Final Report
Biological Inventory and Other Studies at Spirit Mound
Summers 2003-2004

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Project Overview

This report describes studies conducted at Spirit Mound Historic Prairie in the summers of 2003 and 2004. Our goals were to provide the State of South Dakota Game, Fish, and Parks (SD GF&P) with an inventory of plant and selected insect species as well as to establish baseline data on soil quality, plant production, and variation in these around the 320-acre site. Funding for the study was provided by a SD GF&P Small Wildlife Diversity Grant, The Sierra Club, the Spirit Mound Trust, and the National Science Foundation-supported Lewis and Clark REU site at the University of South Dakota.

Background

A prairie is defined as "an open community, dominated by grass, and having less than one tree per acre." [1] Before 1850, the great mid-continental grasslands, or prairies, covered much of the interior United States. They stretched from southern Wisconsin to western Montana, and from central Texas to Canada.[2] The tallgrass prairie covered 250 million acres of the Midwest for thousands of years, including southeastern South Dakota. Today less than one percent of that original prairie remains, and it is found mostly along roadsides, railroads, rivers, and on steep hills[3]. The other 99% has been lost to agriculture and development. These losses "exceed those reported for any other major ecological community in North America."[4] Prairies are valuable in terms of aesthetics, as habitat, and as a means of erosion and flood control and other ecosystem services. The challenge now is to determine mechanisms to return the land to the way it was before the introduction of the plow.

Attempts at prairie restoration began in the 1930's at the University of Wisconsin-Madison Arboretum.[1] Although it has been practiced for several decades, prairie restoration "involves much of the ongoing experimentation and trial of ideas characteristic of a young, rapidly developing discipline"[1] and the "success of many prairie restorations is not well documented."[5] Most prairie restorations follow the same basic guidelines (e.g see Kilde[6]). Although initial results can be observed in just a few years, it is anticipated that prairie restorations will take many years to restore aspects of a native prairie, such as the plants and invertebrate communities, soil structure, and vertebrate populations.[4] It is possible and very likely that some aspects of the native prairie system will never be completely restored because of changes in species complexes, fragmentation, climate, fire frequency, or other important disturbance factors.[4,5]

Spirit Mound is one of only a few of the areas that we know with certainty that Lewis and Clark visited. Many of the other areas along their route are now covered by water

because of the natural wandering of the Missouri River over the course of this 200-year period and because of the channelization of the river in most areas. The restoration at historic Spirit Mound is an effort to recreate the native tallgrass prairie that once existed at this site. On April 14, 1986, the Lewis and Clark-Spirit Mound Trust formed in an attempt to convert the site from agricultural fields, building sites, and a feedlot, back to what it once was, a functional tallgrass prairie. The mission of the Spirit Mound Trust (SM Trust) was to "acquire the 320-acre Spirit Mound site, restoring it as closely as possible to the tallgrass prairie of 1804, and making it freely accessible to the public." With the help of United States Senator Tim Johnson (D-SD), the National Park Service (NPS), and the SD GF&P, the group petitioned for federal funds necessary to purchase the site and reunite it under a single owner. Since the restoration began in 2001, the SM Trust, NPS, and SD GF&P, along with the University of South Dakota, have remained involved with various aspects of the restoration.

Spirit Mound is now managed by the SD GF&P in partnership with the NPS and the SM Trust. The site was planted with a prairie seed mix purchased from Ion Exchange in Harpers Ferry, Iowa in the fall of 2001. Four different seed mixes were selected and planted in different areas at Spirit Mound (Appendix I). The seed mix that was used for the majority of the acres (227-acre Mesic Prairie Mix) was the least diverse of the three main mixes, and is suited to the mesic habitat that is found surrounding the mound. Species in this mix, which contained nine native grass and 19 native forbs, were chosen to emphasize tall and showy wildflowers. The second and most diverse mix (10-acre Mesic/Xeric Mix) was planted in 50-foot strips on either side of the walking trail, for a total area of 10 acres.[8] This mix included nine native grasses and 27 native forb species. The third seed mix (10-acre Wetter Mix) was for a small area in the Northeast portion of the site, about 10 acres in size, which had been identified as a wetland. This mix included species that are better adapted to seasonally wet prairies, and was comprised of three grasses and 13 forbs. The final mix (40-acre Xeric Mix, eight grasses and 26 forbs) was for the mound itself. This mix, with plants better adapted to the steeper slopes and drier soils, was used for approximately 40 acres.[8] Additionally, five grass species and 16 forb species were planted as plugs on the east side of the mound in an area of approximately 10 acres.

Seeds were planted at various seeding rates (Appendix I), depending on the mix, in the fall of 2001 and spring of 2002. The fluffy seed was planted using a Truax drill, while the heavy seed was not drilled, but was dropped by disconnecting the drop tubes prior to the seed reaching the drilling mechanism (Mark Steck, personal communication). The east slope of the mound was hand-planted with prairie plugs in the spring of 2003 because of the steep slope in that area, which could not be accessed by the drill. Interseeding with the original seed mixes was done as needed throughout the prairie. Various sections of the site were mowed after plants became established to prevent the weed species from setting seed. Additionally, herbicide was spot sprayed throughout the growing season on problem weeds that could not be effectively controlled with mowing. The western portion of the mound was burned in the spring of 2003, and the eastern portion was burned in the spring of 2004 to stimulate the growth of native plants and help control weedy species.

Monitoring programs are a necessary part of any restoration project to determine the success of the restoration, and to determine whether the current management strategies are effective, or if they need to be modified. [1,9,10,11] Sprit Mound Historic Prairie was planted and is managed by the SD GF&P. However, SD GF&P does not have the necessary staffing to conduct a monitoring program of the area and accepted a proposal for an inventory and monitoring program. The purpose of this project was to provide the SD GF&P with information regarding the establishment of planted species, a biological inventory, and to evaluate the likelihood of the restoration's success. This report is based in large part upon a graduate thesis[12] resulting from the project.

Several different aspects of prairie composition and production were studied to determine the overall success of the restoration effort. We addressed the following: What prairie and non-prairie species are present? Which of the originally planted species became established? Do species richness and cover increase over the season or between years? Do they vary among the different sampling plots? Do they increase interannually? Does the ratio of forbs to grasses shift? Is there spatial variation in productivity throughout the prairie, and is this tied to prior land use histories?

