RESTORATION IMPLICATIONS OF LAND MANAGEMENT ON ABOVEGROUND VEGETATION AND SEED BANK COMPOSITION OF GRASSLAND COMMUNITIES IN ILLINOIS

BY

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THESIS

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Abstract

A variety of non-prairie landscapes are restored to prairie on a yearly basis including pastures, croplands, and old fields. Most of these restoration efforts do not take into account the seed bank associated with these non-prairie lands as a potential source of plant diversity or weedy interference. In this study, I investigated the similarities or dissimilarities of standing vegetation and seed bank composition for six different land management histories at Midewin National Tallgrass Prairie (IL, USA): restored prairie, remnant prairie, recently planted pasture, historic pasture, abandoned (seral) pasture, and crop field. The goals of this study were to: 1) determine similarities between the standing vegetation and the seed bank composition; 2) determine the role that different land management histories will play on standing vegetation and seed bank composition; 3) determine if restorations are building a prairie seed bank; 4) determine if the seed banks will reflect aboveground species composition; and 5) determine if seed banks can impact restoration success. In 2009, vegetation surveys and soil cores were collected in July and October, respectively, for a total of 30 sites (five sites per land history) and 300 soil cores (10 cores per site). In 2010, soil cores then were grown in a greenhouse and the seedlings identified to species. Results indicate that the seed banks vary per land history and that some of the differences that can be observed from aboveground vegetation are indiscernible in the seed bank composition. In addition, the amount of species similarity between the seed bank and the aboveground vegetation was minimal. Although seed banks may not provide material for prairie restoration, they can provide an idea of the present conditions and the factors that may influence a restoration, such as invasive species.
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Chapter 1: Introduction

Land cover in Illinois has undergone dramatic changes since European settlement of the Midwest. Before European settlement, Illinois was predominantly prairie, with a smaller portion of the state being a combination of forests and wetlands (Iverson, 1988). A number of factors maintained the landscape in its original condition, including grazing by bison, periodic fires, and climate (i.e., precipitation, temperature, and winds) (Knapp et al., 1999; McClain et al., 2010; Transeau, 1935). During settlement, wildfires were suppressed, bison eliminated, and the prairies themselves were plowed. This dramatic change in land use had clear effects on the vegetation composition of Illinois. A state that was once 58% prairie (Iverson, 1988) is now nearly 75% agricultural land (Illinois Department of Agriculture, 2002) with only 0.01% of the original North American prairie landscape remaining as small isolated fragments (Samson & Knopf, 1994).

To save what is left of Illinois prairie, conservation and restoration efforts have been implemented. In the case of conservation, simply setting land aside, protecting it from other uses, and trying to return historic disturbance regimes is the usual approach. In the case of restoration, degraded lands are converted into a more complex state, sometimes through enriching the species present at the site (Betz et al., 1996). Prairie restorations can either occur on degraded sites, as typically found in former pastures, or potentially as de novo restorations conducted on the relatively blank slate of a recently harvested. These practices are still relatively new and many restoration practitioners are still learning the best strategies and tools to accomplish their goals.

One particular component of a restoration site that can benefit land managers and restoration practitioners or can become a management concern is the pre-existing seed
bank of the site to be managed or restored. Seed banks are defined as the collection of dormant, viable seeds in the soil (Bigwood & Inouye, 1988). Seed banks can serve as reservoirs for biodiversity as dormant seeds can persist for over 50 years (Chippindale and Milton 1934) if conditions are not favorable for germination, and then emerge when conditions are right. For this reason, soil seed banks provide a record of the species that dominate the landscape and can potentially be used to restore those species in the event they are lost (Davies & Waite, 1998; Rabinowitz, 1981).

A review of studies comparing aboveground and seed bank vegetation found that grasslands have higher similarity between their aboveground vegetation and seed bank composition than forests and wetlands (Hopfensperger, 2007), however only five North American studies were included. Based on a more thorough review of the literature associated with prairies, studies did not show a strong linkage between above ground vegetation and seed bank composition (Johnson & Anderson, 1986; Leicht-Young et al., 2008; McNicoll & Augspurger, 2010; Rabinowitz, 1981; Romo & Bai, 2004; Schott & Hamburg, 1997). Typically, numerous above ground species are not present in the seed bank and at the same time many weakly competitive weed species present in the seed bank do not appear in the standing vegetation. This dissimilarity between the above ground vegetation and seed bank is attributed partially to a depauperate prairie seed bank (Meiners & Gorchov, 1994). The depauperate seed bank may be a result of most reproduction occurring through vegetative means (i.e., buds) rather than seedling recruitment (Benson & Hartnett, 2006). Another indication of the depauperate composition of the prairie seed banks is that certain species which are aggressive or
weedy have been found to be more abundant in the seed bank relative to other species lacking these traits (Johnson & Anderson, 1986).

In addition to the biological limitations related to prairie seed banks, land use changes and management practices associated with this habitat have affected its seed bank composition. For example, Schott and Hamburg (1997) demonstrated that the conversion of a prairie into an old field resulted in a less species rich seed bank. In addition, once a prairie has been converted to a crop field the intense management of agricultural systems (e.g., crop rotation or tilling, herbicide application, and fertilizer inputs) can alter the species composition, diversity, and abundance of the species found in the seed bank (Davis et al., 2005; Menalled et al., 2001; Smith & Gross, 2006). Of interest is that in prairies prescribed burning, herbicide application, and mowing have been shown to affect aboveground vegetation (Collins et al., 1998; Towne & Owensby, 1984; Wilson & Gerry, 1995), but less is known about the impact on seed bank (Buhler, et al., 2001). The combination of land use changes and management practices can result in an even more depauperate seed bank or a seed bank of unwanted species (i.e., weedy species) that can become a constant management issue in prairie restoration and land management (Ambrose & Wilson, 2003; Piper et al., 2007; Smith & Gross, 2006; Wilson & Gerry, 1995).

Although in the case of prairies the role of seed banks may be somewhat limited for their regeneration, the seed bank of an area that is going to be restored can play a crucial role in the establishment of vegetation and the success of the restoration. The main goals of my thesis are to: 1) determine similarities between the standing vegetation and the seed bank composition; 2) determine the role that different land management
histories will play on standing vegetation and seed bank composition; 3) determine if restorations are building a prairie seed bank; 4) determine if the seed banks will reflect aboveground species composition; and 5) determine if seed banks can impact restoration success. This research will create a better understanding of the factors at play in seed bank composition in Illinois and will determine what sort of relationship, if any, exists between the above ground vegetation and seed bank. This information will assist managers and prairie restoration practitioners to make better decisions regarding allocation of resources and effort and time to restore lands into prairies.

**Literature Cited**


Chapter 2: Seed banks of grasslands in Illinois with different management histories

Abstract:

A variety of non-prairie landscapes are being restored to prairie on a yearly basis including pastures, crop fields, and unmanaged seral ground. Most of these restoration efforts do not take into account the seed bank associated with these non-prairie lands as a potential source of plant diversity. The main goals of this study were to examine the seed bank potential of these non-prairie lands and the relationship between aboveground vegetation and seed bank composition. Six different land histories were surveyed for this study: remnant prairies, restored prairies, new pastures, old pastures, old fields, and crop field at the Midewin National Tallgrass Prairie (Will Co., IL). In 2009, vegetation surveys and soil cores were collected in July and October, respectively, for a total of 30 sites (five sites per land history) and 300 soil cores (10 cores per site). In 2010, soil cores were placed in a greenhouse and emerging seedlings were identified to species. Results indicate that the seed banks vary per land history. In addition, species similarity between the seed bank and the aboveground vegetation was minimal. Although seed banks may not reflect aboveground vegetation, they can provide a snapshot of past vegetation and restoration potential of a site.

Introduction:

Tallgrass prairie is among the most endangered habitats in North America. In 8 of the 12 U.S. states in which this habitat is found 99.99% has been destroyed, a decline greater than any other North American ecosystem (Samson et al., 2004; Samson & Knopf, 1994). In addition, tallgrass prairie has been identified as part of the temperate grasslands and savannas biome with the highest Conservation Risk Index (i.e.,
conversion-to-protection ratio) 10.1, as the result of its extensive habitat loss and under-
protection (Hoekstra et al., 2005). Despite the tremendous prior losses and conservation
efforts, tallgrass prairie continues to disappear.

