), elevation ca.

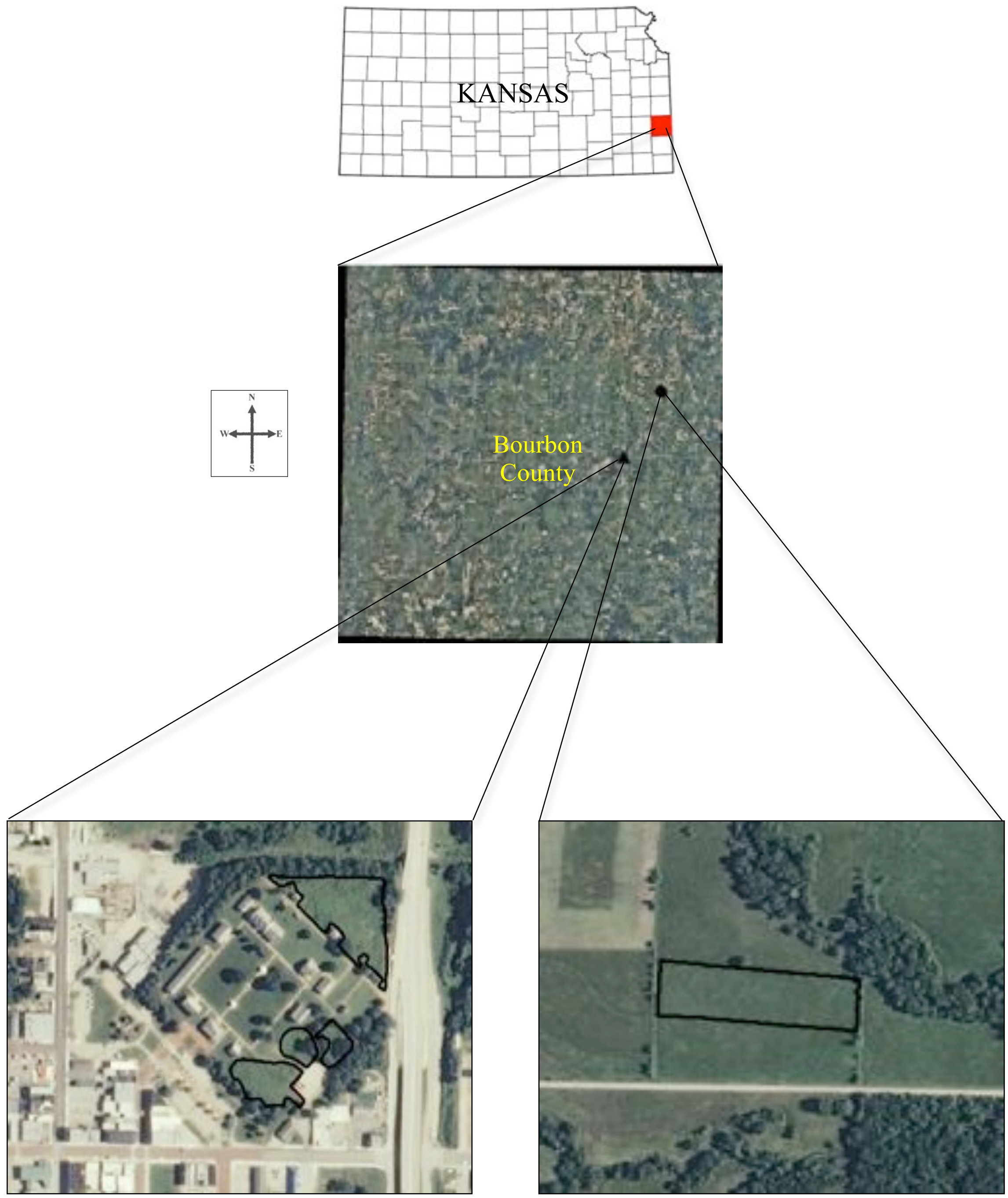

Figure 4. Bourbon County, KS. Location of study areas outlined. Fort Scott National Historic Site (bottom left) (lat. 37°50'N, long. 94°42'W). Native prairie remnant (bottom right) (lat. 37°55'N, long. 94°39'W).

240 m (787 ft). The restoration area is ca. 2 hectares (5 acres) and is sectioned into four units: A, B1, B2, and C. FOSC is surrounded on three sides by urban development, while the remaining northern side consists of a steep bluff, which overlooks the undeveloped Marmaton River flood plain (Bacon 1992; General 1993). Soils at the restored tallgrass prairie consist of the Clarson-Catoosa Association. This soil is "moderately deep, nearly level and gently sloping, well drained soils that have a silty clay and silty clay loam subsoil; on uplands." This association makes up about 15% of Bourbon County (Bell &Fortner 1981).

Native Tallgrass Prairie

The native tallgrass prairie, totals ca. 2 hectares (5 acres), is located in a rural area approximately 10 miles northeast of Fort Scott, KS on Range Rd. between 245th Street and 255th Street, SE ¼, sec. 27, T24S, R25E (lat 37°55'N, long 94°39'W), elevation ca. 255m (836 ft). The site is bordered to the North and West by fescue-dominated (*Schedonorus arundinaceus*) pasture, and to the East and South by native tallgrass prairie. Since 1998, this land has been used strictly for annual hay production. Haying is typically done the second or third week of July. Prescribed burning is also performed on a nearly annual basis. Burning typically takes place during the first or second week in April (communication with owner). For the purposes of this study a prescribed burn was performed on March 24, 2011, to coincide with the prescribed burn performed at the restored tallgrass prairie on March 24, 2011. Soils consist of the Zaar-Catoosa-Clareson Association. This soil is "deep to moderately deep, nearly level to strongly sloping, somewhat poorly drained and well drained soils that have a silty clay and silty clay loam subsoil; on uplands." This association makes up 45% of Bourbon County (Bell &Fortner 1981).

Study Design

Both qualitative walk-through and quantitative quadrat surveys were conducted. A random walk-through vegetation survey was performed at least every two weeks at both locations, beginning on March 20, 2011 and ending on October 30, 2011. The purpose of the walk-through survey was to identify all vascular flowering plants and to generate a complete species list for both sites.

Quadrat sampling was conducted along transects in June (18-28) and September (19-28), 2011. June and September sampling corresponds to the peak growth of both cool and warm season plant species in Kansas (Foster *et al.* 2007, Foster *et al*. 2009, Kindscher & Tieszen 1998). Species observed during quadrat sampling and walk-through surveys were combined to create a master list of species for both locations. Plants within quadrats were identified to species whenever possible.

Comparisons were made between the FOSC restored prairie and the native prairie using the species master lists and quadrat sampling data. The metrics used were species richness, percent of non-native species, percent cover, relative cover, frequency, relative frequency, importance values, floristic quality, and community similarity.

Since the FOSC restored tallgrass prairie is split into four smaller units, comparisons were made among the individual units. Because previous vegetation surveys were conducted at the FOSC restored tallgrass prairie a time-series comparison was made between the 2011 study and the 1997, 1993, and 1985 studies. Time-series comparisons show how the composition of the FOSC restored prairie has changed over time. A time-series comparison was not possible at the native tallgrass prairie remnant because this was the first year a vegetation survey was performed there.

Plant voucher specimens were collected, identified, and reviewed by Dr. Stephen L. Timme, Emeritus Professor of Botany and Director of the Theodore M. Sperry Herbarium, to ensure correct identification. Vouchers are stored in the T. M. Sperry Herbarium at Pittsburg State University. Nomenclature follows; Kansas Floristic Quality Assessment: Coefficients of Conservatism for Kansas plants, developed by C. Freeman, Kansas Biological Survey (Freeman 2002), accessed Oct. 26, 2010. This database has been updated regularly since it was originally created in 2002. In some cases, plants could only be identified to genera because they were not mature enough to key to species when collected.

Collection Methods

Sampling followed a systematic-random design, in which, randomly placed quadrats were positioned along systematically (evenly) spaced transects across the study areas. At FOSC, 117 quadrats were sampled in June and another 128 quadrats were sampled in September, resulting in 245 total quadrats (Figure 5). At the native tallgrass prairie remnant, 153 quadrats were sampled in June and another 153 quadrats were sampled in September, resulting in 306 total quadrats (Figure 6). Based upon species

Figure 5. Arial view of Fort Scott National Historic Site (FOSC) showing outline of prairie Units A, B1, B2, and C and location of quadrats.

Figure 6. Arial view of native prairie remnant showing outline of study area and location of quadrats.

area curves, this amount of sampling appeared to sufficiently represent the flora of both locations (Appendix 2). GPS points were taken to mark the exact location of each transect and quadrat. GPS points for transect locations at FOSC and the native prairie remnant is given in Appendix 3 and 4.

Baselines were established along the border of each location. These baselines served as the starting point for transect lines running perpendicular away from the baselines. Each transect was spaced 10 meters apart and parallel to one another. Nylon twine was laid out on the ground shortly after the prescribed burns to mark the exact location of transect lines. This twine made placement of quadrats much easier after the vegetation had grown. Transect lines were divided into 10 meter intervals starting at the baselines. White flags were used to mark the beginning/end of each 10-meter interval.