We expected plant species richness and total plant cover to increase both throughout the season and interannually during the first few years of the restoration, but to then decrease as the restoration progresses.[5,13] With productivity, it is assumed that this will also increase over the season and interannually, as the plants grow and become better established in the area. Long-term changes in forb and grass biomass are expected to vary as a function of burning, mowing, and other factors.[1, 5,13,14]

Methods

Plant Species Inventory, Richness, and Cover: A plant species inventory was conducted to determine the presence/absence of native, invasive, and planted species at Spirit Mound Historical Prairie as suggested by Masters.[15] Plant sampling began in the summer of 2003. The prairie was divided into different areas based on previous land ownership, and transects were established in each of these areas. Transect locations were recorded using handheld GPS (Compass v.5.1b), which was later used to relocate each transect. Standard plant ecology methods[16] were used and plants were inventoried along thirteen permanent 100-meter line transects, in seven different sites throughout the prairie (Figs. 1a and 1b). Each transect was subdivided into 10-m sections, and within each 10-m section a 1-m^2 sampling frame was placed in front of a marker flag. Every plant species inside the 1-m^2 quadrat was recorded. The percent of the area within the frame that was covered by living plants was estimated by the observer and also recorded.

Additionally, we used a modified pin-frame method to determine the relative abundance of different plant species within each quadrat.[17] The pin frame (or point frame) is a wooden frame one-meter in length with ten evenly spaced holes across the top. A pin is inserted into each hole and every species of plant (or bare ground) that contacts a pin is recorded, as well as the number of pins that touch each species. In our study, we did

not differentiate between basal or foliar cover. Due to the large number of quadrats to be sampled (> 130), we evaluated cover for 10 pins per plot in contrast to the 100 pins/plot that is often recommended.

Plants were identified using various field guides for the Great Plains region (see Appendix II). Any plants that could not be identified were given a unique designation as an unknown and digitally photographed. These images were then entered into a database and were identified later in the growing season after the plant had flowered. In August 2003, Dr. Ted Van Bruggen, Emeritus Professor of Biology (USD) and expert on the flora of the Northern Great Plains toured Spirit Mound Historic Prairie with us and confirmed our plant identifications.

The plant species inventory was repeated once each month in June, July, and August, with the exception of Transect 5. This transect was not recorded after June because the area was sprayed with Roundup herbicide and then mowed to control the weed problem in that area.

In 2004 we added two more transects for a total of 14 (transect 5 still excluded), one on the west side of the site, which was previously unsampled, and one in the feedlot area on the east side of the site (Fig. 1b). Transects were again sampled once a month in June, July, and August. Data from transects within each year and within each area were combined and referred to as 'sites'. For example, the two transects in the southwest plot were referred to as Site 1 in both 2003 and 2004. Species richness was evaluated using a paired t-test comparing richness between years 2003 and 2004 within each site.

For several analyses, plants were classified as prairie forbs, prairie grasses, non-prairie forbs, or non-prairie grasses as determined by The Flora of the Great Plains[14] which was also used for all scientific nomenclature.

We compared the percent cover, as determined using the pin-frame method, of prairie forbs, prairie grasses, non-prairie forbs, and non-prairie grasses using a three-way analysis of variance (ANOVA) with the effects of year, month, and site, and their interactions as independent variables. When ANOVA's were significant, we used a Bonferonni t-test to compare percent cover among different sites, months, and/or years. SAS Version 8 was used for all statistical analyses.[18]

To evaluate the variability in relative cover among different plant species, we evaluated the percent cover by site with a two-way ANOVA (month and year) for species that were either desired prairie species or problem non-prairie species that appeared to be common around the site. Native prairie-grass species analyzed included Big Bluestem, Little Bluestem, Canada Wild Rye, Indian Grass, and Side-Oats Grama. Non-prairie grasses analyzed were Green Foxtail and Yellow Foxtail. Prairie forbs included in the analysis were Wild Bergamot, Black-Eyed Susan, Stiff Goldenrod, Hoary Vervain, Blue Vervain, and Gray-headed Coneflower. Non-prairie forbs included Prickly Lettuce and Horseweed.

We used a Spearman-Rank correlation to determine if our rough estimates of cover (visually estimated percent area within the 1-m^2 frame covered by plants) corresponded to the percent cover as determined by the pin-frame method.

Biomass Sampling: We sampled vegetative biomass on a monthly basis to determine the relative production of different sites within Spirit Mound Historic Prairie and the percentage of both grass and forb biomass present throughout the season. For biomass sampling, the prairie was divided into five sampling regions (Southwest, Northwest, Northeast, Creekside, and East Mound) that roughly approximated the sites used in the transect sampling (Fig. 1b). Within each region, four 1-m^2 plots were haphazardly chosen, and all the above ground biomass was clipped at the base using electric or manual clippers. The location of these four plots within each site varied by month. The plant material was separated into grasses and forbs (dead plant material was excluded), placed into paper bags, and returned to the lab for drying. Biomass samples were dried to a stable dry weight (length of drying varied with bulk of biomass and moisture present when collected). Samples were then weighed and recorded. We conducted biomass sampling in June, July, August, and September. In 2004, we used the same regions for biomass sampling, but instead sampled in May, June, July, and August because the prairie production seemed to begin earlier than in the previous year. We evaluated differences in grass, forb, and total biomass among regions, months (June, July, August), and years using a three-way ANOVA.

Soil Sampling and Land-Use Histories: Soil samples were collected in October 2003 to determine the effect of differences in the soil composition and previous land-use history on the types of plant species, both prairie and non-prairie, growing in each sample location, and the overall restoration success of that location. The following soil sampling protocol follows the recommendations of the Natural Resources Conservation Service (Deron Ruesch, District Conservationist, NRCS, personal communication).