To mitigate for the loss of tallgrass prairies, prairie restorations are seen as one
avenue to bring back some of the lost prairie acreage, and to restore ecosystem
functionality (Foster et al., 2007). Frequently, the starting point for these restorations is
an anthropogenic landscape that has been disturbed to varying degrees resulting in highly
degraded prairies, pasture and/or cropland. One prairie restoration approach is to start
managing prairie remnants to favor the growth of existing prairie species and to
encourage any dormant prairie vegetation to emerge (Packard & Ross, 1997). A potential
source of dormant prairie vegetation can be found in the soil seed bank.

Soil seed banks are defined as the ungerminated but viable seeds that lie in the
soil (Bigwood & Inouye, 1988) and can serve as reservoirs for biodiversity (Thompson &
Grime, 1979; Levin, 1990). Dormant seeds can persist for over 50 years (Chippindale
and Milton 1934) if conditions are not favorable for germination and then emerge when
conditions are right. For this reason, soil seed banks provide a record of the species that
dominate the landscape and can be used to recover that diversity in the event that it is lost
(Davies & Waite, 1998; Rabinowitz, 1981). The seed bank of a prairie could play a
similar role.

Prairie seed bank research has found that the seed bank varies depending on the
degree of degradation, with prairie seed banks having richer and more diverse seed banks
than adjacent old fields (Schott & Hamburg, 1997). However, several studies have
questioned the potential role of seed banks as part of prairie restoration efforts due to: 1)
an absent or almost depleted prairie seed bank (Laughlin, 2003; Meiners & Gorchov, 1994; Wilson, 2002) and 2) a weak relationship or no relationship between seed bank and aboveground vegetation (Johnson & Anderson, 1986; McNicoll & Augspurger, 2010; Romo & Bai, 2004). Another reason for doubting the value of seed banks in prairie restorations is the overwhelming importance of vegetative recruitment. Previous work (Benson & Hartnett, 2006) has determined that >99% of recruitment in existing prairies comes from vegetative growth while less than 1% of growth was the product of seedling recruitment.

Regardless of such doubts prairie restoration projects can utilize seed bank studies and the relationship between seed bank and aboveground vegetation to determine problematic species (i.e. invasive species) depending on the land history. It has been established that weedy species in the seed bank can impact restoration efforts (Piper et al., 2007). Also by studying the seed bank of a site, better decisions can be made regarding which native species need to be added to seed mixes due to their absence in the seed bank. Rosburg & Owens (2004) noted that seed bank studies can provide an evaluation tool for prairie restoration success and assist in determining the fate of the species that have been seeded. Although assessing the species composition of the seed bank could be a useful tool, knowing the land management history of a site is equally important as it could affect seed bank composition.

Research on the role of land management practices on grasslands has shown that they can influence the seed bank (Albrecht & Auerswald, 2009; Dutoit & Alard, 1995; Jacquemyn et al., 2011). These studies have shown that management practices can have significant impacts on the species richness and composition of seed banks (Buhler, et al.,
2001; Dutoit & Alard, 1995; Wellstein, et al., 2007). Some grasslands have been shown to lose richness when management activities cease (Jacquemyn et al., 2011). Seed banks have even been shown to be sensitive to different land management practices in that seeds in frequently disturbed sites have a higher longevity period in the soil than infrequently disturbed sites (Albrecht & Auerswald, 2009). In addition, the link between management practices and seed bank composition is still not completely understood in Midwestern landscapes, in particular for prairies.

In this study, I investigated standing vegetation and seed bank composition for six different land management histories at Midewin National Tallgrass Prairie (IL, USA): restored prairie, remnant prairie, recently planted pasture, historic pasture, abandoned (seral) pasture, and crop field. In particular, I was interested in: 1) determining similarities between the standing vegetation and the seed bank composition; 2) determining the role that different land management histories will play on standing vegetation and seed bank composition; 3) determining if restorations are building a prairie seed bank; 4) determining if the seed banks will reflect aboveground species composition; and 5) determining if seed banks can impact restoration success. I predict that the seed banks of restored and remnant prairies will be more similar in species composition to each other. The similarity between remnants and restored prairies is likely due the fact that most restored prairies use remnant prairies as a guideline for their species composition. In the case of old field, old pastures, and new pastures I predict that they will be similar to each other as the result of their management histories. Lastly, due to the intensive and ongoing management activities, crop fields will have the most dissimilar aboveground vegetation and seed bank composition compared to the rest.
Methods:

Study site

This study was conducted at Midewin National Tallgrass Prairie (MNTP) in Wilmington, Will County, Illinois, USA (Figure 1). This 19,000 acre site is being managed by the U.S. Forest Service and is being restored to a mosaic of prairie, savanna, forest, wetland, and pastures specifically for bird habitat. Prior to being transferred to the U.S. Forest Service, this site was under control of the U.S. Army from 1940 to 1996. During this period, most of the approximately 10,000 acres that was not used for ammunition production was under agricultural or pastoral use. The less than 200 acres of native vegetation were not managed with the exception of grazing, and fires were suppressed until the U.S. Forest Service took over the land.

Field and greenhouse procedures

Six different land management histories were surveyed at MNTP: restored prairie, remnant prairie, new pasture, old pasture, crop field, and old field (Figure 1). The following criteria were used to select the different land management histories. Restored prairie sites were mesic areas that were formerly crop fields and had been undergoing restoration efforts for less than 10 years. These areas surveyed supported mesic to wet mesic vegetation. Remnant prairie areas were selected based on the presence of a dominant matrix of native species and based on input from site managers that these areas had never been plowed or significantly disturbed. These sites also supported a suite of mesic to wet mesic vegetation. New pasture areas were areas that were formerly crop field but had been planted to a mix of cool season grasses and exotic legumes. These areas had been in pasture for less than 10 years. Old pastures were also a mix of cool...
season grasses and exotic legumes but they had been maintained as pastures at least since the early 1940’s when the Army was the primary land manager for the area. Old field sites were formerly pastures that were no longer being grazed. These sites were being mowed annually to control woody vegetation, but otherwise were receiving no management. Crop field sites were selected as areas that had been in row crop production since the time the army began managing the area. At the time of the survey, these areas were in a rotation of glyphosate resistant soybeans (*Glycine max*) and winter wheat (*Triticum aestivum*). Crop field sites were surveyed during years when soybeans were present. For each of the six different land management histories, five sites were surveyed for both vegetation and seed bank.

At each site, a vegetation survey was conducted along a 40 m transect with sampling occurring every 2 m. Each transect was placed in an area representative of the vegetation characteristics of each management type. Sampling took place by surveying a 0.25-m² quadrat located 1m from the transect and recording the percent cover of all vegetation in the quadrat using a modified Daubenmire method (Daubenmire, 1959) for a total of 20 quadrats per transect. Vegetation surveys occurred in July 2009.

Soil cores were collected at locations along the same vegetation transect for a total of 10 cores per transect. Soil cores were 3.18 cm in diameter and taken to a depth of 10 cm. Soil surveys occurred in October 2009 in order to capture as much of the previous year’s seed rain as possible. A total of 300 soil cores were used for this study. Soil cores were bagged and refrigerated at 3°C until April 2010 when they were processed and placed in the greenhouse to begin germination. Processing consisted of breaking of the cores mechanically over a mesh screen to remove any roots or other non-
seed propagules and to provide some degree of separation of the soil. The soil cores were spread over a greenhouse soil mixture and seedling emergence was tracked on a weekly basis and seedlings were identified to species whenever possible. Seedlings were counted in the greenhouse to track abundance. Once positive identification was made, seedlings were removed. Germination was allowed to continue until January 2011 newly emerged plants had dropped to the point that further time was deemed unnecessary.

**Data analysis**

From the aboveground vegetation and seed bank surveys the following data were generated for analyses: species richness, floristic quality index (FQI), mean coefficient of conservatism value (mean C), and Shannon diversity index.