Within each interval, a 1 x ½ meter quadrat was placed using a random numbers table. For example, if a seven was selected from the random numbers table, then the quadrat for that interval was placed seven meters from the starting flag. Quadrats were centered on each transect and arranged with the longest (one meter) edge parallel to the transect line. The 1 x ½ meter rectangular quadrat was chosen because the 1:2 side ratio yields better results than other shapes for plant sampling (Brower *et al*. 1998). This is also the quadrat size used in the previous two studies conducted at FOSC, which aids in making comparisons. The quadrat frame was constructed from ½ inch PVC pipe.

Within each quadrat, cover estimates for all plant species were visually estimated and assigned to one of seven cover-value ranges of the modified Daubenmire cover scale (Bailey & Poulton 1968) (Table 1). Cover, defined as foliar cover, is the proportion of

Table 1. Modified Daubenmire cover class scale.

Cover Class	Cover Range (percent)	Class Midpoints (percent)
1	0-1	0.5
2	1-5	3.0
3	5-25	15.0
4	25-50	37.5
5	50-75	62.5
6	75-95	85.0
7	95-100	97.5

the ground within the quadrat occupied by the perpendicular projection to the ground from the outline of the aerial parts of the members of the plant species (Brower *et al*. 1998). Only plants rooted within the quadrat were used in making foliar estimates. To diminish an edge effect no quadrat sampling took place within one meter of the prairie borders.

Data Analysis

A one-way analysis of variance (ANOVA) using JMP 9.0 and the Tukey Honestly Significant Difference (HSD) procedure as a post-hoc test was used to compare species richness per quadrat among sites and seasons for all species as well as only native species (Jog *et al*. 2006; Kindscher & Tieszen 1998). ANOVA was used because these data were nearly normally distributed. Species richness and the percentage of non-native species were determined using the master list of species created for each study site. At FOSC, species were combined from all prairie units for an aggregate analysis of the site as well as analyzed individually. Based on the master lists, Sorensen's Coefficient of Community Similarity was used to compare spatial and time-series community similarity.

The Sorensen Coefficient of Community Similarity,

$$CC_s = \frac{2c}{s_1 + s_2}$$

where, s_1 and s_2 are the numbers of species in communities 1 and 2, c is the number of species common to both communities (Brower *et al*. 1998).

An overall comparison of floristic quality was made using the species master lists from both locations. The Floristic Quality Assessment Index (FQI), designed by Swink and Wilhelm (1979), offers a characterization of plant communities based upon the degree of species conservatism (Jog *et al*. 2006). Species conservatism is based on the premise that individual plant species display varying degrees of tolerance to disturbance and likewise varying degrees of fidelity to specific natural habitats (McIndoe *et al*. 2008). Based on this premise, coefficient of conservatism (CC) values were assigned to native Kansas species by the Kansas Biological Survey at the University of Kansas and obtained from C. Freeman (2002). CC values range from 0 to10; non-native species are not assigned a value. CC values ranging from 0 to 3 are assigned to generalist natives and species that are tolerant of high disturbances. These species are generally found in a variety of habitats. CC values ranging from 4 to 6 are assigned to species that are tolerant of moderate disturbance, meaning these species are often associated with remnant habitats. CC values ranging from 7 to 8 are assigned to species found in high quality remnant habitats. However, they may tolerate some disturbance from time to time. CC values ranging from 9 to 10 are restricted to only remnant habitats that have suffered very little post-settlement disturbance (Jog *et al*. 2006, Rothrock 2004). ANOVA using JMP 9.0 and the Tukey Honestly Significant Difference (HSD) procedure as a post-hoc test were used to compare FQI and mean CC values per quadrat among sites and seasons for native species (Jog *et al*. 2006).

FQI was calculated from the following formula,

$$\text{FQI} = R/\sqrt{N}$$

where, R= sum of coefficients of conservatism for all plants recorded in the area, and N= number of different native plants recorded (Jog *et al*. 2006).

The mean CC value was also calculated for each location.

$$\text{Mean CC}= \sum\left(c_1 + c_2 + c_3 + \ldots\ c_n\right)/N$$

where, c= CC value for each native species recorded in the area, and N= number of different native plants recorded.

Cover of native dominant species (species with cover greater than 5%) and plant cover by guild were compared among sites and seasons (Kindscher & Wells 1995; Kinsdcher & Tieszen 1998). The comparison of prairie plant guilds used methods established by Kindscher and Wells (1995) when they examined tallgrass prairies in northeast Kansas. They defined plant guilds as "groups of species with similar morphological, physiological, and ecological traits." Guilds may include many widely unrelated species, which have evolved to utilize the same environmental resources in a similar way (Kindscher & Wells 1995). Species were separated into one of eight guilds, by following the description of guild characteristics and guilds assigned to species by Kindscher and Wells (1995). Guild cover data was based on composite summations of individual species cover collected during June and September quadrat sampling. The eight guilds are: C_4 photosynthetic pathway (warm-season) grasses, C_3 photosynthetic pathway (cool-season) grasses and sedges, annual and biennial forbs, spring ephemeral forbs, spring forbs, summer/fall forbs, legumes, and woody shrubs (Kindscher & Wells 1995). The average percent cover for each guild at each location and season was standardized to 100% for comparisons.

Species richness, cover, relative cover, frequency, relative frequency, and importance values were calculated to summarize seasonal quadrat data. Species richness was defined as the number of species. Plant cover was calculated as the sum of cover values for a species divided by the total number of quadrats sampled in a season.

Relative cover was calculated as the cover of a species divided by the total cover for all species. Frequency was calculated as the number of quadrats a species occurred in divided by the total number of quadrats sampled during a season. Relative frequency was calculated as the frequency of a species divided by the total frequency for all species. Species importance values were calculated by summing the relative cover and relative frequency for a species and dividing by two (Brower *et al*. 1998).

A percentage of similarity comparison was made using relative cover values calculated from the June and September quadrat sampling (Brower *et al*. 1998). Relative cover for each species was used in place of species abundances or density. Percent similarity was used to spatially compare species similarity between the FOSC restored prairie and the native remnant prairie in June and September. A comparison was also made at each location between the June and September sampling efforts.

Percentage of similarity is defined as,

$$\text{PS} = \sum \left(lowest\ percentage\ for\ each\ species \right)$$

CHAPTER IV

RESULTS

General Descriptive Analysis

A total of 255 species were observed at both study locations, represented by 184 genera and 59 families (Appendix 5). Of these 255 species, 199 (78%) were native and 56 (22%) were non-native. Families represented by the most number of species were Asteraceae (44), Poaceae (37), Fabaceae (33), and Cyperaceae (10). The largest genera were *Asclepias* and *Helianthus* each with six species, followed by *Carex* with five species. Plants were identified to species; however, in some cases plants could only be identified to genera because they were immature when observed.

Overall species richness was 187 at the Fort Scott National Historic Site (FOSC) restored prairie, represented by 144 genera and 50 families (Appendix 5). Of these 187 species, 141 (75%) were native and 46 (25%) were non-native. Of the 187 total species, 79 were not found in either June or September quadrat sampling (Appendix 6). Two of the non-native species are considered noxious weeds in Kansas: *Convolvulus arvensis* (field bindweed) and *Sorghum halepense* (Johnson grass) (United States Department of Agriculture 2003). Twenty-seven woody species were observed: 21 native and six non-native. The overall Floristic Quality Assessment Index (FQI) was 34.5 with a mean Coefficient of Conservatism (CC) of 2.9 (Table 2).

Table 2. Comparison of overall species richness, native species richness, percentage (%) of native species, number of non-native species, percentage (%) of non-native species, number of species not found during quadrat sampling, number of genera, number of families, number of noxious species, number of woody species, floristic quality assessment index (FQI), and mean coefficient of conservatism (CC) at the Fort Scott National Historic Site (FOSC) restored prairie and a native prairie remnant in 2011.

	FOSC restored prairie	**Native prairie remnant**
Overall species richness	187	134
Native species richness	141	118
% native species	75	88
No. of non-native species	46	16
% non-native species	25	12
No. of species not found in quadrats	79	52
No. of genera	144	103
No. of families	50	38
No. of noxious species	2	0
No. of woody species	27	6
FQI	34.5	46.7
Mean CC	2.9	4.3

Families represented by the most number of species were Asteraceae (36), Poaceae (27), Fabaceae (19), Euphorbiceae (7), and Liliaceae (7).

Overall species richness was 134 at the native tallgrass prairie remnant, represented by 103 genera and 38 families (Appendix 5). Of these 134 species, 118 (88%) were native and 16 (12%) were non-native. Of the 134 total species, 52 were not found in either June or September quadrat sampling (Appendix 6). Six native woody species were observed, all of which occurred in low frequency with the exception of *Amorpha canescens* (lead plant), which is a species characteristic of tallgrass prairies (Jog *et al*. 2006). The overall FQI was 46.7 with a mean CC of 4.3 (Table 2). Families represented by the most number of species were Poaceae (22), Fabaceae (19), Asteraceae (19), and Cyperaceae (8).