For soil sampling, the prairie was divided into nine areas that roughly corresponded to those of the plant species inventory (Fig. 1c), with the addition of one area that was sprayed with herbicide in 2003 (southeast corner, 5-1 in Fig. 1c). Two samples were taken in each of these areas. For each sample, 20 soil cores were taken using a soil-sampling probe that takes cores approximately 2.5 cm (1") in diameter at two depths, 0-15.24 cm and 15.25-60.96 cm (0-6" and 6-24"). The 20 cores from each sample were mixed together to make one representative sample for each depth. The samples were sent to the SDSU Soil Testing Laboratory for determination of the levels of nitrate-nitrogen, phosphorus, potassium, pH, soluble salts, texture, and organic matter. The resulting levels were averaged for each sampling plot. We were unable to statistically compare these due to low replication (only two samples from several cores that were mixed).

Butterfly Sampling: Butterflies are considered good indicator species for prairies and are of keen interest to the public.[19,20] Therefore, butterfly sampling was conducted to determine which butterfly species are present at Spirit Mound, with special attention

given to the Regal Fritillary (*Speyeria idalia* Drury (Lepidoptera: Nymphalidae)), which was observed and digitally recorded, but not collected.

Butterfly species were inventoried at several sites throughout the prairie by direct observation, photographs taken while doing other sampling, and by direct capture with butterfly nets. Sampling was rather informal, with a few hours during the morning spent collecting different species seen once each month. Standard collection procedures were followed to collect butterflies. Representative individuals were placed into glassine envelopes and mounted in a reference collection. Butterflies were only collected in the summer of 2003.

We reviewed species observed to determine which butterfly species were present and whether there were any prairie specialists at the site. We also sampled terrestrial invertebrates but these samples have not yet been sorted or identified to lowest taxonomic level.

Birds: As part of this project, we solicited support for an avian survey at Spirit Mound in summer 2003. Methods used in avian surveys can be found in the recent publication in *South Dakota Bird Notes.*[21] The avian survey was not directly supported by this SD GF&P contract.

Results and Discussion

Plant Species Inventory, Richness, and Cover: In 2003, over 100 different species of plants were observed and identified at Spirit Mound, as well as a few unknowns that could not be identified to species. Of those that were identified, the majority were native tallgrass prairie species representative of the mixes that were planted (Table 1). Also, nearly all of the planted species in all mixes were observed, with only a few species from the wetland mix not observed. The '227-acre mesic-prairie mix', which was planted on most of the site (Appendix I), contained only three grass species and three forb species that were not observed: rough dropseed, prairie dropseed, porcupine grass, showy goldenrod, smooth blue aster, and round-headed bushclover.

We observed a few new plant species in 2004, including large-flowered beard-tongue, poison ivy, ten-petal blazing star, silky aster, sky blue aster, and smooth blue aster as well as a few additional unidentified species. There were also a few species that were not observed in 2004 that had been seen the previous year, including Rocky Mountain bee plant, little knotweed, dwarf indigo, toothed spurge, false boneset, blue grama grass, sand bur, and pepper grass.

In 2003 and 2004 combined, 132 total species were observed and identified, along with some other species that could not be positively identified to species (Table 1). In both years combined, there were 97 unknowns, most of which were later identified to species and included in the analysis. Out of all of the identified species, 61% (n=81) were tallgrass prairie species native to this area as determined by *Flora of the Great Plains.*[14] Of these native tallgrass prairie species observed, 35% (n=28) were not a part of any of

the seed mixes used in the restoration. A total of 53 different species were intentionally planted from all four mixes combined. Of these, 74% of the forbs (n=43) and 70% of the grasses (n=10) were observed in at least one of the two years. The 14 species (total from all mixes) that were not observed in either year included three grasses (rough dropseed, prairie dropseed, porcupine grass) and eleven forbs, most of which were from the wetland mix or were planted as plugs. From the three main seed mixes used to plant the prairie (Xeric, Mesic/Xeric, and Mesic), 86% of the planted species were observed.

These data indicate that many different prairie species can germinate in just a few years, although some prairie species may take several years to germinate.[1] The low establishment rates of the planted wetland species suggest that the area that was formerly a wetland may no longer be as well suited for growing plants adapted to these wetter conditions as it once was.

No significant differences in plant species richness existed between years (paired on site; $t = 0.412$, $P > 0.05$).

The percent cover of prairie forbs, prairie grasses, non-prairie forbs, and non-prairie grasses were also evaluated. A three-way ANOVA indicated that the main effects of year ($F_{1,704} = 11.03$, $P < 0.001$) and site ($F_{5,704} = 15.5$, $P < 0.001$) were the only significant predictors of prairie-forb cover. Prairie forb cover was lower in 2003 (6.11 ± 0.579%) than in 2004 (9.48 ± 0.752%). In 2003, Sites 1 and 2 (Southwest and East Mound, respectively) had the highest percentages of prairie-forb cover, which was less than 15% in all months. All of the remaining sites had on average than 6% prairie forb cover. Similar patterns were observed in 2004, with the highest percentages of prairie forbs again in Sites 1 and 2, and Site 7 (new sampling area in 2004) also having a higher percentage of prairie forbs than the remaining areas (Fig. 2).

A significant interaction of year by site existed for non-prairie forbs ($F_{5,704} = 12.06$, $P < 0.001$), but the greatest percentage of explainable variation was due to differences among sites (78.8%; $F_{5,704} = 52.13$, $P < 0.001$). In 2003, non-prairie forbs were most abundant in the East Mound area (Site 2), and represented a higher percentage of the cover than in all other sites in 2003 (Fig 2, Table 2). At Site 2, non-prairie forb cover increased over the season to nearly 50% of the total cover in August. In contrast, non-prairie forb cover remained the same or decreased over the season in the other sites. Dominant non-prairie forb species (weeds) at Site 2 were pigweed and lambsquarters.

In 2004, non-prairie forbs were again most abundant in the East Mound area (Site 2), followed by the Northeast, Northwest, and West mound sites (Sites 4, 5, and 7 respectively). Again, pigweed and lambsquarters were abundant as was kochia.