FQI and mean C are both quantitative measures of the floristic integrity of a site. The coefficient of conservatism value (C value), a value that ranges from 0 to 10, is assigned to each native plant species found at the site. Higher values are given to species demonstrating a stronger fidelity to habitats with a high degree of integrity. As a metric mean C value provides a rough estimation of the degree of degradation at a site. Species with low C values are less conservative, and as their presence at a site increases and as more conservative species are lost, it becomes clear that degradation has occurred. The FQI takes into consideration the number of native species found at a site and in doing so helps to provide an accurate representation of quality for areas that may have similar mean C values but widely different species richness. For the purpose of this study we followed the method described by Taft et al. (1997) to calculate FQI and mean C value using the formulas as listed below:
1) Mean \( C = \frac{\Sigma (CC_{S1} + CC_{S2} + \ldots )}{SR_{site}} \) where \( CC \) is the coefficient of conservatism for each species (\( S1, S2, \ldots \)), and \( SR_{site} \) is the species richness.

2) Floristic Quality Index (FQI) = Mean \( C / \sqrt{N_{site}} \); where \( N_{site} \) is the species richness.

I also followed Taft et al. (1997) in defining species having a \( C \) value of 3 or less as species associated with ruderal environments. For the purposes of this study species with a \( C \) value of 3 or less are described as weedy. Also, species identified only to genus were not included when calculating FQI or mean \( C \) values. Lastly, EstimateS software (Colwell, 2005) was used to calculate Sorenson similarity index and Shannon diversity index.

One way and two way ANOVAs followed by Tukey’s post hoc test were used to determine differences among the six land management histories for species richness, FQI, mean \( C \) and Shannon diversity index. One way ANOVAs were used to determine differences among land management histories for aboveground vegetation data and seed bank data. In addition, two way ANOVAs were used to determine how different the seed bank composition was from the aboveground vegetation among land management types by examining the interaction effect between land management history and survey location (seed bank or aboveground vegetation). To meet the assumptions of normality and/or equal of variance for the ANOVAs the log10 (\( n + 1 \)) was used, and for the purpose of data presentation, data were back transformed. Species presence/absence on a site level was used to compare aboveground vegetation and seed bank data due to the aboveground vegetation being recorded as percent cover and the seed bank data being recorded as abundances. For the purposes of data analyses above ground vegetation and seed bank data were pooled by site.
Vegetation composition of aboveground vegetation, the seed bank vegetation, and the combined data for both was displayed using non-metric multidimensional scaling (NMDS) of Bray–Curtis dissimilarity matrices with the WinKyst 1.0 add-in for CANOCO 4.5. A two-dimensional solution was chosen in an effort to be able to accurately depict the results graphically.

Results:

Aboveground vegetation

All together 228 plants were identified to genus or species level during field surveys. There were 21% graminoids and 79% forbs. The most frequently observed species were *Poa pratensis* (61.5%), *Daucus carota* (47.9%), *Solidago canadensis* (42.5%), and *Bromus inermis* (38.7%). Non-native species comprised 18.6% of the aboveground vegetation and native species comprised the other 81.4% of the aboveground vegetation. Weedy species, accounted for 57.0% of the observed aboveground vegetation cover. These data are summarized in Table 1. Appendix A shows all species that were recorded from this study by land management history.

Mean aboveground species richness varied by land management history (F=15.1, P<0.001; Figure 2). Remnants had the highest overall species richness (Table 1). Both restorations and remnants had more species compared to crop fields, new pastures, and old pastures. Lastly, the species richness of old fields was higher than in crop fields.

Significant differences were also found for FQI (F= 131.8; P<0.001) and mean C values (F= 86.3; P<0.001) among land management types. Both remnants and restorations had higher FQI than old fields, crop fields, new pastures, and old pastures (Figure 3, Figure 4). Also, old fields had higher FQI than crop fields, new pastures, and
old pastures. Similar results were found for the mean C values with the exception that no differences were found between restorations and old fields (Figure 4).

A one way ANOVA found significant differences in Shannon diversity among land management types (F=19.6, P<0.001; Figure 5). The aboveground vegetation for remnants and restorations was more diverse compared to crop fields and new pastures. In addition, remnants had more species diversity than old pastures. Crop field vegetation had the lowest species diversity compared to any of the other management history.

Lastly, the non-metric multidimensional scaling (NMS) analysis showed that aboveground vegetation separated in ordination space based on land management history with some in closer proximity. Old pastures and new pastures had some degree of overlap, but the rest of the management histories were isolated. In particular, crop fields had the greatest degree of separation (Figure 6).

**Seed bank**

All together 2096 seedlings germinated from the seed bank. Most of the seedlings (86.8%) were identified to the species or genus level. A total of 93 species were identified from the seed bank. Of these species 21% were graminoids and 79% were forbs. The most abundant species were *Mollugo verticillata* (6.4%), *Oxalis stricta* (6.4%), *Setaria faberi* (6.0%), and *Veronica peregrina* (6.0%). *Mollugo verticillata* was highly concentrated in a single sample with over 87% of the individuals found in the entire study coming from a single site (restored prairie site 3, Table 1). Based on the number of species, non-natives comprised 22% of the seed bank composition. Weedy species accounted for 87.0% of the observed seedlings. Table 1 summarizes these data. A rapid emergence of seedlings occurred within the first nine weeks followed by a slow
tapering off of new emergence after that period (Figure 7). By the ninth week 85.1% of the total observed seedlings had been observed. The remaining 14.9% germinated and were observed over the following 21 weeks of the study. A full accounting of species found in this study can be found in Appendix A.

Restorations had a much larger number of seedlings than any of the other land management histories. The total abundance of seedlings in the restoration sites was 844. The abundances of the new pastures (300 seedlings), the old pastures (316 seedlings), and the old fields (299 seedlings) were very similar; with the range of abundances for these three land management histories being only 17. Lastly, remnant prairies had an observed abundance of 214 and row crop sites had the lowest amount of emergence (123 seedlings).

For the seed bank, significant differences were found among land management histories for total species richness (F=6.797; P<0.001). Fewer species were found in the seed bank of crop fields compared to restorations, old fields, old pastures, and remnants (Figure 8). In addition, more species were found in the restorations compared to new pastures.

In the case of FQI (F=7.730; P<0.001; Figure 9) and mean C values (F=6.323; P<0.001; Figure 10) significant differences were found among the land management histories for the seed bank. The FQI for the seed bank of remnants was significantly greater than the FQI for crop fields and new pastures (Figure 9). Also, significant differences were found for the mean C value. Remnant mean C values were higher than cropfields, old pastures, or new pastures. With the exception of remnants, all the other land management histories had statistically similar mean C values.
Also, significant differences were found for the Shannon diversity among the seed bank of land management types (F=6.328; P<0.001; Figure 11). Crop fields again had lower species diversity compared to all other management types, with the exception of new pastures. The seed bank flora of the rest of the management histories had similar levels of species diversity.

Lastly, in the case of the non-metric multidimensional scaling analysis for the seed bank, land history management sites separated less in ordination space, with the exception of crop fields (Figure 12). The decreased amount of separation in this analysis indicates that differences between management histories were less distinct than they were when the same analysis was conducted using the aboveground vegetation data.

**Comparisons between the seed bank and aboveground vegetation**

Of the 255 species observed in the study, 162 were unique to the field sites and 27 were unique to the seed bank study (Table 2). There were 66 species shared between aboveground vegetation and seed bank. These data show that the seed bank has only 28.9% of the species found in the aboveground vegetation, while the aboveground vegetation contains 70.9% of the species found in the seed bank. Of the 255 species observed, 60 were non-native. Table 1 lists the species with the 5 highest relative frequency values between the field and seed bank studies for each land management history. The combined species found in this study can be found in Appendix A.