Species with CC values of four or lower (excluding non-natives) comprise 74% of all species at FOSC. Species with CC values of four or lower (excluding non-natives) comprise 51% of all species at the native prairie remnant. Species with CC values of five and higher comprise only 26% of species at FOSC restored prairie, but total 49% of species at the native prairie remnant (Table 3). *Buchnera americana* (American bluehearts) and *Asclepias meadii* (Mead's milkweed), occurring only in the remnant prairie, were the most conservative species with CC values of nine and 10. *Carex bicknellii* (Bicknell's sedge) and *Sporobolus heterolepis* (prairie dropseed) were the most conservative species at FOSC with CC values of eight, both species were also found in the native remnant prairie.

A total of 65 species were common between study locations (59 native and 6 non-native) resulting in a species level Sorensen Coefficient of Community Similarity of

Table 3. Coefficient of Conservatism (CC) tallies for Fort Scott National Historic Site (FOSC) restored tallgrass prairie and the native tallgrass prairie remnant.

CC values	FOSC restored prairie CC tallies	Native prairie remnant CC tallies
Non-native	46	16
0	25	7
1	23	12
2	19	10
3	20	15
4	18	15
5	13	18
6	11	15
7	10	14
8	2	9
9	0	1
10	0	1

40.6%. A total of 63 genera were common to both locations, resulting in a genera level Sorenson Coefficient of Community Similarity of 51.0%. A total of 31 families were common to both locations, resulting in a family level Sorenson Coefficient of Community Similarity of 70.5%. An increase in community similarity is expected as species are grouped into higher taxonomic levels.

Descriptive Analysis of June Quadrats

In the 117 quadrats sampled at the FOSC restored prairie in June 99 taxa were recorded (Appendix 7). Of these 99 taxa, 75 (76%) were native and 24 (24%) were non-native. Taxa richness within quadrats ranged from 2-15 species with a mean of nine species. Seven plants could only be identified to genera: *Carex, Helianthus, Oenothera, Symphyotrichum, Trifolium, Viola,* and *Vitis.* The five most frequently encountered species within quadrats were *Andropogon gerardii* (big bluestem) (56%), *Euphorbia dentata* (toothed spurge) (47.9%), and *Ambrosia trifida* (giant ragweed) (47%), *Solanum carolinense* (Carolina horsenettle) (43.6%), and *Helianthus maximilianii* (Maximilian's sunflower) (30.8%) (Table 4). Importance values for the FOSC restored prairie show *A. gerardii* with the highest importance, followed by *A. trifida*, *H. maximilianii, Solidago altissima* (tall goldenrod), and *S. carolinense* (Table 5).

Differences in cover were observed among dominant species (species with at least 5% cover) at the FOSC restored prairie (Table 6). The C_4 grass, *A. gerardii*, dominated the FOSC prairie, which accounts for 19.1% of the total cover. Forbs with the largest cover were *H. maximilianii*, *A. trifida*, and *S. altissima*, which accounted for

Table 4. Percent frequency of species occurring in at least 20% of quadrats at Fort Scott National Historic Site (FOSC) restored prairie and a native prairie remnant in June and September 2011.

	FOSC restored prairie (% frequency)		**Native prairie (% frequency)**	
Species	*June*	*September*	*June*	*September*
Acalphya virginica	0.0	35.2	0.0	0.0
Agrostis hyemalis	0.0	0.0	27.5	0.0
Ambrosia artemisiifolia	24.8	25.0	0.0	0.0
Ambrosia trifida	47.0	39.1	0.0	0.0
Andropogon gerardii	56.4	65.6	95.4	96.1
Antennaria neglecta	0.0	0.0	39.2	33.3
Carex spp.	20.5	22.7	66.0	55.6
Cirsium altissimum	23.1	0.0	0.0	0.0
Convolvulus arvensis	20.5	0.0	0.0	0.0
Croton monanthogynus	0.0	27.3	0.0	0.0
Desmodium sessilifolium	0.0	0.0	22.2	0.0
Dichanthelium oligosanthes	0.0	0.0	86.9	88.9
Eleocharis spp.	0.0	0.0	68.0	0.0
Erigeron strigosus	0.0	0.0	81.7	45.1
Eupatorium altissimum	0.0	28.1	0.0	0.0
Euphorbia dentata	47.9	0.0	0.0	0.0
Geranium carolinianum	26.5	0.0	0.0	0.0
Helianthus maximilianii	30.8	28.1	0.0	0.0
Helianthus mollis	0.0	0.0	47.7	45.8
Oxalis spp.	0.0	0.0	22.2	0.0
Panicum virgatum	22.2	36.7	0.0	0.0
Penstemon digitalis	0.0	0.0	20.9	0.0
Physalis longifolia	22.2	0.0	0.0	0.0
Polygala sanguinea	0.0	0.0	64.7	0.0
Potentilla simplex	0.0	0.0	47.7	24.8
Pycnanthemum tenuifolium	0.0	0.0	35.9	38.6
Ruellia humilis	0.0	0.0	75.8	54.9
Schizachyrium scoparium	0.0	0.0	60.8	79.7
Solanum carolinense	43.6	0.0	0.0	0.0
Solidago altissima	25.6	21.1	0.0	0.0
Sorghastrum nutans	20.5	0.0	38.6	59.5
Strophostyles leiosperma	0.0	0.0	34.0	0.0
Tripsacum dactyloides	0.0	0.0	50.3	48.4
Viola pedata	0.0	0.0	28.1	0.0

Table 5. Species with the 10 highest importance values at Fort Scott National Historic Site (FOSC) restored prairie and a native remnant prairie in June and September 2011.

	FOSC restored prairie		**Native prairie**	
Species	*June*	*September*	*June*	*September*
Acalphya virginica	0.000	0.031	0.000	0.000
Ambrosia artemisiifolia	0.026	0.042	0.000	0.000
Ambrosia trifida	0.055	0.064	0.000	0.000
Andropogon gerardii	0.107	0.147	0.207	0.242
Bromus inermis	0.000	0.033	0.000	0.000
Carex spp.	0.030	0.000	0.033	0.036
Dichanthelium oligosanthes	0.000	0.000	0.042	0.061
Eleocharis spp.	0.000	0.000	0.041	0.000
Erigeron strigosus	0.000	0.000	0.040	0.029
Eupatorium altissimum	0.000	0.046	0.000	0.000
Euphorbia dentata	0.032	0.000	0.000	0.000
Helianthus maximilianii	0.051	0.055	0.000	0.000
Helianthus mollis	0.000	0.000	0.000	0.061
Hieracium longipilum	0.000	0.000	0.044	0.000
Panicum virgatum	0.000	0.055	0.000	0.000
Pycnanthemum tenuifolium	0.000	0.000	0.000	0.029
Ratibida pinnata	0.000	0.027	0.000	0.000
Ruellia humilis	0.000	0.000	0.031	0.036
Schedonorus arundinaceus	0.026	0.000	0.000	0.000
Schizachyrium scoparium	0.000	0.000	0.088	0.120
Solanum carolinense	0.034	0.000	0.000	0.000
Solidago altissima	0.042	0.044	0.000	0.000
Sorghastrum nutans	0.024	0.000	0.027	0.082
Tripsacum dactyloides	0.000	0.000	0.065	0.078

Table 6. Percent cover of native species with at least 5% cover at Fort Scott National Historic Site (FOSC) restored prairie and a native remnant prairie in June and September 2011.

	FOSC restored prairie (% cover)		**Native prairie (% cover)**	
Species	*June*	*September*	*June*	*September*
Ambrosia artemisiifolia	0.0	5.1	0.0	0.0
Ambrosia trifida	7.3	7.3	0.0	0.0
Andropogon gerardii	19.1	20.8	44.0	46.0
Eupatorium altissimum	0.0	5.4	0.0	0.0
Helianthus maximilianii	8.5	7.2	0.0	0.0
Helianthus mollis	0.0	0.0	10.0	8.8
Panicum virgatum	0.0	5.8	0.0	0.0
Schizachyrium scoparium	0.0	0.0	16.7	18.7
Solidago altissima	7.1	6.1	0.0	0.0
Sorghastrum nutans	0.0	0.0	0.0	12.1
Tripsacum dactyloides	0.0	0.0	11.8	12.4

8.5%, 7.3%, and 7.1% of the total cover. The legume with the largest cover (also a forb) was *Securigera varia* (crown vetch), at 2.8% of the cover. *S. varia* is a non-native species and can become invasive. Appendix 8 lists the complete cover matrix for all taxa observed at FOSC during June quadrat sampling.

A comparison of guilds using native species revealed summer/fall forbs and annuals were the dominant guilds at FOSC in June, with 46.5% and 21.1% of the total cover. Woody shrubs and C_4 grasses made up 10.7% and 10% of the total cover. C_3 grasses and sedges totaled 6.1%, followed by legumes (2.6%), spring forbs (2.5), and spring ephemeral forbs with the least amount of cover at 0.4% (Table 7).