A significant three-way interaction (year*site*month; $F_{10,704} = 2.53$, $P < 0.005$) existed for prairie-grass cover, however, site again contributed the greatest percentage of explainable variation (78.24%; $F_{5,704} = 110.92$, $P < 0.001$). In all months in both years, the mound itself (Site 6) had very little prairie grass cover (dominated by the non-native

smooth brome. The East Mound (Site 2), dominated by non-prairie forbs in both years, also had significantly less prairie grass cover than all other sites except Site 6 (Fig. 2). Site 1 (Southwest) had the greatest percentage of prairie grass cover, followed by Site 4 (Northeast) and then Sites 5 and 3 (Northwest and Streamside, respectively) which did not statistically differ from each other. In Sites 1, 2, and 4, Canada wild rye was the dominant prairie grass in both years. Prairie grasses accounted for the largest percentage of cover in all areas except Site 2 and Site 6 in 2004.

A three-way interaction also existed for non-prairie grasses ($F_{10,704} = 7.61$, $P < 0.001$) but the greatest percent of explainable variation (84.15%) was again due to differences among sites ($F_{5,704} = 425.3$, $P < 0.001$). On the mound (Site 6), there was a constant dominance by the non-prairie grass smooth brome. Non-prairie grasses were absent at Sites 1 (Southeast) and nearly absent at Sites 2 and 4 (East Mound and Northeast). At Site 5, green and yellow foxtail became quite abundant later in the summer in 2003 (51% season average), but were much less abundant in 2004 (5%).

We also examined the percentage of bare ground to evaluate increases in total cover. A year*site interaction ($F_{5,681} = 12.95$, $P < 0.001$) resulted from the large decrease in percent bare ground at Site 4 (Northeast) between 2003 and 2004 (Table 2). This statistical difference did not exist at the other sites, although the trend was always for a reduction in percent bare ground from 2003 to 2004 (Fig. 2, Table 2).

As noted above, there were strong and consistent patterns of significant differences among sites. In order to gain a greater understanding of what was going on within each site, seven grass and eight forb species were evaluated individually within each site to compare the variability in percent cover of these important plant species. The species that were chosen were either desired prairie species or problem non-prairie species that appeared to be common in the restoration (see species listed on page 5 of this document).

In Site 1 (Southwest), there were fewer non-prairie forbs overall in 2004 than in 2003 (Table 2), with the biggest differences in June. This is because there were many different non-prairie species present in Site 1 in 2003, but by the following year, the main non-prairie forb was horseweed, which seemed to replace many of the non-prairie forb species seen the previous summer, which included pigweed and prickly lettuce, as well as others.

There were two prairie-grass species that showed significant differences among months or years at Site 1. There was a significant effect of month for Indian grass ($F_{2,114} = 4.98$, $P < 0.01$) because the percentage of Indian grass decreased from June to July, but then doubled by August. Side-Oats Grama showed a significant reduction between 2003 (8%) and 2004 (3%; $F_{1,114} = 7.36$, $P < 0.01$).

Site 2, formerly a feedlot, was dominated by non-prairie forbs in both years, which included pigweed, kochia, and lambsquarters. (It should be noted that after June 2004, transect 14 was no longer used because it was sprayed and mowed to control weeds,

which were a problem in that area. In 2003, transect 13 was moved slightly after June because of mowing as well.) The non-prairie grasses at Site 2 increased in July of 2003, and then decreased again in August. In 2004, there were low densities of non-prairie grasses present in June, but they disappeared as the growing season progressed (Fig. 2). The most common non-prairie grasses present both years were green and yellow foxtail.

There was a significant difference between years in the amount of yellow foxtail present at Site 2 ($F_{1,134} = 3.85$, $P < 0.05$). In 2003, yellow foxtail made up a very small proportion of the total cover (2%), but was not present at all the following year. There was also a significant difference between years in the percent of prickly lettuce cover observed in the former feedlot site ($F_{1,114} = 33.25$, $P < 0.0001$). The first summer, prickly lettuce made up less than 3% of the total cover, but in 2004 it comprised nearly 18% of the total cover.

At Site 3 (Creekside), the prairie grass Canada Wild Rye had a significant month*year interaction ($F_{2,114} = 5.92$, $P < 0.01$). No other species showed significant differences among months or years at this site. In 2003, there was no Canada Wild Rye observed in this location, but in 2004, this species was low in June, and then increased each month, to over 21% by August. Overall, the percentage of prairie grasses decreased slightly over the season in 2003, but increased by the end of the season in 2004. The increase in prairie grasses reflects the increase in prairie cordgrass and Canada wild rye observed in August than in June or July.

There was a striking reduction in non-prairie grasses at Site 3 in August 2004. This reduction may have resulted from the flooding that occurs in this area. In late June of 2004, large amounts of rain caused the creek to flood and spill out of its banks. This caused many of the grasses to be bent down instead of standing straight up. In July when the sampling was done, many of the grasses were still prostrate, which may have made it more difficult for us to sample species that were underneath the top layer of grass. Further matting of the grass could have shaded out any species that were below the topmost layer of grass. In August, the percent grass cover increased, but this time there were more prairie grasses and fewer non-prairie species. This could possibly be due to prairie grasses out-competing the other species after the flood, because there was an increase in two of the main prairie grasses in that area after that time.

At Site 4, prairie-grass cover remained about the same throughout the summer in 2003. In 2004, however, prairie-grass densities were low relative to non-prairie species in June and then increased in July and August. This difference between years resulted in a significant month by year interaction for the prairie grass species Canada Wild Rye ($F_{2,114} = 5.94$, $P < 0.01$). In 2003, the percentage of Canada Wild Rye stayed about the same each month (64-67%). In 2004, however, the amount of Canada Wild Rye increased each month, starting at only 28% in June, but increasing to over 65% by the end of the summer in August. In 2004 we began to observe more little bluestem and Indian grass in July and August as well, although these increases were not statistically significant.

The percentage of non-prairie grasses at Site 4 increased each month in 2003, mainly due to the growth of yellow and green foxtail. In 2004, the amount of non-prairie grasses started high, again largely due to green and yellow foxtail, but then disappeared in July and August as the foxtail disappeared. Green foxtail showed significant differences between years at Site 4 ($F_{1,114} = 4.95$, $P < 0.05$). The amount of green foxtail at this site was higher in 2003 than in 2004 when it was not observed at all, although it was relatively low in 2003 as well, making up less than 3% of the total cover. The dominant non-prairie grass species in Site 4 was yellow foxtail. Yellow foxtail showed a significant interaction of month*year in the Northeast site ($F_{2,114}= 41.45$, $P < 0.0001$). The percentage of yellow foxtail was zero in June, and very low in July and August (less than 2% in both months) in 2003. In June of 2004, there was a very high percentage of yellow foxtail (27.25%), which then disappeared in July and August.