A two way ANOVA found significant interactions between land management history and survey location (i.e., aboveground vegetation and seed bank) for species richness (F= 3.147, P= 0.015; Appendix B – Table B.1), FQI (F= 9.703, P<0.001; Appendix B – Table B.2), mean C (F=8.712, P<0.001; Appendix B – Table B.3) and
Shannon (F=3.937, P=0.005; Appendix B – Table B.4). In the case of restorations, old fields, and remnants, the aboveground vegetation had more species and was more diverse than the seed bank (Figures 13 and 16). Although no significant differences were found for old pastures, new pastures, and crop fields, the FQI and mean C of the seed bank were higher than the aboveground vegetation (Figures 14 and 15). Also, values for FQI and mean C for the seed bank of restorations, old fields, and remnants were greater than the aboveground vegetation of old pastures, new pastures, and crop fields. In the case of species richness and Shannon diversity the trend for aboveground vegetation was greater than in the seed bank (Figures 13, and 16); but the aboveground vegetation of row crop fields had fewer species and was less diverse than the seed bank of the other land management histories (Figures 13, and 16). Lastly, when both aboveground and seed bank data are combined in the NMDS analysis no distinct separation was found among land management histories (Figure 17).

**Discussion:**

Many studies have been conducted to determine aboveground vegetation and seed bank similarities in grasslands (Benson & Hartnett, 2006; Chippindale & Milton, 1934; Johnson & Anderson, 1986; Laughlin, 2003; Leicht-Young, et al, 2008; McNicoll & Augspurger, 2010; Meiners & Gorchov, 1994; Perez, et al, 1998; Rabinowitz, 1981; Thompson & Grime, 1979). At the ecosystem level it has been determined that grasslands have relatively higher similarity between aboveground vegetation and seed bank than forested and wetland systems (Hopfensperger, 2007). However, this overall pattern of similarity between the seed banks and aboveground vegetation for grasslands varies depending on the type of grassland. For example, in European mesic grasslands
(Wellstein et al., 2007) and European wet swales (Blomqvist et al., 2003) there was a lack of similarity between aboveground vegetation and the seed bank. In North American grasslands seed bank studies have shown a lack of strong similarity to the aboveground vegetation in prairies (Johnson & Anderson, 1986; McNicoll & Augspurger, 2010; Perez et al., 1998; Rabinowitz, 1981), marshes (Wilson et al., 1993) and pastures (Coffin & Laurenroth, 1989). In this study I found a similar result. Regardless of the management history (i.e., remnant prairies, restored prairies, old fields, old pastures, new pastures, and crop fields) similarity between the aboveground vegetation and seed bank was lacking.

Management history clearly has an impact on the aboveground vegetation in terms of both richness and quality, however, the impact of land management history on the aboveground vegetation does not always translate across to the seed bank. For example, restoration sites and remnant sites had the highest floristic quality and species richness in their aboveground vegetation compared to the other land management histories. This result was expected because these sites are typically managed for a diverse assemblage of species. However, the clear differences found between these management histories and the other histories in the aboveground vegetation were less obvious in the seed bank due in part to similar original land management history (see NMDS discussion). In addition, given that even relatively undisturbed sites in this study (i.e., remnant prairies) showed a depauperate seed bank when compared to the aboveground vegetation, this result suggests that seed banks are simply less rich and of lower quality than their aboveground counterparts, regardless of management practices, or that the techniques in this study did not capture the full extent of the seed bank.
composition. Despite this wide trend, the aboveground vegetation of crop fields had fewer species and was less diverse than the seed bank of the other land management histories, though this is not a surprising outcome due to the intense management associated with these crop fields.

In regard to species richness and diversity, the management practices appear to have a direct effect on the richness and diversity of the aboveground vegetation and seed bank. For restorations, remnants, and old fields the lack of management activities designed to promote a limited suite of species (i.e., crops or pasture grasses) has resulted in a higher quality aboveground floristic component. While in crop fields, new pastures, and historical pastures there was much less richness and less diversity. However, compared to the aboveground vegetation, the seed bank richness of the remnants, restorations, and old fields was much lower and less diverse. A potential explanation for the lack of species richness in the seed bank is associated with modes of reproduction (i.e., sexual vs. asexual reproduction). There are many plants that do not rely strongly on seed for reproduction (Ott & Hartnett, 2011). These plants can be present in the aboveground vegetation, but since they do not rely heavily on seed for reproduction, they may not be present or have fewer seeds in the seed bank. For example, major prairie grasses such as *Andropogon gerardii* and *Sorghastrum nutans* reproduce vegetatively (McKendrick et al., 1975) as well as a number of prairie forbs such as *Vernonia baldwinii*, *Solidago canadensis*, *Pityopsis graminifolia*, and *Silphium speciosum* (Hartnett, 1990).

In this study several of the severely impacted land management types such as crop fields and both old and new pastures had higher FQI and mean C value in the seed bank.
than the aboveground vegetation, although not significantly higher. These land management types are so intensively managed (e.g., tilling, grazing) that the aboveground vegetation is actually less floristically rich than the seed bank flora. While not exceeding the aboveground vegetation, other studies of pastures have shown very similar levels of floristic richness in above and seed bank composition (López-Mariño et al., 2000) as well as variable weed densities in crop fields (Menalled et al., 2001). If the vegetation in these areas was allowed to grow without intensive management the results would potentially be more similar to the other sites in this study. For example, the old fields from this study are former pastures, and appear to have recovered from their previous intensive grazing. It is well known that abandoned crop fields will revert to a more natural state over time (Inouye et al., 1987). However, under current conditions, this management history is resulting in a more floristically diverse seed bank than the aboveground vegetation.

The non-metric multidimensional scaling (NMDS) shows that similar land management histories had similar aboveground vegetation and a much less similar seed bank composition (Figures 6 and 12). In addition, both of these NMDS show crop field sites are more separated than other land management histories. This result shows that the high degree of intensive management in crop fields sets them apart from other management types. The NMDS based on the seed bank demonstrated a lesser degree of similarity among the land management histories. This could be a result of the fact that the new pastures and restorations from this study share a similar history as both were converted recently from crop fields. There is a possibility that there is a lag time before a new cover type builds a seed bank that is representative of the aboveground vegetation.
Lastly the combined NMDS confirmed the lack of similarity between aboveground vegetation and seed bank (Figure 17). Other studies have found similar patterns when using this approach to compare remnant and restored prairies in Illinois (Sluis, 2002) and European grasslands (Török et al., 2009).

The balance of native to non-native species for different land management histories showed interesting results. The similar proportions of native to non-native species in restorations and remnants were unexpected (Table 1). Landscapes undergoing restoration typically have a broad suite of weedy pioneer species as well as higher quality restoration target species, so it was expected that restorations would have a higher ratio of non-native to native species (Wilson, et al, 2004). One possible explanation for the similar proportions of native to non-native species in restorations and remnants could be the variable quality among the different prairie remnant sites. While all remnant sites were managed to maintain the natural vegetation that persisted there, the management practices and approach varied over the course of recent history. Some sites were likely burned more often than others, or had varying degrees of prior grazing pressures. Without clear records, the exact influence of prior management efforts will remain unknown.

Although the FQI was similar between restorations and remnants for both seed bank and field vegetation, it should not be used as the only tool to evaluate them. When comparing aboveground vegetation no significant difference in FQI between restorations and remnant sites was found and this result should be a goal for restoration efforts. Nonetheless, personal observations showed a dramatic difference between remnant and restoration parcels. The abundance of weedy natives species such as Solidago
canadensis and early stage restoration species such as *Elymus canadensis* made it obvious to the trained eye that these areas were restoration efforts. This result supports the findings of Bowles and Jones (2006) that FQI is not a robust enough metric to discern subtle differences in the overall quality and level of disturbance of tallgrass prairie sites. Because FQI does not consider the abundance of any particular species it does not provide a full picture of the composition of a site.