In the 153 quadrats sampled at the native prairie in June, 84 taxa were recorded (Appendix 9). Of these 84 taxa, 75 (89%) were native and nine (11%) were non-native. Taxa richness within quadrats ranged from 5-20 species with a mean of 13 species. Ten plants could only be identified to Genus: *Bolboschoenus, Carex, Cyperus, Eleocharis, Juncus, Oxalis, Physalis, Plantago, Rubus,* and *Vernonia*. The five most frequently encountered species within quadrats were *A. gerardii* (95%), *Dichanthelium oligosanthes scribnerianum* (Scribner's dichanthelium) (86.9%), *Erigeron strigosus* (daisy fleabane) (81.7%), *Ruellia humilis* (hairy wild petunia) (75.8%), and *Eleocharis spp*. (spike rush) (68%) (Table 4). Importance values for the native remnant prairie show *A. gerardii* with the highest importance, followed by *Schizachyrium scoparium* (little bluestem), *Tripsacum dactyloides* (eastern gama grass), *Hieracium longipilum* (long-beard hawk-weed), and *D. oligosanthes scribnerianum* (Table 5).

Table 7. Average percent cover (standardized to 100%) for native plant guilds for the areas sampled at the Fort Scott National Historic Site (FOSC) restored prairie and a native prairie remnant in June and September 2011.

	FOSC restored prairie (% cover)		**Native prairie (% cover)**	
Guild	*June*	*September*	*June*	*September*
Woody shrub	10.7	4.7	0.2	0.2
Legume	2.6	0.4	6.4	2.8
Annual forb	21.1	19.7	4.8	1.2
Spring ephemeral forb	0.4	0.1	0.5	0.2
Spring forb	2.5	1.6	8.6	4.4
Summer/fall forb	46.5	30.9	11.4	11.1
C_3 grass & sedge	6.1	3.5	7.8	4.9
C_4 grass	10.0	39.0	60.3	75.2

The native prairie was dominated by C_4 grasses, *A. gerardii*, *S. scoparium*, and *T. dactyloides*, which account for 44%, 16.7%, and 11.8% of the total cover. The forb with the largest cover was *Helianthus mollis* (ashy-leaf sunflower), with 10% of the total cover (Table 6). The legume with the greatest cover was *Psoralidium tenuiflorum* (scurfy pea), at 2.3% of the cover. Appendix 10 lists the complete cover matrix for all taxa observed at the native prairie remnant during June quadrat sampling.

A comparison of guilds using native species reveals C4 grasses and summer/fall forbs were the dominant guilds at the native prairie remnant in June, with 60.3% and 11.4% of the total cover. Spring forbs and C_3 grasses and sedges made up 8.6% and 7.8% of the total cover. Legumes totaled 6.4% followed by annuals (4.8%), spring ephemeral forbs (0.5%), and woody shrubs with the least amount of cover at 0.2% (Table 7).

Descriptive Analysis of September Quadrats

In the 128 quadrats sampled at the FOSC restored prairie in September, 91 taxa were recorded (Appendix 11). Of these 91 taxa, 72 (79%) were native and 19 (21%) were non-native. Taxa richness within quadrats ranged from 2-13 species with a mean of seven species. Eight plants could only be identified to Genus: *Carex, Chamaesyce, Oxalis, Paspalum, Rubus, Symphyotrichum, Viola,* and *Vitis*. The six most frequently encountered species within quadrats were *A. gerardii* (65.6%), *A. trifida,* (39.1%), *Panicum virgatum* (switch grass) (36.7%), *Acalypha virginica* (Virginia copperleaf) 35.2%), *Eupatorium altissimum* (tall joe-pye-weed) (28.1%), and *H. maximilianii* (28.1%) (Table 4). Importance values for the FOSC restored prairie show *A. gerardii* with the highest importance, followed by *A. trifida, P. virgatum, H. maximilianii,* and *E. altissimum* (Table 5).

The C_4 grass, *A. gerardii*, at 20.8% of the total cover, dominated the FOSC prairie. Forbs with the largest cover were *A. trifida*, *H. maximilianii*, and *S. altissima*, which account for 7.3%, 7.2%, and 6.1% of the total cover (Table 6). The legume with the largest cover was *Melilotus officinalis* (yellow sweet clover), at 0.32% of the cover. *M. officinalis* is a non-native species and can become invasive. Appendix 12 lists the complete cover matrix for all taxa observed at FOSC during September quadrat sampling.

A comparison of guilds using native species reveals C_4 grasses and summer/fall forbs were the dominant guilds at FOSC in September, with 39.0% and 30.9% of the total cover. Annuals and woody shrubs made up 19.7% and 4.7% of the total cover. C_3 grasses and sedges totaled 3.5%, followed by spring forbs (1.6%), legumes (0.4%), and spring ephemeral forbs with the least amount of cover at 0.1% (Table 7).

In the 153 quadrats sampled at the native prairie in September, 60 taxa were recorded (Appendix 13). Of these 60 taxa, 56 (93%) were native and four (7%) were non-native. Taxa richness within quadrats ranged from 4-16 species with a mean of nine species. Five plants could only be identified to Genus: *Carex, Eleocharis, Oxalis, Rubus,* and *Vernonia*. The five most frequently encountered species within quadrats were *A. gerardii* (96.1%), *D. oligosanthes scribnerianum* (88.9%), *S. scoparium* (79.7%), *Sorghastrum nutans* (Indian grass) (59.5%), and *Carex spp*. (sedge) (55.6%) (Table 4). Importance values for the native remnant prairie show *A. gerardii* with the highest importance, followed by *S. scoparium, S. nutans, T. dactyloides,* and *H. mollis* (Table 5).

The native prairie was dominated by C_4 grasses, *A. gerardii*, *S. scoparium*, *T. dactyloides*, and *S. nutans*, which account for 46%, 18.7%, and 12.4%, and 12.1% of the total cover. The forb with the largest cover was *H. mollis*, at 8.8% of the total cover (Table 6). The legume with the most cover was *Baptisia bracteata* (cream wild indigo), at 1.3% of the cover. Appendix 14 lists the complete cover matrix for all taxa observed at the native prairie remnant during September quadrat sampling.

A comparison of guilds using native species reveals C_4 grasses and summer/fall forbs were the dominant guilds at the native prairie remnant in September, with 75.2% and 11.1% of the total cover. C_3 grasses and sedges and spring forbs made up 4.9% and 4.4% of the total cover. Legumes totaled 2.8% followed by annuals with 1.2%. Spring ephemeral forbs and woody shrubs had the least amount of cover at 0.2% (Table 7).

Seasonal Trends and Comparisons

Species richness decreased from June to September in both study sites, with greater decreases found in the native prairie than at FOSC. Species richness among sites and seasons and their interaction differ significantly ($P \leq 0.0001$) (Table 8). Both study areas had significantly higher ($P \leq 0.0001$) species richness in June than September. Species richness at the native prairie in June was significantly higher ($P \leq 0.0001$) than any other treatment, while species richness at the FOSC restored prairie in September was significantly lower ($P \leq 0.0001$) than any other treatment. No significant difference was found between the FOSC restored prairie in June and the native prairie in September. Comparisons of species richness using only native species were consistent with

Table 8. Comparison of species richness at Fort Scott National Historic Site restored prairie and a native prairie remnant in June and September 2011. Numbers not connected by the same letter are significantly different (all species, $P \leq 0.0001$) (native species only, $P \leq 0.0004$).

Location & season	Species Richness (all species)				Species Richness (natives only)				
Native prairie, June	13.424837	A			10.967320	A			
Native prairie, Sept.	9.274510		B		8.104575		B		
FOSC, June	8.871795		B		6.717949			C	
FOSC, Sept.	6.539062			C	5.281250				D

comparisons of total species richness. Species richness of only native species was significantly different among all treatments ($P \leq 0.0004$) (Table 8).

The Floristic Quality Assessment Index (FQI) among sites and seasons and their interaction differ significantly ($P \leq 0.0001$) (Table 9). The FQI in the native prairie in June is significantly higher than any other treatment, while the FQI at the native prairie in September is significantly higher than any FOSC season. FQI decreased significantly ($P \leq 0.0001$) from June to September at the native prairie, but increased slightly, although not significantly, from June to September at the FOSC restored prairie. Mean coefficient of conservatism (CC) values differ significantly ($P \leq 0.0044$) among sites and seasons, but not between seasons at the FOSC restored prairie or the native prairie. Mean CC values decreased slightly from June to September at the native prairie, but increased slightly from June to September at FOSC. Neither decrease nor increase in CC values between seasons was significant (Table 9).

Andropogon gerardii was the only dominant species (cover greater than 5%) found occurring in both locations (Table 6). Aside from *A. gerardii,* there were no other dominant species common to both locations in June or September. Cover of *A. gerardii* increased slightly from June to September at both locations, with an overall mean cover of 45% at the native prairie compared to 20% at FOSC. The cover of *A. gerardii* at the native prairie was double that of the FOSC restored prairie during each season. Overall, the native prairie had nearly double the coverage of dominant species compared to the FOSC restored prairie.