At Site 4, there were more non-prairie forbs in all months in 2004 than there were in 2003 (Fig. 2), and the amounts decreased each month as the summer went on in both years. The increase in non-prairie forbs in 2004 is most likely due to two species, prickly lettuce and horseweed, which were seen in much higher numbers the second year. There was a significant month*year interaction for prickly lettuce at Site 4 (Northeast) ($F_{2,114} = 6.36$, $P < 0.01$). In 2003, the percent cover of prickly lettuce was highest in July, and zero in the other two months. In 2004, the amount of prickly lettuce was highest in June, and then decreased each month. Horseweed showed a significant difference between years ($F_{1,114} = 56.01$, $P < 0.0001$). The total percent cover of horseweed was higher in 2004 (5.6%) than in 2003 (0.4%). As noted earlier, the percent bare ground at this site also decreased dramatically between 2003 and 2004.

At Site 5, prairie grasses started high and then decreased steadily in 2003, while non-prairie grasses (mainly green and yellow foxtail) increased each month. In 2004, prairie grasses started low, then increased slightly in July and August, while non-prairie grasses (again green and yellow foxtail) started high and then disappeared (Fig. 2). There was a significant year effect at Site 5 for Canada Wild Rye ($F_{1,114} = 35.5$, $P < 0.001$). The mean percentage was nearly double in 2004 (62%) when compared to 2003 (32%). After June of 2003, some of the little bluestem and Indian grass that had been observed at this site was no longer present. Similar to Canada Wild Rye, in 2004 Little Bluestem and Side-Oats Grama gained in cover as the summer went on, although these differences were not statistically significant.

Green foxtail showed a significant interaction of month*year at Site 5 ($F_{2,114} = 15.23$, $P < 0.0001$). In 2003, the amount of green foxtail increased each month, to almost 71% by August. In 2004, there was no green foxtail recorded in any month at this site. Yellow foxtail showed a significant interaction of month*year as well ($F_{2,114} = 13.92$, $P < 0.0001$). In 2003, there was no yellow foxtail observed until August, and in 2004, it started at its highest level in June (15.3%), and then disappeared by July.

At Site 5, overall, there were more non-prairie forbs in all months in 2004 than there were in 2003 (Table 2), again due to the large amounts of horseweed and prickly lettuce

seen the second summer. There was a significant difference between years for the total amount of prickly lettuce observed at the Northwest site ($F_{1,114} = 12.45$, $P < 0.001$). Again the total amount of prickly lettuce increased in the second summer, from 0.1% in 2003 up to 5.4% in 2004. Horseweed showed a significant difference between years at Site 5 as well ($F_{1,114} = 32.10$, $P < 0.0001$). The total amount of horseweed was again higher in 2004 (13%) than in 2003 (0%).

At Site 5, there was a significant month*year interaction ($F_{2,114} = 5.55$, $P < 0.01$) for Wild Bergamot which was the only prairie forb with significant differences among months or years for any of the sites. This was explained by the fact that in 2003, there was no Wild Bergamot present along our transects in any month at this location, but in 2004, it was present in June, and then decreased in July and again in August. Wild Bergamot is an early flowering species, so it is more common earlier in the summer, and then begins to die or fade as the summer goes on, which explains this observation.

On the Mound (Site 6), non-prairie grasses dominated in both years, with the next highest percentage of cover from non-prairie forbs. There were no significant differences among months or years for any of the analyzed species at this site, probably because most of the species analyzed did not occur at this location. Non-prairie forbs present on the Mound included ragweed, creeping jenny, and black medick. Some of the planted prairie plugs that were observed on the east slope of the mound included hoary vervain, plains (whorled) milkweed, stiff goldenrod, and side-oats grama. Most of these were observed in 2004. The plugs may take a few years to become established, so hopefully more of them will emerge and become successful in the coming years.

At Site 7 (West Mound), the most common type of plants observed were prairie grasses, mainly Canada Wild Rye. There were also quite a few prairie forbs, which is encouraging. Non-prairie forbs found at this site were mainly prickly lettuce and horseweed. Amounts of grasses, prairie forbs, and non-prairie forbs remained relatively constant throughout the growing season. This site is most comparable to the Southwest (Site 1).

Visual estimates of cover and the cover estimates as determined using the pin-frame were highly correlated ($R = 0.39$, $P < 0.0001$, $N=685$) indicating that the modified pin-frame method was consistent with our visual estimates of cover.

Results from the cover estimates corresponded well with what we observed within the different sites. The Southwest area (Site 1) seemed to be the most successful in terms of the establishment of prairie species and the lack of weedy forbs and grasses. The Northeast and Northwest sites were not as successful in the first year, but the germination of planted seed began to catch up to the Southwest site by the middle of the second summer. In 2003, these sites were dominated by non-prairie grasses which were replaced by prairie grasses and some non-prairie forbs during 2004. Additionally, there was more bare ground in these areas the first year than the second, indicating that as time went on, more plants became established here. It was noted that the levels of non-prairie forbs in the Southwest site decreased in 2004, which may possibly

indicate that levels of non-prairie forbs in the northern sites will decrease next summer, as these areas seem to be about a year behind in their establishment. Because these weedy species most likely make up a large portion of the seed bed, it may take a few years before they are completely out-competed. Non-prairie forbs are most prominent in the East Mound area, and are probably preventing most of the planted prairie species from becoming established. The same is true with the smooth brome on the mound. It may be difficult for the planted prairie species to become established when the area is already dominated by another competing species. Further management may be needed in these two areas for them to become successful.