The aboveground vegetation carried a higher proportion of the seed bank flora than vice versa. Many of the species found only in the seed bank are weedy colonizer species (e.g., *Digitaria sanguinalis*, *Euphorbia maculata*, *Mollugo verticillata*) or early flowering species (e.g., *Capsella bursa-pastoris*, *Cardamine hirsuta*, *Thlaspi arvense*) that may have senesced by the time the vegetation surveys occurred in July. It is possible that these species were present in the aboveground vegetation and they were simply missed during our surveys, or that they are persistent elements of the seed bank waiting for a significant disturbance event to colonize newly available habitat. Previous studies have established that weed emergence can depend highly on local conditions and recent land use history (Forcella et al., 1997; Smith & Gross, 2006). The large number of species present in the aboveground vegetation that were not expressed in the seed bank for the remnant, restoration, and old field sites was not surprising as it has been shown in other studies (McNicoll & Augspurger, 2010; Romo & Bai, 2004; Rosburg & Owens, 2004; Schott & Hamburg, 1997). It is unknown if these species were present in the seed bank but conditions were simply not right for germination, or whether the seed for these species was absent from our seed bank samples. An alternative explanation is that other factors are affecting seed production and thus affecting the seed bank. Today most
natural vegetation in Illinois exists as pockets in an otherwise heavily degraded landscape matrix (Warner, 1994). An absence or alteration of pollinators (Goulson et al., 2008), seed dispersers (Nathan & Muller-Landau, 2000), or a reduced genetic pool (Menges, 1991) could all lead to a lower than expected seed set. A reduced seed set for many species could result in fewer contributions to the seed bank, despite being present in the aboveground vegetation.

The heavy emergence of weedy species in the seed bank samples may possibly be an effect of the methods used in this study. Most weedy species are adapted to thriving in disturbed areas, which are typically characterized by bare soil and regular disturbance (Hobbs & Huenneke, 1992). A greenhouse tray full of soil being regularly watered fits these characteristics closely. The presence of these weedy species in the seed bank and their readiness to germinate given the proper conditions should be a source of concern for restoration practitioners. Vegetation emerging from the seed bank has been shown to impede restoration efforts (Larson et al., 2011). Likewise, studies from agricultural research have shown that weedy seed banks will vary depending on the management practices and have the potential to impact cropping efforts (Dessaint et al., 1997; Menalled et al., 2001). For the restoration practitioner, the good news is that management practices such as intensive site preparation by using herbicide application, tilling, and burning can help contain weedy species and help ensure a successful restoration (Blumenthal et al., 2005).

Two caveats are associated with this study. First, seed bank composition studies have limitations. At each step in the process of conducting a seed bank study there is the potential to miss species. A number of factors from determining the number of soil cores...
and size of soil core, to conditions used to stimulate seed germination (e.g., stratification, scarification, etc.), to other factors that cannot be replicated in the greenhouse, will all influence the outcome of a seed bank study. For these reasons, I follow the philosophy of Thompson and Grime (1979) that seed bank studies are “not designed to provide a complete assessment of the seed flora present”, but are still the best means available to determine the composition of the seed bank. Second, in addition to the traditional data analyses use to compare aboveground vegetation and seed bank, I used the interaction effect associated with the two way ANOVA to assess differences between the aboveground vegetation and seed bank and the interpretation of the results should be regarded with caution. Several aspects could influence seed emergence in the greenhouse as noted above and for these reasons a complete assessment of the seed bank is not possible. In addition, a onetime assessment of the above ground vegetation will miss some species. Nonetheless, the observed patterns of differences between the aboveground vegetation and seed bank have been observed in other grassland studies (Johnson & Anderson, 1986; McNicoll & Augspurger, 2010; Perez et al., 1998; Rabinowitz, 1981). Of interest is that the analysis is showing that in some cases the seed bank of a less intensely manage site can have more species and be of greater quality than the above ground vegetation of a more intensely manage site.

In conclusion, this study was able to detect differences in seed bank and aboveground vegetation based on species richness, FQI, mean C, Shannon diversity and NMDS. The lack of many species in the seed bank flora does not provide much hope for the recovery of lost species from seed bank sources. However, most of the man made disturbances in this study have been occurring for extended periods of time. Recently
disturbed habitats may still have some native seeds that can be prompted to germinate and thrive with proper management. From the findings of this study it appears that the use of seed banks as predictors of future states, or indicators of past states is highly unreliable and that efforts to learn more about field sites may be better focused on other components of the landscape. One encouraging outcome of this study was that the restoration efforts at Midewin National Tallgrass Prairie have resulted in remnants and restorations having aboveground vegetations that are indistinguishable from each other based on FQI and mean C values. This is an encouraging result for future restoration efforts, however there is still much to learn about the restoration process, as well as some previously mentioned shortcomings of the FQI. The results from the seed bank composition do not provide encouraging prospects for restoration. The few available methods for managing the seed bank directly are currently too costly for widespread utilization and potentially cost efficient methods such as microbial control of seeds or exploiting germination biology of seeds are still experimental (Davis, 2006). As a result of this, most weed seed management occurs only after the seeds have germinated into seedlings. Realizing the challenges presented by the seed bank is only part of the restoration effort and further research into dealing with the challenges of a problematic seed bank will help provide new tactics to maximize restoration potential. Chapter 3 will address the specific management recommendations for the aboveground vegetation and seed bank that could assist with the current management and restoration of the lands studied at Midewin National Tallgrass Prairie.

**Literature Cited**


Figure 1 - Location of transects used in the study

Legend
Research points
Treatment
- Crop field
- New pasture
- Old Field
- Old pasture
- Remnant
- Restoration
- Midewin Boundary
Figure 2: Mean aboveground vegetation species richness (±SE) by management history. Letters denote significant differences (α=0.05) among management histories. OF=old field, CF=crop field, NP=new pasture, C=old pasture, R=remnant, NR=restoration.
Figure 3: Mean aboveground vegetation FQI (±SE) by management history. Letters denote significant differences (α=0.05) among management histories. OF=old field, CF=crop field, NP=new pasture, C=old pasture, R=remnant, NR=restoration.
Figure 4: Mean aboveground vegetation mean C (±SE) by management history. Letters denote significant differences (α=0.05) among management histories. OF=old field, CF=crop field, NP=new pasture, C=old pasture, R=remnant, NR=restoration.
Figure 5: Mean aboveground vegetation Shannon diversity (±SE) by management history. Letters denote significant differences ($\alpha=0.05$) among management histories. OF=old field, CF=crop field, NP=new pasture, C=old pasture, R=remnant, NR=restoration.
Figure 6: Non-metric multidimensional scaling (NMDS) of presence of species in the aboveground vegetation by management history. A two dimensional solution was found after 42 iterations with a stress of 0.14515.
Figure 7: Percent of total seedling emergence in the greenhouse by week.
Figure 8: Mean seed bank species richness (±SE) by management history. Letters denote significant differences ($\alpha=0.05$) among management histories. OF=old field, CF=crop field, NP=new pasture, C=old pasture, R=remnant, NR=restoration
Figure 9: Mean seed bank FQI (±SE) by management history. Letters denote significant differences (α=0.05) among management histories. OF=old field, CF=crop field, NP=new pasture, C=old pasture, R=remnant, NR=restoration.
Figure 10: Mean seed bank mean C (±SE) by management history. Letters denote significant differences ($\alpha=0.05$) among management histories. OF=old field, CF=crop field, NP=new pasture, C=old pasture, R=remnant, NR=restoration.
Figure 11: Mean seed bank Shannon diversity (±SE) by management history. Letters denote significant differences (α=0.05) among management histories. OF=old field, CF=crop field, NP=new pasture, C=old pasture, R=remnant, NR=restoration.
Figure 12: Non-metric multidimensional scaling (NMDS) of presence of species in the seed bank by management history. A two dimensional solution was found after 22 iterations with a stress of 0.22225.
Figure 13: Mean species richness (±SE) by management history and survey location (i.e., above ground vegetation or seed bank). OF=old field, CF=crop field, NP=new pasture, C=old pasture, R=remnant, NR=restoration.
Figure 14: Mean FQI (±SE) by management history and survey location (i.e., above ground vegetation or seed bank). OF=old field, CF=crop field, NP=new pasture, C=old pasture, R=remnant, NR=restoration.
Figure 15: Mean mean C (±SE) by management history and survey location (i.e., above ground vegetation or seed bank). OF=old field, CF=crop field, NP=new pasture, C=old pasture, R=remnant, NR=restoration.
Figure 16: Mean Shannon diversity (±SE) by management history and survey location (i.e., above ground vegetation or seed bank). OF=old field, CF=crop field, NP=new pasture, C=old pasture, R=remnant, NR=restoration.
Figure 17: Non-metric multidimensional scaling (NMDS) of presence of species found in the combined aboveground vegetation and seed bank field. Aboveground samples are prefixed with F and seed bank samples are prefixed with G. A two dimensional solution was found after 28 iterations with a stress of 0.37119.
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<tr>
<th>Site</th>
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<th>% Native</th>
<th>% Non-Native</th>
<th>% Weedy Species</th>
<th>Total Richness</th>
<th>Graminoid richness</th>
<th>Forb richness</th>
<th>Woody species richness</th>
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<td>59.29%</td>
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<td>17.32%</td>
<td>51.97%</td>
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Table 1 (continued): Five most dominant species and summary floristic composition information by survey location and management history