Major differences in cover by guild were observed between study areas (Table 7). The percentage of C_4 grasses exceeded all other guilds combined in both seasons at the

Table 9. Comparison of Floristic Quality Assessment Index (FQI) and mean coefficient of conservatism (CC) values at the Fort Scott National Historic Site restored prairie and a native prairie remnant in June and September 2011. Numbers not connected by the same letter are significantly different (FQI, $P \leq 0.0001$), (mean CC, $P \leq 0.0044$).

Location & season	**FQI**		**Mean CC**	
Native prairie, June	14.469475	A	4.4198652	A
Native prairie, Sept.	12.040273	B	4.2476899	A
FOSC, Sept.	5.215238	C	2.3435972	B
FOSC, June	4.492182	C	2.0430226	B

native prairie. In contrast, C_4 grasses made up only 10% of the total guild cover in June and 39% of the total in September at the FOSC restored prairie. Woody shrubs had the lowest guild cover at the native prairie, with less than half a percent in either season, but made up nearly 11% and 5% of total guild cover in June and September at FOSC. The decline in woody shrubs from June to September at FOSC is likely the result of management activities designed to eliminate woody species, which occurred between sampling seasons. Spring ephemeral forbs represented the lowest cover of any guild at FOSC in both seasons. Legumes, an important species for adding nitrogen to soil, had double the guild cover in June and seven times the guild cover in September at the native prairie than the FOSC restored prairie. Annual and summer/fall forbs had much higher guild cover in both seasons at FOSC than the native prairie, while spring forbs had higher guild cover at the native prairie than FOSC. Spring ephemeral forbs and C_3 grasses and sedges had similar guild cover between study sites and seasons. Seasonal trends were observed at both locations in which the C_4 grass guild increased from June to September, while all other guilds decreased in cover or remained unchanged from June to September.

The percentage of similarity was calculated between locations and seasons using relative cover values. There was a 24% similarity in June and a 27% similarity in September between locations. A comparison of sampling seasons at FOSC shows a 65% similarity, with the native prairie showing a 72% similarity between the June and September samplings.

FOSC Unit Comparisons

The FOSC restored prairie was divided into three sections: Units A, Unit B, and Unit C. Unit B was composed of two smaller units called B1 and B2, which are managed and treated as one unit. A species list for each unit can be found in Appendix 15. Unit A had an overall species richness of 144. Of these 144 species, 113 (78%) were native and 31 (22%) were non-native. The FQI was 31.5 with a mean CC of 3.0. Unit B had an overall species richness of 110. Of these 110 species, 79 (72%) were native and 31 (28%) were non-native. The FQI was 22.1 with a Mean CC of 2.5. Unit C had an overall species richness of 77. Of these 77 species, 54 (70%) were native and 23 (30%) were non-native. The FQI was 17.6 with a mean CC of 2.4 (Table 10).

A comparison of Units A, B (B1 and B2), and C revealed no significant differences in species richness (all taxa or natives only) among units in June or September. This is not surprising since the units were started with similar seed mixtures, at nearly the same time, within close proximity to one another, and are managed uniformly. Species richness (all taxa) of Units A, B, and C were significantly higher in June than in September. Unit B had significantly higher species richness (natives only) in June than in September, while Units A and C experienced declines in native species richness from June to September, but not significantly.

No significant differences were found in FQI among Units A, B (B1 and B2), and C in June or September, with the exception of Unit C, which had significantly higher FQI in September than Unit B1 in September. Unit C experienced significantly higher FQI in September than in June. Units A and B (B1 and B2) also had higher FQI in September

Table 10. Comparison of overall species richness, native species richness, percentage (%) of native species, number of non-native species, percentage (%) of non-native species, floristic quality assessment index (FQI), and mean coefficient of conservatism (CC) at the Fort Scott National Historic Site restored prairie, Unit A, Unit B, and Unit C in 2011.

	Unit A	**Unit B**	**Unit C**
Overall species richness	144	110	77
Native species richness	113	79	54
% native species	78	72	70
No. of non-native species	31	31	23
% non-native species	22	28	30
FQI	31.5	22.1	17.6
Mean CC	3.0	2.5	2.4

than June, but not significantly. Mean CC was not significantly different among units in June or September. Unit C had significantly higher mean CC in September than in June, while Units A and B did not show significant seasonal differences in mean CC.

Unit A, the largest of the FOSC prairie units, had the highest species richness, highest number of native species, lowest number of non-native species, and the highest FQI and mean CC values. The larger size of this unit may explain some of these findings, however, another factor could provide the more likely answer. In 1995, 0.58 hectares (1.43 acres) of native prairie sod was transplanted into Unit A, but not Units B or C. Aside from this difference, similar management practices have been used uniformly across all three units. Having native prairie transplanted into Unit A increased species richness and the number of native species. Native prairie species likely contributed to higher FQI and mean CC values.

Community similarity was calculated between units using Sorensen's Coefficient of Community Similarity. Sorenson's Coefficient shows the greatest similarity between Units A and B at 59.8%, followed by Units B and C at 56.7%, and Units A and C at 55.2%. Species migrating from Unit A into B could explain the closer similarity between these two units. Another explanation is that Units A and B were both started during the 1979 seeding, while Unit C was started in 1984. Taxa frequency, relative frequency, cover, relative cover, and importance values were calculated for each FOSC unit in June and September (Appendix 16-25).

FOSC Historic Comparisons

Initially, 13 native species were seeded to begin the FOSC restoration in 1979. The 1985 vegetation survey records a species richness of 66. Of these 66 species, 41 (62%) were native and 25 (38%) were non-native. The 1993 vegetation survey records a species richness of 110. Of these 110 species, 71 (65%) were native and 39 (35%) were non-native. The 1997 vegetation survey records a species richness of 143. Of these 143 species, 114 (80%) were native and 29 (20%) were non-native. The 2011 vegetation survey records a species richness of 187. Of these 187 species, 141 (75%) were native and 46 (25%) were non-native (Table 11).

FQI and mean CC values were calculated for the survey years 1985, 1993, 1997, and 2011, as well as the initial seeding in 1979 (Table 10). The highest possible mean CC value is 10.0; this would occur only in a community where all species had CC values of 10.0. FQI values depend on native species richness in addition to CC values. A community with a species richness of three, each with CC values of 10 would have a much lower FQI value than a community with 30 species, each with CC values of 10. This was apparent in 1979 when mean CC values were highest for all years (4.5); however, the FQI was only 16.4, due to low species richness in the initial planting of 13 native species. A survey was not completed in 1979; therefore, only the initial 13 species were taken into account in making the FQI and mean CC calculations.

Sorensen's Coefficient of Community Similarity was calculated for the sampling years 1985, 1993, 1997, and 2011, as well as, the initial 1979 seeding (Table 12). The overall trend is a decrease in community similarity as the restoration increased in

Table 11. Comparison of overall species richness, native species richness, percentage (%) of native species, number of non-native species, percentage (%) of non-native species, Floristic Quality Assessment Index (FQI), and mean coefficient of conservatism (CC) at Fort Scott National Historic Site restored tallgrass prairie in 1979, 1985, 1993, 1997, and 2011.

	1979	**1985**	**1993**	**1997**	**2011**
Overall species richness	13	66	110	143	187
Native species richness	13	41	71	114	141
% native species	100	62	65	80	75
No. of non-native species	0	25	39	29	46
% non-native species	0	38	35	20	25
FQI	16.4	14.5	21.8	36.2	34.5
Mean CC	4.5	2.3	2.6	3.4	2.9

Table 12. Sorenson's coefficient of community similarity at Fort Scott National Historic Site restored tallgrass prairie in 1985, 1993, 1997, and 2011.

Year	**1985**	**1993**	**1997**	**2011**
1979	17.7	13.0	14.1	12.0
1985		45.5	23.9	38.7
1993			48.2	43.8
1997				52.7

age. Exceptions to this trend occur between 1979 and 1993 and between 1985 and 1997. The probable explanation for the drop in similarity between 1985 and 1997 is once again the influx of native species from the 1995 sod transplant, resulting in a greater than expected difference in similarity. Different community similarity values from one survey to another indicate that the restored prairie is changing over time.

CHAPTER V

DISCUSSION

General Comparisons

There was significantly higher total species richness and total native species richness in the native prairie remnant than the FOSC restored prairie during both sampling seasons. These results are consistent with those of Allison (2002), Jog *et al*. (2006), Kindscher & Tieszen (1998), Kuchrik *et al*. (2006), Martin *et al*. (2005), Polley *et al*. (2005), and Sluis (2002), who found lower species richness in restored tallgrass prairies than native prairie remnants. The FOSC restored prairie averaged between five and seven native species per quadrat, which was similar to the seven to nine native species found in plots in a northeast Kansas restored prairie (Piper *et al*. 2007). The native prairie remnant averaged between eight and 11 native species per quadrat. Lower total native species richness at the FOSC restored prairie could be a result of the original seeding mixture lacking many of the species found in the native prairie.