Biomass Sampling: There was a significant year*month*plot interaction for total biomass ($F_{8,89} = 4.76$, $P < 0.0001$; only data from June, July, and August analyzed). In 2003, in the Northwest (Site 5), East Central (Site 2), and Southwest (Site 1) sites, the total amount of biomass increased each month. In the Northeast (Site 4) and Creekside (Site 3) sites, total biomass increased from June to July, but then decreased in August. In 2004, the Northeast (Site 4), Northwest (Site 5), and Southwest (Site 1) sites showed an increase in total biomass each month, whereas the East Central (Site 2) and Creekside (Site 3) sites showed an increase from June to July, and then a decrease from July to August. By August of the first summer, the highest total biomass was observed in the East Central (Site 2) area, followed by Northwest (Site 5), Southwest (Site 1), Creekside (Site 3), and Northeast (Site 4). In 2004, however, total biomass in August was highest in the Northeast site (Site 4), followed by Southwest (Site 1), Northwest (Site 5), East Central (Site 2), and the Creekside area (Site 3). Overall, the amount of total biomass increased each month from June-August (Fig. 3), as would be expected in a newly restored prairie.

There was also a significant year*month*plot interaction for the biomass of grasses sampled ($F_{8,90} = 2.81$, $P < 0.01$). Most of this could be explained by the difference between months, as the total amount of grass increased each month as the grasses got taller.

There was no significant difference among years, months, plots, or their interactions in forb biomass, although it was greater in all months in 2004 than in the same month in 2003. The ratio of percent grasses to percent forbs did not significantly vary between years ($F_{29,118} = 1.28$, $P > 0.05$) as is expected in a tallgrass prairie restoration.[3] The reason for this is that it is probably still too early in the restoration (only third growing season) for this shift to occur. In the first few years following the restoration, Canada wild rye, gray-headed coneflower, ox-eye, and wild bergamot will become well established and bloom, and may be persist as the dominant species for the first three to four years. Three to five years into the restoration, big bluestem, little bluestem, switchgrass, Indian grass, side-oats grama, purple coneflower, compass plant, and white and purple prairie clover will become more common and begin to flower. By this point, most weed species will also have been out-competed and replaced by these long-lived perennials. Long-lived perennials, such as compass plant, prairie cinquefoil, and sky-blue aster will become established six or more years after the initial restoration. Some species, such as prairie dropseed and lead plant, may take 13 to 40 years to

establish themselves and often represent the final stage of succession in the restoration process.[3]

Soil Sampling and Land-Use Histories: Results of the soil sampling showed differences among the sampling sites in soil nutrients. Most striking was the high nutrient loading in the East Mound site (Site 2) which was the former feedlot site. This site had higher levels of nitrogen, phosphorus, potassium, and organics than any of the other sites. The levels shown in Figure 4 are averages of the two samples from each site. In the East Mound site (Site 2), the maximum levels were even higher than those shown in the figure. Many of the nutrient levels observed in the former feedlot site were several times greater than the ideal levels for the successful establishment of prairie plants which may explain why this area supports mainly weed species that are better able to tolerate a broader nutrient range.[22] Soil levels of phosphorus that are > 16 ppm are considered very high for new seedings of grass.[23] Above that level, farmers should not add any more phosphorus fertilizer, because it this inhibits rather than promotes healthy establishment of the grass species. Soil phosphorus levels measured in the east mound area (former feedlot site, Site 2) were 640 ppm on average.

Potassium showed the same pattern. Soil test levels of 161+ ppm are considered very high for new seeding of grass,[23] and the feedlot area (Site 2) had potassium measurements of 3240 ppm. The Creekside site (Site 3) had the highest salt levels of any site, which may be attributed to erosion and salt deposition that occurs in this area during flooding events. The high levels of potassium in the southeast site (not a plant-sampling site) could be the result of the different type of soil that is found there or due to machine storage at that site (Ron Thaden, current land manager at Spirit Mound and former Clay County extension agent, personal communication).

High soil nutrient levels have been found to be one of the most important abiotic factors affecting the success of a prairie restoration.[22] High nutrient levels are likely to promote the growth and establishment of weedy perennials and competitive grass species which often become the dominant plant types in the earliest stages of prairie restoration because they are able to out-compete the desired prairie species and can tolerate these higher nutrient levels.[22] Rates of prairie seed establishment on former agricultural soils where nutrient levels are high have been found to be very slow.[22]

Butterfly Sampling: Eleven different species of butterflies were observed and/or collected during the summer of 2003 at the site (Table 3). The three most common species recorded were clouded sulphur, red admiral, and cabbage white. All observed butterfly species have been previously recorded in Clay County, South Dakota.[24] Additionally, all species observed are generalist species. It should also be noted that the regal fritillary was observed in the Northern portion of the prairie. The regal fritillary is a more specialist species, preferring areas of tallgrass prairie.[25]

Birds: Over 50 species of breeding birds were observed at Spirit Mound in the summer of 2003. For more information, please consult Carlisle et al. 2004.

Conclusions

To determine whether the initial stages of the restoration at Spirit Mound were successful, we compared the species observed at the restoration site to the intentionally planted species. With a majority of the planted species (74%) observed after only three complete growing seasons, we conclude that the initiation of the Spirit Mound Historic Prairie restoration has been very successful. The area has been converted from buildings, a feedlot, and several independently owned agricultural fields which supported one or two species of crops, along with a few weed species, to a tallgrass prairie comprised of more than 80 different tallgrass prairie species. As the site continues to develop, it is expected that many non-prairie species of grasses and forbs will be out-competed and replaced by native prairie species, which are better adapted to the tallgrass prairie ecosystem.[3,6] Additionally, as the site remains out of cultivation, weed species in the seedbed should become depleted and should present less of a problem in the future. Rotational burning and interseeding with the original seed mix will favor prairie species and keep non-prairie species at a disadvantage. Additional species may also be added to the seed mix in the future to increase the overall diversity of this prairie.

We expect plant productivity to become more homogeneous from year to year as the prairie matures and the planted species become better established throughout the site. The forb cover observed should decrease and be replaced by prairie grasses.[3] This has not yet occurred, since the forb production in 2004 was higher each month than in 2003.

Soil nutrient levels are not expected to change much throughout the prairie, with the exception of the East Mound area, which should be mined (reverse fertilization, see below) to attempt to reduce the levels of some nutrients and promote the growth of prairie plants.

As the restored prairie site matures, we expect to see more species of animals taking advantage of the area as habitat as well. In the few years since the restoration began, several species of birds, insects, and mammals have already been observed. A 2003 study indicated that more than 50 species of breeding birds have already become established on the site.[21] Additionally, from our own observations, it is evident that the pheasant population has also increased since the restoration began, which is good evidence that the vertebrate community is already increasing at Spirit Mound.