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<tr>
<th>Above ground site</th>
<th>Species</th>
<th>Relative Frequency</th>
<th>% Native</th>
<th>% Non-Native</th>
<th>% Weedy Species</th>
<th>Total Richness</th>
<th>Graminoid richness</th>
<th>Forb richness</th>
<th>Woody species richness</th>
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<td>Cropfield</td>
<td><em>Glycine max</em></td>
<td>43.48</td>
<td>36.84%</td>
<td>63.16%</td>
<td>94.74%</td>
<td>19</td>
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<td><em>Chenopodium album</em></td>
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<td></td>
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<th>% Non-Native</th>
<th>% Weedy Species</th>
<th>Total Richness</th>
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<td><em>Oxalis stricta</em></td>
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<td>46.34%</td>
<td>53.66%</td>
<td>92.68%</td>
<td>41</td>
<td>9</td>
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<td><em>Solanum ptycanthum</em></td>
<td>21.32</td>
<td>57.14%</td>
<td>42.86%</td>
<td>96.43%</td>
<td>28</td>
<td>5</td>
<td>22</td>
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<tr>
<td></td>
<td><em>Daucus carota</em></td>
<td>14.34</td>
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<td>12.87</td>
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<td></td>
<td><em>Poa compressa</em></td>
<td>11.40</td>
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<tr>
<td></td>
<td><em>Setaria faberi</em></td>
<td>6.62</td>
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Table 1 (continued): Five most dominant species and summary floristic composition information by survey location and management history

<table>
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<tr>
<th>Seed bank site</th>
<th>Species</th>
<th>Relative Frequency</th>
<th>% Native</th>
<th>% Non-Native</th>
<th>% Weedy Species</th>
<th>Total Richness</th>
<th>Graminoid richness</th>
<th>Forb richness</th>
<th>Woody species richness</th>
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<tbody>
<tr>
<td>Old Field</td>
<td><em>Eupatorium serotinium</em></td>
<td>22.92</td>
<td>64.10%</td>
<td>35.90%</td>
<td>92.31%</td>
<td>39</td>
<td>9</td>
<td>29</td>
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<tr>
<td></td>
<td><em>Daucus carota</em></td>
<td>9.49</td>
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<tr>
<td></td>
<td><em>Poa compressa</em></td>
<td>6.32</td>
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<tr>
<td></td>
<td><em>Carex sp.</em></td>
<td>5.93</td>
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<tr>
<td></td>
<td><em>Oxalis stricta</em></td>
<td>5.93</td>
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<tr>
<td></td>
<td><em>Agrostis alba</em></td>
<td>4.35</td>
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<tr>
<td></td>
<td><em>Conobea multifida</em></td>
<td>4.35</td>
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<tr>
<td>Restoration</td>
<td><em>Mollugo verticillata</em></td>
<td>18.32</td>
<td>59.65%</td>
<td>40.35%</td>
<td>87.72%</td>
<td>57</td>
<td>14</td>
<td>42</td>
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<td></td>
<td><em>Setaria faberi</em></td>
<td>14.06</td>
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<tr>
<td></td>
<td><em>Veronica peregrina</em></td>
<td>10.65</td>
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<tr>
<td></td>
<td><em>Eupatorium serotininum</em></td>
<td>7.24</td>
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<tr>
<td></td>
<td><em>Aster pilosus</em></td>
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<td></td>
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<tr>
<td>Remnant</td>
<td><em>Aster pilosus</em></td>
<td>14.74</td>
<td>78.26%</td>
<td>21.74%</td>
<td>78.26%</td>
<td>46</td>
<td>13</td>
<td>33</td>
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<td></td>
<td><em>Eupatorium altissimum</em></td>
<td>7.89</td>
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<td></td>
<td><em>Juncus interior</em></td>
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<tr>
<td></td>
<td><em>Poa compressa</em></td>
<td>4.74</td>
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<tr>
<td></td>
<td><em>Solidago canadensis</em></td>
<td>8.95</td>
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</tr>
<tr>
<td>Cropfield</td>
<td><em>Chenopodium album</em></td>
<td>25.23</td>
<td>52.38%</td>
<td>47.62%</td>
<td>95.24%</td>
<td>21</td>
<td>2</td>
<td>18</td>
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<tr>
<td></td>
<td><em>Veronica peregrina</em></td>
<td>20.56</td>
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<tr>
<td></td>
<td><em>Oxalis stricta</em></td>
<td>10.28</td>
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<td></td>
<td><em>Populus deltoides</em></td>
<td>8.41</td>
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<td><em>Setaria faberi</em></td>
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Table 2: Species unique to survey location and shared species

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<th>Field only species</th>
<th>Greenhouse only species</th>
<th>Shared species</th>
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<tr>
<td>Acer saccharinum</td>
<td>Aristida oligosantha</td>
<td>Abutilon theophrasti</td>
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<td>Achillea millefolium</td>
<td>Capsella bursa-pastoris</td>
<td>Acalypha rhomboidea</td>
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<td>Agalinis tenuifolia</td>
<td>Cardamine hirsuta</td>
<td>Agrostis alba</td>
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<tr>
<td>Agrimonia parviflora</td>
<td>Carex tribuloides</td>
<td>Amaranthus tuberculatus</td>
</tr>
<tr>
<td>Agrimonia pubescens</td>
<td>Conobea multifida</td>
<td>Ambrosia artemisiaefolia</td>
</tr>
<tr>
<td>Agropyron repens</td>
<td>Cyperus esculentus</td>
<td>Ambrosia trifida</td>
</tr>
<tr>
<td>Allium cernuum</td>
<td>Cyperus strigosus</td>
<td>Aster pilosus</td>
</tr>
<tr>
<td>Andropogon gerardii</td>
<td>Descurania sophia</td>
<td>Barbarea vulgaris</td>
</tr>
<tr>
<td>Antennaria neglecta</td>
<td>Digitaria sanguinalis</td>
<td>Brassica sp.</td>
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<tr>
<td>Apocynum cannabinum</td>
<td>Euphorbia maculata</td>
<td>Carex sp.</td>
</tr>
<tr>
<td>Asclepias incarnata</td>
<td>Fragaria virginiana</td>
<td>Cassia fasciculata</td>
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<td>Asclepias sullivantii</td>
<td>Juncus interior</td>
<td>Cerastium vulgatum</td>
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<tr>
<td>Asclepias syriaca</td>
<td>Lycopus americana</td>
<td>Chenopodium album</td>
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<td>Asclepias verticillata</td>
<td>Medicago lupulina</td>
<td>Cirsium arvense</td>
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<tr>
<td>Aster azureus</td>
<td>Mollugo verticillata</td>
<td>Conyza canadensis</td>
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<td>Aster ericoides</td>
<td>Nepeta cataria</td>
<td>Dactylis glomerata</td>
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<td>Aster laevis</td>
<td>Panicum clandestinum</td>
<td>Daucus carota</td>
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<td>Aster novae-angliae</td>
<td>Panicum dichotomiflorum</td>
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<td>Aster simplex</td>
<td>Panicum implicatum</td>
<td>Dicanthemium sp.</td>
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<td>Baptisia lactea</td>
<td>Penthorum sedoides</td>
<td>Echinochloa muricata</td>
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<td>Bidens sp.</td>
<td>Populous deltoides</td>
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<td>Bromus inermis</td>
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<td>Bromus japonicus</td>
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<td>Erigeron philadelphicus</td>
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<td>Calystegia sepium</td>
<td>Thlaspi arvense</td>
<td>Eupatorium altissimum</td>
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<tr>
<td>Carex annectens</td>
<td>Verbascum thaspus</td>
<td>Eupatorium serotinum</td>
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<tr>
<td>Carex bicknellii</td>
<td></td>
<td>Festuca pratensis</td>
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<tr>
<td>Carex brevior</td>
<td></td>
<td>Fragaria virginiana</td>
</tr>
<tr>
<td>Carex crawei</td>
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<td>Geum laciniatum</td>
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<td>Carex granularis</td>
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<td>Hibiscus trionum</td>
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<td>Carex gravida</td>
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<td>Juncus dudleyi</td>
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<td>Carex lanuginosa</td>
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<td>Juncus tenuis</td>
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<td>Lepidium sp.</td>
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<td>Carex vulpinoidea</td>
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<td>Oenothera biennis</td>
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<td>Chamaesyce maculata</td>
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<td>Panicum sp.</td>
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<td>Cirsium discolor</td>
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<td>Penstemon digitalis</td>
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### Table 2 (continued): Species unique to survey location and shared species