Non-native species comprised 25% of the total species richness observed at the FOSC restored prairie, which was double the amount observed at the native prairie remnant. This is consistent with findings by Martin *et al*. (2005), which showed double the number of exotic species in a restored tallgrass prairie compared to three remnant prairies in southern Iowa. Several reasons could contribute to higher numbers of non-native species at the FOSC restored prairie. (1) Soil disturbances, which have occurred since the construction of Fort Scott, provide many opportunities for non-native invaders to find a foothold. (2) Invasion of non-natives into the FOSC prairie units is made easier by the fragmented design of the restored prairie. (3) Management practices designed to eliminate or reduce non-native species have not been consistently practiced.

Andropogon gerardii (big bluestem) had the greatest cover of any species at both study areas and was the only dominant species common to both study areas in either sampling season. Dominance of *A. gerardii* in tallgrass prairie has also been found within the Flint Hills of Kansas at the Konza Prairie (McCain *et al*. 2010) and in several native prairie remnants within northeast Kansas (Jog *et al*. 2006; Kindscher & Tieszen 1998; Kindscher & Wells 1995). The dominance of *A. gerardii* within multiple prairie remnants in Kansas provides strong support for *A. gerardii* being the dominant species within the FOSC restored prairie.

Other dominant grass species found within the native prairie remnant include: *Schizachyrium scoparium* (little bluestem), *Sorghastrum nutans* (Indian grass), and *Tripsacum dactyloides* (eastern gama grass), all of which have been reported as dominant species within several native prairie remnants within northeast Kansas (Jog *et al*. 2006; Kindscher & Tieszen 1998; Kindscher & Wells 1995). These species are all present within the FOSC restored prairie but have much lower coverage than other native Kansas prairies. Kindscher and Tieszen (1998) proposed the possibility that restored prairies could reach an alternative stable state, which differs from native remnant prairies in terms of plant species composition. This could be happening at FOSC; however, given the highly dynamic nature of the FOSC prairie this might not be the case. The FOSC prairie could still be experiencing a great deal of colonization and succession.

Most of the species richness and diversity found in tallgrass prairie is due to the large numbers of forb species, so it was not surprising to see a trend in which seasonal decreases in forb guilds corresponded to decreases in species richness from June to September at both locations. Declines in all plant guilds were observed among seasons, except C_4 grasses, which increased from June to September at both locations. The C_4 grass guild comprised only 10% of the total cover at FOSC in June, compared to 60% at the native prairie in June. C_4 grasses did increase to 39% at FOSC by September but this was still much lower than the 75% observed at the native prairie in September. Kindscher and Wells (1995) observed C_4 grass guild coverage between 49 and 66% at three native remnant prairies in June in northeast Kansas. The similarity between C_4 grass guilds in the study by Kindscher and Wells (1995) and the native prairie in this study suggest the C_4 grass guild at the FOSC restored prairie have not reached levels comparable to those currently found in Kansas tallgrass prairies.

Written accounts of the prairie around Fort Scott in the 1840s indicate a high number of forbs, which seems to justify the high percentage of cover in the summer/fall forb guild. The summer/fall forb guild had 46.5% cover in June and 31% cover in September, which was much higher than the 11% found at the native prairie remnant in both seasons. However, Kindscher and Wells (1995) point out that species within the spring forb guild comprise most of the showy wildflower bloom that characterizes prairies. It is possible that the early accounts of the numerous wildflowers in the prairie around Fort Scott were describing spring forbs and not summer/fall forbs. The spring forb guild at FOSC in June totaled 2.5% compared to 8.6% found at the native prairie in

June or the 13.9% reported by Kindscher and Wells (1995) in June, which was aggregate data from three prairies.

The legume guild has the greatest coverage at both study areas in June, with 2.6% at FOSC and 6.4% at the native prairie. Kindscher and Wells (1995) report 7% cover of legumes at the prairies they studied. Lower coverage of legumes was reported in restored prairies by Kindscher and Tieszen (1998) compared to native prairies in northeast Kansas. They concluded that the absence of native legumes in the restored prairies could significantly delay the recovery of those systems. The coverage of annuals at FOSC was nearly consistent throughout the growing season with 21% coverage in June and 20% in September. This was much higher than the 5% in June and 1.2% in September observed in the native prairie studied. Kindscher and Wells (1995) reported a 3.5% cover of annuals in June at a native remnant prairie in northeast Kansas, which is managed by annual haying each year. Woody shrubs had much higher coverage at FOSC than the native prairie in both seasons. The invasion of woody species into the FOSC prairie is likely due to the same reasons previously given for the high numbers of non-native species in the restored prairie. Cover amounts of spring ephemeral forbs and C_3 grasses and sedges were similar at both study areas in both seasons.

The FOSC restored prairie had a lower Floristic Quality Assessment Index (FQI) and mean coefficient of conservatism (CC) value than the native prairie remnant. This result was not surprising given the numerous species with low CC values found at FOSC compared to the native prairie remnant. The FOSC restored prairie had an overall FQI of 34.5, which was higher than the average FQI of 32 reported by Jog *et al*. (2006) when studying 20 native prairie remnants in northeast Kansas. The highest FQI of any native prairie reported by Jog *et al*. (2006) was 41, which was lower than the FQI of 46.7 found at the native prairie in this study.

Asclepias meadii (Mead's milkweed), observed at the native prairie remnant is a federally threatened species, known to be extant only in Iowa, Illinois, Kansas, and Missouri, with most populations in eastern Kansas. Habitat loss and modification are cited as the greatest threat to this species (U.S. Fish and Wildlife Service 2003). Identification of *A. meadii* at the native prairie remnant was confirmed using photographs by Dr. Craig Freeman, Curator of the R.L. McGregor Herbarium at the University of Kansas. The presence of *A. meadii*, along with high overall FQI, indicates the need to preserve this native prairie remnant.

The native prairie showed a seasonal trend of significantly higher FQI in June than September. The decrease in FQI at the native prairie could be attributed to current management practices that involve annual haying in mid-July. Haying at the same time each year prevents many species from completing their reproductive cycles. The prevention of sexual reproduction results in an altered population structure and reduction in genetic diversity (U.S. Fish and Wildlife Service 2003). Even though haying did not occur during the year of this study it had occurred annually during the previous 14 years, and probably much longer. The FOSC restored prairie showed an opposite trend, in which FQI increased from June to September, but not significantly.

A noticeable difference between the FOSC restored prairie and the native prairie remnant is how intermingled species were at the native prairie, with many species occupying a small space. In contrast, species at FOSC had a more clumped distribution, in some places forming almost complete monocultures of species. This was evident when comparing species richness within quadrats, which was significantly higher at the native prairie remnant than FOSC. The tendency of native prairies to be more intermingled, while restored prairies have more clumped distributions was also observed by Allison (2002) when studying a restored prairie and two native prairies in Illinois. The reason for the clumped distribution at FOSC is unclear. However, it could be attributed to how the prairie was originally seeded.

The FOSC sod transplant project offers an interesting look at species establishment and migration. Portions of a local native prairie were transplanted into Unit A near the walking path in 1995. According to survey records, (Appendix 26) various species persisted for a few years after being transplanted but either died or occurred in such low frequency that they were not observed in 2011. Some species appear to have survived and migrated out from the original transplant areas into the rest of Unit A as well as Units B and C. Other species have survived since the sod transplanting, but appeared to have had little or no migration from where they were originally planted. Similar patterns of species establishment and migration were described by Sperry (1994) as occurring at the Curtis Prairie restoration in Wisconsin. A similar technique of transplanting native prairie sod was used at the Curtis prairie between 1936 and 1941. After 50 years, Sperry observed that some species had failed to survive; others had spread into areas they were not originally planted in, while other species survived but remained in their original planting areas. Sperry (1994) believed that species gradually migrated into the best-adapted habitats, with some species favoring drier soils and other species favoring moister soils. Similar distribution patterns could be occurring among species transplanted into the FOSC restored prairie. Species that failed to survive might not have been well suited to the new location or suffered too much stress during the transplanting process. Other species may have found favorable conditions and spread from their original areas, while others have persisted, although unable to migrate further due to current conditions.

FOSC Historical Comparisons

Since it was started, the FOSC restored prairie has experienced a trend of increasing species richness. This is contrary to observations by Sluis (2002) in which he observed a decrease in species richness over time in an Illinois tallgrass prairie restoration. The number of native species also increased over time, with a noticeable peak of 80% native species observed in 1997. The increase in native species from 65% in 1993 to 80% in 1997 is likely due to the prairie sod transplanting effort in 1995. The number of native species then declined to 75% in 2011, which may be attributed to many of the sod transplant species failing to have long-term survival success (Appendix 26). Native species richness for only species identified from the sod transplant areas in 1997 was 67; by 2011, this number had dropped to 41, a 39% loss.