According the SER Primer on Ecological Restoration,[11] a restoration can be considered successful when "it will sustain itself structurally and functionally and demonstrate resilience to normal ranges of environmental stress and disturbance." Even though the restoration at Spirit Mound appears to be going well, there are several factors to consider with respect to the long term success of the project. First, nutrient levels at the East Central site (Site 2, former feedlot) are extremely high. A recommended approach for removing excessive soil nutrients is 'soil mining' or 'reverse fertilization' by planting and harvesting crops at the contaminated site. By cropping a contaminated area, it is expected that more nutrients, especially phosphorus, will be removed from the soil than

are added as inputs by the crop.[22] However, reverse fertilization is not always successful. "Increased off-take of nutrients within the crop has not always been followed by significant reductions in soil concentrations" and "cropping has been ineffective where large reductions in soil nutrients have been required for restoration."[22] Even if the East Central site (Site 2) is planted to alfalfa which is harvested and removed from the site for a number of years, this does not guarantee that soil nutrient levels will be reduced. Thus, we can not be confident that the former feedlot area will ever have the conditions favored for the establishment of native prairie plants.

A second issue of concern is the frequency of fire at the Spirit Mound Historic Prairie site. Because this site is fairly small (only 320 acres), only a small portion can be burned each year to ensure that there is a large enough unburned portion to provide a refuge for the vertebrate and insect species that inhabit the site. Therefore, the recommended three to four year burn cycle for the entire prairie will probably not be able to be followed. This could lead to a loss in overall species diversity, and especially in shorter plants such as the forb understory and short to medium height grasses[26] that require the bare soil conditions created by fires for re-colonization and growth.

With nearly 75% of the planted species observed just a few years after initial planting, this site seems to be on its way to successful establishment of prairie species. With continued management of the restoration site, especially in terms of reducing nutrient levels in the former feedlot site, controlling and eliminating problem weed species with mowing or herbicide applications, and rotational burning of different portions of the site, we would expect this restoration to continue to be successful. Without this management, at least in the initial stages of the restoration, however, the overall success of the restoration may decrease, and the site may become dominated by only one or a few species. As the restoration progresses, the extent of management necessary should become less, and the prairie should become more self-sustaining, perhaps with the exception of the necessary burning. Compared to the feedlot and fields that comprised Spirit Mound just three years ago, hundreds of visitors are now enjoying "a most butifull landscape" (Capt. William Clark, August 25, 1804).

Public Outreach

Over the past two years, we have made several presentations about the restoration efforts at Spirit Mound:

- Lewis &Clark NSF-Research Experiences for Undergraduates Cohorts (both summers).
- W.H. Over Museum in April and August, 2003.
- Wyandotte County (Kansas City) Chamber of Commerce-August 2003.
- Spirit Mound Trust, Oct. 2003
- Missouri River Institute Symposium, Vermillion, SD, February 2004
- USD's Graduate Student Research Forum in April 2004.
- August 25, 2004 Lewis & Clark bicentennial celebration organized by SD GF&P.
- North American Prairie Conference, Madison Wisconsin, August, 2004.

- SD Biocomplexity Conference, Sioux Falls, SD, August 2004.
- SD NSF-EPSCoR Conference, Rapid City, August 2004.
- Informally talk with people at the site on a regular basis.

Press coverage included:

- *A grass roots approach: project is restoring prarie at Spirit Mound.* June 27, 2003.
- *Native prairie, birds and bugs thriving as Spirit Mound enjoys transformation.* Sioux City Journal. August 3, 2003.
- *Prairie restoration of Spirit Mound continues.* Yankton Daily Press and Dakotan. August 5, 2003.
- *Prairie restoration of Spirit Mound continues.* Rapid City Journal. August 20, 2003.
- *Students restore Spirit Mound: Site provides students with research opportunities.* USD Volante. October 15, 2003.

Project Website: www.usd.edu/prairie includes images of many plants and a table of plant species observed in 2003.

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Table 1. Plant species observed at Spirit Mound Historic Prairie during 2003 and 2004. P=Prairie species, NP=Non-prairie species, U=Unknown, T=Woody plants. Shading indicates intentionally planted species.

Family	Latin Name	2003	2004	P/NP	Common Name
Cannabaceae	*Cannabis sativa* L.	X	X	NP	Hemp
Chenopodiaceae	*Chenopodium album* L.	X	X	NP	Lambsquarters
	Kochia scoparia (L.) Schrad.	X	X	NP	Kochia
Amaranthaceae	*Amaranthus* species	X	X	NP	Pigweed
	Amaranthus rudis Sauer.	X		P	Water Hemp
Polygonaceae	*Polygonom lapathifolium* L.	X	X	NP	Pale Smartweed
	Polygonum convolvulus L.	X	X	NP	Black Bindweed
	Polygonum hydropiper L.	X	X	P	Smart weed
	Polygonum species L.	X		NP	Little Knotweed
	Rumex crispus L.	X	X	NP	Dock
Malvaceae	*Abutilon theopharasti* Medic.	X	X	NP	Velvet Leaf
Violaceae	*Viola* L.	X	X	P	Violet
Cucurbitaceae	*Echinocystis lobata* (Michx.) T.&G.	X	X	P	Wild Cucumber
Capparaceae	*Cleome serrulata* Pursh.	X		P	Rocky Mountain Bee Plant
Brassicaceae	*Capsella bursa-pastoris* (L.) Medic.	X	X	NP	Shepherd's Purse
	Lepidium perfoliatum L.	X		P	Pepper Grass
	Sisymbrium altissimum L.	X	X	NP	Tumble Mustard
	Thlaspi arvense L.	X	X	NP	Field Penny Cress
Rosaceae	*Potentilla arguta* Pursh.	X	X	P	Prairie Cinquefoil
	Prunus L.	X		T	Cherry
Caesalpiniaceae	*Cassia chamaecrista* L.	X	X	P	Partridge Pea
Fabaceae	*Amorpha nana* Nutt.	X		P	Dwarf Indigo