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<thead>
<tr>
<th>Field only species</th>
<th>Shared species</th>
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<tbody>
<tr>
<td>Cirsium vulgare</td>
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<tr>
<td>Comandra umbellata</td>
<td>Phyla lanceolata</td>
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<td>Convulvulus arvensis</td>
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<td>Coreopsis tripteris</td>
<td>Plantago rugelii</td>
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<td>Crataegus crus-galli</td>
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<td>Crataegus mollis</td>
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<td>Ranunculus abortivus</td>
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<td>Dalea purpurea</td>
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<td>Rumex crispus</td>
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<td>Dichanthelium acuminatum fasciculatum</td>
<td>Schizachyrium scoparium</td>
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<td>Eragrostis sp.</td>
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<td>Galium obtusum</td>
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<td>Geum canadense</td>
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<td>Glycine max</td>
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<td>Helianthus rigidus</td>
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<tr>
<td>Heliopsis helianthoides</td>
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</tbody>
</table>
Table 2 (continued): Species unique to survey location and shared species

**Field only species**

- *Hordeum jubatum*
- *Hypericum punctatum*
- *Hypericum sphaerocarpum*
- *Ipomoea hederacea*
- *Juncus sp.*
- *Juncus torreyi*
- *Koeleria macrantha*
- *Kummerowia stipulacea*
- *Lactuca canadensis*
- *Lactuca serriola*
- *Lactuca sp.*
- *Leersia oryzoides*
- *Leucanthemum vulgare*
- *Leucospora multifida*
- *Liatris pycnostachya*
- *Liatris sp.*
- *Liparis liliifolia*
- *Lobelia spicata*
- *Lotus corniculatus*
- *Lycopus americanus*
- *Lycopus uniflorus*
- *Lysimachia lanceolata*
- *Lysimachia nummularia*
- *Lythrum alatum*
- *Maclura pomifera*
- *Malus ioensis*
- *Medicago lupulina*
- *Medicago sativa*
- *Melilotus alba*
- *Melilotus officinalis*
- *Monarda fistulosa*
- *Morus alba*
- *Parthenium integrifolium*
- *Pastinaca sativa*
- *Penstemon pallidus*
- *Physalis sp.*
- *Physalis subglabrata*
- *Physostegia virginiana*
- *Polygonum hydropiper*
Table 2 (continued): Species unique to survey location and shared species

**Field only species**

- *Polygonum ramosissimum*
- *Polygonum sp.*
- *Potentilla simplex*
- *Prunella vulgaris*
- *Prunus serotina*
- *Pycnanthemum sp.*
- *Rhamnus cathartica*
- *Rosa carolina*
- *Rosa multiflora*
- *Rosa setigera*
- *Rudbeckia subtomentosa*
- *Salix exigua*
- *Sanicula canadensis*
- *Scirpus atrovirens*
- *Scirpus pendulus*
- *Scirpus sp.*
- *Scutellaria galericulata*
- *Scutellaria sp.*
- *Senecio plattensis*
- *Silphium integrifolium*
- *Silphium laciniatum*
- *Silphium perfoliatum*
- *Silphium terebinthinaceum*
- *Sisyrinchium albidum*
- *Smilacina stellata*
- *Solanum carolinense*
- *Solanum sp.*
- *Solidago gigantea*
- *Solidago rigida*
- *Solidago sp.*
- *Stellaria media*
- *Stellaria sp.*
- *Thymelaea passerina*
- *Tomanthera auriculata*
- *Toxicodendron radicans*
- *Tradescantia ohiensis*
- *Tragopogon pratensis*
- *Ulmus americana*
- *Vernonia fasciculata*
<table>
<thead>
<tr>
<th>Field only species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vernonia gigantea</td>
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<tr>
<td>Veronica spp.</td>
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<td>Viola sororia</td>
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<tr>
<td>Vitis riparia</td>
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<td>Vitis sp.</td>
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<tr>
<td>Zizia aurea</td>
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</tbody>
</table>
Chapter 3: Management Recommendations

The Midewin National Tallgrass Prairie (MNTP) is the largest block of protected open space in the Chicago area with a total of 10,040 acres (4063 hectares) to be restored (MNTPLRMP, 2002). Although the ultimate goal of this large scale prairie restoration is to eventually turn the entire site into a matrix of native species some grazing areas for grassland bird habitat and agricultural fields have been maintained (MNTPLRMP, 2002). In this study the standing vegetation and seed bank composition for six different land management histories (restored prairie, remnant prairie, new pasture, old pasture, old field, and crop field) were studied at MNTP. Though the main finding of this study was that there is a lack of correspondence between above and below ground vegetation; by studying the above ground vegetation and seed bank of each individual management history, management recommendations can be made to assist with the current management and restoration of these lands at MNTP.

Crop field sites stood out more than any of the other management histories in this study as the result of an extremely depauperate flora in both above ground vegetation and seed bank. The lack of undesirable vegetation is indicative that current weed management practices are having their desired effect. The vegetation surveys were conducted during the rotation of Roundup Ready soybeans. Standard practices to maximize soybean yield include multiple applications of a broad spectrum herbicide during the growing season. This practice seems to be highly effective in reducing both the above ground vegetation as well as depleting the seed bank. Additionally, this management approach will help create a suitable foundation for whichever land use follows row crops. Land managers prefer to restore prairie planted on former soybean
fields because they find it to be the easiest land cover to convert (Rowe, 2010). Converting row crop fields to pasture will also likely be successful due to a lack of weedy competition. Despite providing little wildlife habitat and having a flora nearly devoid of native species, maintaining areas as crop fields under a management routine of Roundup Ready soybeans and winter wheat rotation provides a predictable, profitable, and easy to maintain landcover.

On the other end of the spectrum, remnant areas showed some of the highest native plant richness both in the seed bank and in the above ground vegetation. These areas are being maintained regularly by a variety of practices. Non-native invasive species are removed via herbicide, mowing, or brush cutting (MNTPLRMP, 2002). Native species are encouraged by burning and periodic brush removal when necessary. The management practices for these areas seem to be having a positive impact on the local aboveground flora. In addition these management practices also seem to be reducing the number of weeds present at the prairie remnant sites. Maintaining the quality in these areas will require continuing with the current management practices. Regular burning is critical to maintaining a high quality prairie (Bowles et al, 1996; Rooney & Leach, 2010; Van Dyke et al., 2004) and staying vigilant for potential invaders will help keep remnant areas high quality. If fire is not possible due to administrative or atmospheric issues, mowing can be a suitable alternative to fire. The disturbance provided by limited mowing at certain times of year effectively mimics the effects of fire (Hover & Bragg, 1981), and while not a perfect solution, this can help maintain areas over the short term until fire can be returned to the landscape. The quality present within remnant prairies should be a goal and a comparison point for other restorations.
Restoration sites that were a part of the study showed a blend of weedy species as well as prairie species. These restorations are all in the relatively early stages (less than 10 years old) after being converted from crop fields. There was abundant floristic richness at these sites, however, it was almost evenly split between desirable native species, and undesirable weedy species (see Chapter 2). Proper management such as mowing early stage restoration to reduce the vigor and seed set of weedy annuals is a critical management practice (Wilson 2001). Applying prescribed fire as soon as there is sufficient fuel to carry the fire is another management practice that will greatly benefit the desirable natives while setting back the undesirable weedy species (Heslinga & Grese, 2010). Not all weedy species are negatively impacted by fire or mowing. To prevent young restorations from getting overrun by species with similar responses to disturbance as prairie plants, a routine of herbicide targeting likely weed species in early restorations is advisable to keep problematic species from gaining a foothold in early stage restorations. These treatments should especially target perennial species that may become long-term problems rather than annual species that typically see population booms after a major change in land use and then gradually decline.