Beginning with the 1985 survey, an overall increase in FQI and mean CC were observed. The exception was found in 1997 when the FQI and the mean CC values were greater than 2011 values. This was likely due to the influx of native species from the 1995 sod-transplanting project. Higher FQI and mean CC values in 1997 indicate more native species with higher CC values than in other years. The 2011 decrease in values indicates that some native species with high CC values were lost, while native species with low CC, values were becoming established within the restoration.

Andropogon gerardii was the dominant species at both study locations in terms of frequency, cover, and importance values. Since no previous surveys exist, it is impossible to say how long *A. gerardii* has been the dominant species at the native remnant prairie. However, survey records at FOSC indicate that *A. gerardii* was not always the dominant species. The 1985 survey listed seven species having the highest relative frequency (species with an asterisk are not native to North America): *Bromus tectorum* (downy brome)* (100%), *Aegilops cylindrica* (jointed goat grass) * (86%), *Cerastium fontanum* (common chickweed)* (71%), *Trifolium dubium* (small hop clover)* (68%), *Hordium pussillum* (little barley) (55%), *Panicum virgatum* (switch grass) (55%), and *Chaerophyllum procumbens* (spreading chervil) (55%). The five species having greatest relative cover were *A. cylindrica** (100%), *Bromus inermis* (smooth brome)* (91%), *Bouteloua curtipendula* (side-oats grama grass) (90%), *Trifolium repens* (white clover)* (86%), and *A. gerardii* (82%) (Knoblauch & Jackson 1986). It should be noted that the values for each species were based on the species with the highest frequency or cover as 100%; relative frequency and relative cover were calculated in relation to this. Actual frequency and cover values were not included in the report.

The 1993 FOSC survey listed the five most frequent species as: (species with an asterisk are not native to North America) *P. virgatum* (65%), *Bromus secalinus* (rye brome)* (62%), *A. gerardii* (46%), *Bouteloua curtipendula* (side-oats grama grass) (44%), and *Dalea purpurea* (purple prairie clover) (36%). The five species having the greatest cover values were *Prunus hortulana* (Hortulan plum) (98%), *Celtis occidentalis* (hackberry) (66%), *Chenopodium album* (lamb's quarters) (56%), *Helianthus maximillianii* (Maximillian sunflower) (54%), and *Rubus frondosus* (blackberry) (52%) (Gifford 1993).

The 1997 FOSC survey lists the five most frequent species as *A. gerardii* (72%), *B. curtipendula* (51%), *P. virgatum* (47%), *S. nutans* (45%), and *Ageratina altissima* (white snakeroot) (33%) (Compton 1998). Frequency was based on actual values. Cover values were not included in the report. A survey of Unit C was not performed in 1997 (Compton 1996-1997).

Since 1985, the dominant species, in terms of frequency and cover, have changed a great deal at FOSC. The four most frequently encountered species were non-native, while three of the five species with the greatest cover values were non-native. By 1993, only one non-native species was observed in the five most frequent species, and native species represented the five highest cover values. This can be explained by the native species becoming better established and out-competing the non-natives. Beginning in 1997, native species had the highest frequency and greatest cover values. *Panicum virgatum* was the most frequent species in 1993, but was replaced with *A. gerardii* by 1997. *Andropogon gerardii* continued to be the most frequent species encountered in 2011 and had the greatest cover value. A shift in cover from woody to herbaceous plants occurred between 1993 and 2011. This shift can be attributed to changes in prairie management designed to eliminate and reduce woody species, such as prescribed burns and tree removal.

The historical comparisons made at FOSC should be interpreted with caution. The studies performed all vary in the methods and techniques used. The results described in the 1985 survey are the least compatible with later surveys because the data was collected using far fewer quadrats and quadrats of a different size. The 1993, 1997, and 2011 surveys all used the same size quadrats, which were placed similarly throughout the prairie units. The exception is the 1997 survey, which did not include Unit C. This could have resulted in an underestimate of species richness and non-native species, as well as misrepresentative results of species frequency, cover, FQI, and mean CC values. However, based on the number of species encountered in Units A and B, the 1997 sampling effort likely represents an accurate account of the prairie at that time.

The major difference with past surveys and the 2011 survey is the duration and intensity of the 2011 survey and the collection of voucher specimens. Previous surveys were conducted at one time of year, lasted only up to two weeks, and focused primarily on species observed during quadrat sampling. The short duration of these surveys and the time of year in which they occurred likely resulted in many species not being reported because they were never encountered. In contrast, the 2011 survey spanned the entire growing season. By surveying the prairie during the entire growing season, a more complete species list was generated. Quadrat sampling in both June and September provided a more complete picture of species frequency, cover, and changes throughout the growing season.

The goal of the FOSC prairie restoration project was to "restore and cultivate the native vegetation, which provides the historic setting for the primary historic restoration and interpretive period 1842 to 1853" (FOSC General Management Plan 1993). In a strict since, this goal will never be possible. Too many exotic species that were not present in the mid 1800s have become naturalized in the Midwest. These species continuously invade the restored prairie and are present within the native prairie studied to a lesser degree. Many species found at the native prairie remnant do not occur within the FOSC restoration; the majority of the native species found at FOSC occur in abundances very different from those found in the remnant prairie studied. Had the writers of the FOSC General Management Plan understood the daunting task of restoring the native vegetation of the area they may have instead set a goal of creating a visually appealing prairie, which would serve as a model of the original landscape.

CHAPTER VI

CONCLUSION

Differences in cover amounts and community composition of dominant species between study areas shows that the FOSC restored prairie has not returned to a condition similar to that of the native prairie remnant in terms of plant species composition. *Andropogon gerardii* (big bluestem) is the only dominant species (species with cover greater than 5%) common to both study areas, with 20% mean coverage of *A. gerardii* at FOSC, and 45% mean coverage at the native prairie remnant. The combined cover of dominant species at the native prairie was nearly double that of combined cover of dominant species found at the FOSC restored prairie.

Six of the eight prairie guilds found at the FOSC restored prairie do not have amounts of total coverage comparable to the native prairie remnant, which indicates that the FOSC restored prairie is functionally dissimilar from native tallgrass prairies of the area. Guild dominance is split at the FOSC restored prairie between the summer/fall forbs in June with 46.5% of the total cover of all species and the C_4 grasses in September with 39% of the total cover of all species. The C_4 grass guild is the dominant guild at the native prairie remnant in both seasons. This guild makes up 60% of the total cover of all species at the native prairie in June and 75% of the total cover of all species in September. The legume and spring forb guilds have lower amounts of total cover at the FOSC restored prairie in both seasons than the native prairie remnant. The annual forb, summer/fall forb, and woody shrub guilds have greater amounts of total cover in both seasons at FOSC than the native prairie remnant. The spring ephemeral forb and C_3 grass and sedge guilds have similar amounts of cover at both study areas in both seasons.

Comparisons of community similarity, percentage of non-native species, species richness, and FQI, between the FOSC restored prairie and a local native prairie remnant, all indicate important differences. Of the 255 species identified in this study, only 65 species were common to both locations, resulting in a Sorensen coefficient of community similarity of 40.6%. The FOSC restored prairie contained 25% non-native species, which was double the percentage of non-native species found at the native prairie remnant. An analysis of quadrat data reveals significantly greater overall species richness and significantly greater native species richness at the native prairie remnant than the FOSC restored prairie. Differences in the number of highly conservative species and FQI values between locations indicate that the FOSC restored prairie has not reached a level of floristic quality as high as the native prairie remnant. The native prairie remnant had 25 high fidelity species with CC values of seven or greater. In contrast, the FOSC restored prairie had only 12 species with CC values of seven or greater. Additionally, 105 species with CC values of four or lower were found at the FOSC restored prairie, compared to 59 species with CC values of four or lower found at the native prairie remnant. The native prairie remnant had significantly higher floristic quality assessment index (FQI) and mean coefficient of conservatism (CC) values than the FOSC restored prairie.

A comparison of prairie units at FOSC showed similar species composition and coverage among the units. Unit A had the greatest overall species richness, greatest native species richness, highest FQI and mean CC values, while also having the lowest percentage of non-native species, among prairie units. Comparisons with previous vegetation surveys at FOSC showed an increase in overall species richness and native species richness since the FOSC restored prairie was started. There has been an overall increase in FQI and mean CC since the restoration was first surveyed in 1985, with a decrease from 1997 to 2011. This decrease is likely the result of many of the native species from the Unit A transplant areas not having long-term survival success. Future surveys are needed to determine whether the decrease in FQI and mean CC will continue. Differences in Sorenson's coefficient of community similarity between survey years indicate that vegetation composition within the restored prairie continues to change.