The seed bank of restorations had floristic quality characteristics that were significantly different from those of pastures or crop fields (Chapter 2, Figure 9, Figure 10) and also had a higher percentage of native species and lower percentage of weedy species (Chapter 2, Table 1). Based on these results it appears that restorations are developing seed banks that are higher quality and more appropriate to prairies than other management types. They still lag behind in comparison to the seed banks for remnants, however. This result is encouraging from a management perspective because it shows
that restorations should be increasingly resilient to impacts and disturbance since their seed bank is similar to prairies, rather than other management types.

Both old pastures and new pastures showed similar results in this study as their seed banks and the above ground vegetation were lacking in species. High quality species, or remnant prairie species were absent and over 90% of the observed species were weedy (Chapter 2, Table 1). There are a few possible reasons for this result. Intense grazing pressures may select for a limited suite of species. Another possible reason is that similar, common pasture species may be used for supplemental plantings within the pastures. Yet another possible reason is that the vegetative growth of pasture grasses (i.e., buds and tillers) may compensate for the lack of seed bank flora. An unexpected finding for both old and new pastures was the limited number of undesirable invasive species both the seed bank and the above ground vegetation. While there were plenty of species considered invasive in prairies or natural areas, the pasture grasses in these fields should not be considered weeds as they were purposely planted in these areas for grazing. Maintaining periodic herbicide treatment of undesirable forage species such as thistles will help ensure that the pastures continue to be productive for grazing. If these areas are to be converted to prairie at some point, it may be best to put them into row crops for a short time before converting them to prairie. The amount and quality of native vegetation in these areas is negligible, however, the pasture grasses that are present can create considerable competition for seedling prairie plants.

Old fields present an interesting challenge for management at MNTP. While their current management is nothing more than occasional mowing to reduce the amount of woody species present, they do contain a fair number of quality native species such as
Asclepias sullivantii, Schizachyrium scoparium, and Ratibida pinnata (Chapter 2, Table 1). These species would be desirable in a restoration project, however, the seral fields also have a high number of undesirable weedy species such as Cirsium arvense, Dipsacus laciniatus, and Elaeagnus umbellata (Chapter 2, Table 1). It is possible that these areas can serve as enrichment zones or satellites (Collins & Glenn, 1990; Gotelli & Simberloff, 1987). They can be seeded with desirable species concurrently while targeting undesirable species with herbicide. This approach may result in maintaining some of the existing native character while providing a richer flora. A second approach would be to simply wipe the area clean of existing vegetation by converting these areas to row crop for a number of years and starting over with a native seed mix. Both approaches have their pros and cons, and the best approach is best chosen depending on the ultimate goals of the restoration.

Management recommendations for managing seed banks directly are harder to provide based on this study and the existing body of research. Although managing weed seed banks directly has shown to be a potentially effective practice, feasible methods to accomplish this are currently lacking (Davis, 2006). Potential approaches to directly manage the seed bank include management practices to make seed more available to predators (Westerman et al., 2006), microbial control of seed bank seeds (Hallett, 2005), steaming soil to kill undesirable seeds prior to germination (Melander & Jørgensen, 2005), and manipulating germination of weed seeds through management practices so that the weed seeds germinate at times that are not advantageous to survival (Dyer, 1995). These approaches have been studied in an agricultural setting and not in a restoration management setting, so their efficacy remains unknown. Ultimately, the best way to
approach controlling the seed bank may be to address the previous generation of plants in order to reduce their seed output (Gallandt, 2006). Further research is needed on these methods to see if they are practical for managing restorations and also to develop new methods to directly manage the seed bank.

In conclusion by studying the standing vegetation and seed bank composition for six different land management histories at MNTP this study provided valuable insight into the relationship between the seed bank and standing vegetation. The knowledge of what is present, and not present, in seed banks will help natural area managers make decisions about what type of seed mixes are to be used in restoration efforts. Although it does not seem from this study that seed banks will provide a high degree of native richness, managers at MNTP are now armed with this knowledge and can plan accordingly. Ultimately, it seems that there is still a good deal to be learned about the nature of seed banks, and further research on this topic will provide invaluable insight.

**Literature Cited**


## Appendix A: Species presence by survey location and management history

OF=old field, CF=crop field, NP=new pasture, C=old pasture, R=remnant, NR=restoration

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<th>Species</th>
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### Appendix A (continued): Species presence by survey location and management history

OF=old field, CF=crop field, NP=new pasture, C=old pasture, R=remnant, NR=restoration

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### Appendix A (continued): Species presence by survey location and management history

**OF=old field, CF=crop field, NP=new pasture, C=old pasture, R=remnant, NR=restoration**

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Appendix A (continued): Species presence by survey location and management history

OF=old field, CF=crop field, NP=new pasture, C=old pasture, R=remnant, NR=restoration

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## Appendix A (continued): Species presence by survey location and management history

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## Appendix A (continued): Species presence by survey location and management history

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## Appendix A (continued): Species presence by survey location and management history

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<tr>
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<th>Seed bank</th>
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<tbody>
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## Appendix A (continued): Species presence by survey location and management history

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<td>Seed bank</td>
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<td><strong>Seed bank</strong></td>
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<td>Vitis riparia</td>
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<td>Zizia aurea</td>
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</table>
Appendix B: Two way ANOVA results

Table B.1: Two way ANOVA showing differences for species richness by management history ([MH] i.e., crop field, old field, new pasture, old pasture, remnant, or restoration) and survey location ([SL], i.e., above ground vegetation or seed bank).

<table>
<thead>
<tr>
<th>Factor</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>P</th>
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<tr>
<td>SL</td>
<td>1</td>
<td>2996.267</td>
<td>2996.267</td>
<td>65.492</td>
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</tr>
<tr>
<td>MH</td>
<td>5</td>
<td>4665.333</td>
<td>933.067</td>
<td>20.395</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SL x MH</td>
<td>5</td>
<td>1562.133</td>
<td>312.427</td>
<td>6.829</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Residual</td>
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<td>2196.000</td>
<td>45.750</td>
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</tr>
<tr>
<td>Total</td>
<td>59</td>
<td>11419.733</td>
<td>193.555</td>
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</table>
Appendix B (continued): Two way ANOVA results

Table B.2: Two way ANOVA showing differences for FQI by management history ([MH] i.e., crop field, old field, new pasture, old pasture, remnant, or restoration) and survey location ([SL], i.e., above ground vegetation or seed bank).

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>DF</th>
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<th>F</th>
<th>P</th>
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<tbody>
<tr>
<td>SL</td>
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<td>280.696</td>
<td>5.848</td>
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<td>Total</td>
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<td>2003.600</td>
<td>33.959</td>
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</table>
Appendix B (continued): Two way ANOVA results

Table B.3: Two way ANOVA showing differences for mean C by management history ([MH] i.e., crop field, old field, new pasture, old pasture, remnant, or restoration) and survey location ([SL], i.e., above ground vegetation or seed bank).

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>DF</th>
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<th>MS</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>MH</td>
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<td>SL x MH</td>
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<td>Residual</td>
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<td>6.864</td>
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Table B.4: Two way ANOVA showing differences for Shannon diversity by management history ([MH] i.e., crop field, old field, new pasture, old pasture, remnant, or restoration) and survey location ([SL], i.e., above ground vegetation or seed bank).

<table>
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<th>Source of Variation</th>
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<td>SL x MH</td>
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