It seems that fully restoring the native vegetation once found in the area surrounding Fort Scott will take longer than 32 years, possibly due to several causes. (1) The methods used to seed the FOSC prairie may have resulted in the clumped distribution of species observed. (2) Seed planting mixtures used may not have reflected the floristic quality and species richness found in prairies around Fort Scott. (3) The fragmented design at FOSC may contribute to higher percentages of non-native species by allowing more edge area for potential invasion. (4) Soil disturbances may have created areas within the restoration not conducive to the growth of some species. (5) Localized climate conditions, such as drought, may have altered the cover amounts of various species. (6) The remnant prairie used in this study may not reflect the floristic composition once found in the Fort Scott area. Allison (2002) points out that using remnant prairies as models of comparison for restored prairies can be problematic because these remnants have likely changed since pre-settlement times.

Restoration ecologists acknowledge the difficulty in recreating ecosystems, which have been degraded, damaged, or destroyed (SER 2004). Previous research comparing restored tallgrass prairies and native tallgrass prairie remnants has lead to the conclusion that we do not presently know enough about the mechanisms causing species patterns and richness to recreate the patterns of species found in native prairie remnants (Sluis 2002). Sperry (1994) concluded that homogeneity in ecological dispersion is essentially unknown. Other researchers believe that restoring the high diversity of the original tallgrass prairie ecosystem will occur only over long periods of time, perhaps centuries (Kindscher & Tieszen 1998). Efforts to fully restore the tallgrass prairie ecosystem once found at the Fort Scott National Historic Site may eventually be successful, but will likely take a considerable amount of time and continued management.

Management Recommendations

The fragmented design of the FOSC restored prairie makes the encroachment of non-native and weedy native species an ongoing management concern. Specific action is needed in order to fulfill the goal of recreating the historic vegetation found around Fort Scott in the 1840s. Because the FOSC restored prairie is well-established, management activities designed to benefit native tallgrass prairies can be applied.

Management activities at FOSC fall into two broad categories: activities that eliminate and reduce unwanted species and activities that increase desired species. Prescribed burning simultaneously decreases unwanted species, while improving growth opportunities for desired species. The FOSC restored prairie is on a three year prescribed burn schedule, which is consistent with the 3-5 year burning rotation recommended to maintain grass dominance and species diversity typical of native prairies (Davison &

Kindscher 1999). No change in prescribed burn regimen is needed. Activities involving eliminating or controlling non-native or woody species are needed on a yearly basis for the foreseeable future. The main non-native species in need of control are *Bromus inermis* (smooth brome), *Campsis radicans* (trumpet-creeper), *Lonicera japonica* (Japanese honeysuckle), *Securigera varia* (crown vetch), and *Sorghum halepense* (Johnson grass). These species threaten the restoration because they are highly invasive and will often outcompete native species.

Mowing or removing seed heads will help to control the spread of these species if performed throughout the growing season. Spot treatment with herbicides is the most effective way to control and eliminate these species. Herbicide application should be performed when the species are actively growing, preferably prior to seed production, possibly several times throughout the growing season.

Numerous trees, shrubs, and woody vines are found throughout the restoration and must be eliminated. Primarily trees and tall shrubs are a threat to the restoration by shading out native species, competing for water and nutrients, and giving cool-season exotic grasses a shady foothold. Given the small size of the restoration it is feasible to cut out most woody species by hand and treat the stumps with herbicides to kill the roots and prevent re-sprouting. This practice can be used throughout the growing season but will produce the best results in late summer or early fall. A few weedy native species such as *Ambrosia trifida* (giant ragweed) are found throughout the restoration in high frequency. This species would only be found in low frequencies in tallgrass prairies, if at all. Giant ragweed mostly occurs along the prairie edges and can be controlled using the same methods described for controlling exotic species. Controlling giant ragweed and woody species would also create a more visually appealing prairie for visitors to experience.

Unit B2 is in the worst condition of all the FOSC units. Nearly half of this unit is covered with *Lonicera japonica* (Japanese honeysuckle) along with numerous other non-native and woody species. These unwanted species are thriving in the shade cast by a large American elm (*Ulmus americana*) and other trees. In contrast, native prairie species are fully established in the areas receiving full sun. The current shady conditions mean about half of this unit is not suitable for tallgrass prairie restoration. Presently, the best option for Unit B2 is to control the large number of non-native species thriving in the shady areas. This can be done through herbicide application and mowing. A combination of the two methods may be most effective. As long as this unit remains partially shaded, tallgrass prairie species will not be able to establish themselves across the entire unit. If no action is taken, non-native species that mainly grow in shady areas will spread into areas receiving full sun and start displacing native species, which is already beginning to occur.

Activities to increase desired species should also be considered. The native legume guild is one group of species underrepresented at the FOSC restoration in comparison to the native remnant prairie. Interseeding of native legumes could potentially benefit many other desirable native species by increasing soil nitrogen caused by nitrogen fixing bacteria living within the root systems of legumes. Possible legume species to consider are: *Amorpha canescens* (lead plant), *Baptisia australis* (blue wild indigo, *Baptisia bracteata* (cream wild indigo), *Dalea candida* (white prairie clover), *Desmodium sessilifolium* (sessile-leaf tickclover), *Lespedeza capitata* (round-head bush-clover), *Lespedeza violacea* (violet bush-clover), *Lespedeza virginica* (slender bush-clover), *Mimosa quadrivalvis* var. *nuttallii* (sensitive briar), *Psoralidium tenuiflorum* (narrow-leaf scurf-pea), and *Strophostyles leiosperma* (slick-seed wildbean). These legumes were observed at the reference remnant prairie and would greatly contribute to the diversity, floristic quality, and health of the restoration. To further increase diversity and floristic quality, a number of spring forbs could be planted. Species found at the reference prairie to consider include: *Antennaria neglecta* (field pussy's-toes), *Asclepias viridiflora* (green milkweed), *Ruellia humilis* (hairy wild petunia), *Euphorbia corollata* (flowering spurge), *Pedicularis canadensis* (wood betony), *Penstemon digitalis* (smooth beardtongue), *Physostegia virginiana* (obedient plant), and *Polytaenia nuttallii* (Nuttall's prairie-parsley).

Haying is a management practice not used at FOSC. Haying each section each year may not be desirable, since interpretive programs related to the restored prairie are designed to educate visitors on the pre-settlement vegetation of the area. Instead, a rotating schedule in which one unit each year was hayed would still help to improve the health of the restoration, while leaving most of the prairie intact for visitors to experience.

The native tallgrass prairie that was studied is a fine example of high quality habitat. This remnant of tallgrass prairie persists as an island within a landscape dominated by cropland, woodlots, cool-season pastures, and urban development. Its relatively small size does not preclude it from supporting numerous high fidelity native species and relatively few exotic species. Many of the high fidelity species are only able to survive in undisturbed remnant prairies, making them a rarity in southeast Kansas.

High FQI, as evidenced by 25 species with CC values of seven or higher, including *Asclepias meadii,* indicate this prairie is in near pristine condition. In order to maintain the high floristic quality and diversity of this native prairie current management practices should be continued, but perhaps modified. The Kansas Biological Survey (KBS) recognizes hay production as one of the best ways to maintain the biodiversity and the ecological value of native remnant prairies. KBS recommends a rotating yearly management regime in which 1/3 of a prairie is rested, 1/3 is burned in spring and hayed in mid summer, and 1/3 is hayed in mid summer but not burned (Kindscher & Byczynski 2009). However, this recommendation may not be practical. The fragmented and small size of many tallgrass prairie remnants makes this type of management regime inconvenient for landowners. Small remnant prairies in southeast Kansas are typically entirely burned and entirely hayed each year, and not split up into thirds for biodiversity management. This practice would be easier to implement on larger remnants several hundred or thousands of hectares.

Currently, the native prairie in this study is hayed annually in mid-July and burned nearly every year in April. Native prairies in Kansas are hayed in July to coincide with the peak nutrient value of most warm-season prairie grasses. In order to reduce the amount of genetic diversity lost through annual haying, a small portion (10-25%) could be left uncut each year. The section not hayed could be rotated every year to give all species the chance to complete their reproductive cycles. A change in burn regimen from annual to every three years is also recommended. Studies have shown that annual burning can cause a significant reduction in soil organic nitrogen (N), lower microbial biomass, and lower N availability (Ojima *et al*. 1994). Efforts to control the few exotic and woody species should be focused along the prairie edges. Woody species, such as *Celtis occidentalis* (hackberry), are found growing in the fencerows bordering the native prairie. These trees shade out native species, while giving non-native grasses, such as *Schedonorus arundinaceus* (tall fescue), a foothold into the prairie. The elimination of trees within the fencerows would allow native species to better compete with encroaching non-native species, and in turn decrease non-natives along the prairie edges. These management recommendations are designed to continue benefiting the landowner as well as the native flora and fauna of the region.

Time and money are the other essential ingredients to any prairie management plan. Even the best management plans are of no use if the strategies within them are not implemented. Current management practices to maintain and improve the condition of the native prairie remnant need to be continued and modified somewhat, which would not be cost prohibitive. The management challenges at FOSC involve re-creating a lost ecosystem. This type of undertaking requires considerable resources each year just to maintain the current condition of the restoration. Activities designed to further enhance and improve the condition of the FOSC restored prairie will require additional expenditures.

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