	Amorpha canescens Pursh.	X	X	P	Leadplant
	Astragalus canadensis L.	X	X	P	Milk Vetch
	Dalea candida Michx. ex Willd.	X	X	P	White Prairie Clover
	Dalea purpurea Vent.	X	X	P	Purple Prairie Clover
	Lotus corniculatus L.	X	X	P	Birdfoot trefoil
	Medicago lupulina L.	X	X	NP	Black Medick
	Medicago sativa L.	X	X	NP	Alfalfa
	Melilotus officinalis (L.) Pall.	X	X	NP	Yellow Sweet Clover
	Melilotus alba Medic.	X	X	NP	White Sweet Clover
Onagraceae	*Oenothera villosa* Thunb.	X	X	P	Evening Primrose
Euphorbiaceae	*Euphorbia dentata* Michx.	X		P	Toothed spurge
	Euphorbia marginata Pursh.	X	X	P	Snow on the mountain
	Euphorbia prostrata Ait.	X	X	U	Prostrate Euphorb
	Euphorbia esula L.	X	X	NP	Leafy Spurge
Oxalidaceae	*Oxalis species* L.	X	X	NP	Oxalis
	Oxalis stricta L.	X	X	NP	Yellow Wood Sorrel
Asclepidaceae	*Asclepias verticillata* L.	X	X	P	Whorled Milkweed
	Asclepias syriaca L.	X	X	P	Common Milkweed
	Asclepias incarnata L.	X	X	P	Swamp Milkweed
	Asclepias tuberosa L.	X	X	P	Butterfly Milkweed
Solanaceae	*Physalis species* L.	X	X	P	Groundcherry
	Solanum species L.	X	X	NP	Nightshade
	Solanum rostratum Dun.	X	X	P	Buffalo Burr
Plantaginaceae	*Plantago major* L.	X	X	NP	Common plantain
Convolvulaceae	*Convolvulus arvensis* L.	X	X	NP	Field Bindweed
Verbenaceae	*Verbena bracteata* Lag. & Rodr.	X		P	Prostrate Vervain
	Verbena hastata L.	X	X	P	Blue Vervain

	Verbena stricta Vent.	X	X	P	Hoary Vervain
Lamiaceae	*Lycopus asper* Greene.	X	X	P	Rough Bugleweed
	Mentha piperata L.	X	X	NP	Peppermint
	Monarda fistulosa L.	X	X	P	Beebalm/Wild Bergamot
	Unidentified mint	X	X	U	Mint
Scrophulariaceae	*Verbascum thapsus* L.	X	X	NP	Common Mullein
	Veronica persica Poir.	X		NP	Birdseye speedwell
	Veronica arvensis L.	X		NP	Corn speedwell
	Penstemon grandiflorus Nutt.		X	P	Large-flowered beard-tongue
Asteraceae	*Achillea millefolium* L.	X		P	Yarrow
	Ambrosia artemisiifolia L.	X	X	P	Ragweed
	Ambrosia trifida L.	X	X	P	Giant Ragweed
	Artemisia ludoviciana Nutt.	X	X	P	Silver Sage
	Aster azureus Lindl.		X	P	Sky-blue aster
	Aster ericoides L. or *falcalutus* Lindl.	X	X	P	Heath or White Prairie Aster
	Aster laevis L.		X	P	Smooth Blue Aster
	Aster novae-angliae L.	X	X	P	New England Aster
	Aster sericeus Vent.		X	P	Silky aster
	Carduus nutans L.	X	X	NP	Musk Thistle
	Cichorium intybus L.	X	X	NP	Wild chicory
	Cirsium arvense (L.) Scop.	X	X	NP	Canada Thistle
	Cirsium species	X	X	NP	Thistle (various)
	Conyza canadensis (L.) Cronq.	X	X	NP	Horseweed
	Echinacea angustifolia DC.	X	X	P	Purple Cone Flower
	Helianthus annuus L.	X	X	P	Annual Sunflower
	Helianthus grosseserratus Martens.	X	X	P	Sawtooth Sunflower
	Helianthus maximillinae Schrad.	X	X	P	Maximillian Sunflower

	Helianthus rigidus (Cass.) Desf.	X	X	P	Stiff/Rigid Sunflower
	Heliopsis helianthoides (L.) Fern.	X	X	P	Ox Eye
	Kuhnia eupatorioides L.	X		P	False boneset
	Lactuca serriola L.	X	X	NP	Prickly lettuce
	Liatris aspera Michx.	X	X	P	Rough Blazing Star
	Mentzelia decapetala (Pursh.) Urban & Gilg.		X	P	Ten-petal Blazingstar
	Ratibida columnifera (Nutt.) Woot. & Standl.	X	X	P	Upright Prairie Coneflower
	Ratibida pinnata (Vent.) Barnh.	X	X	P	Grey-headed Coneflower
	Rudbeckia hirta L.	X	X	P	Black-eyed Susan
	Silphium laciniatum L.	X	X	P	Compass Plant
	Silphium perfoliatum L.	X	X	P	Cup Plant
	Solidago canadensis L.	X	X	P	Canada goldenrod
	Solidago missouriensis Nutt.	X	X	P	Missouri Goldenrod
	Solidago nemoralis Ait.	X	X	P	Grey Goldenrod
	Solidago rigida L.	X	X	P	Stiff Goldenrod
	Solidago speciosa Nutt.	X	X	P	Showy Goldenrod
	Sonchus oleraceus L.	X	X	NP	Sow Thistle
	Taraxacum officinale Weber.	X	X	NP	Dandelion
	Tragopogon pratensis L.	X	X	NP	Goatsbeard
	Vernonia faciculata Michx.	X	X	P	Ironweed
	Xanthium strumarium L.	X	X	NP	Cocklebur
Nyctaginaceae	*Mirabilis nyctaginea* (Michx.) MacM.	X	X	P	Wild 4 o'clock
Commelinaceae	*Tradescantia bracteata* Small.	X	X	P	Spiderwort
Juncaceae	*Juncus* L.	X		U	Rush
Anacardiaceae	*Toxicodendron radicans* (L.) O. Ktze.		X	P	Poison Ivy
Cyperaceae	*Carex species* L.	X		U	Sedge
	Carex brevior (Dew.) Mack.	X		U	Fescue Sedge

Moraceae	*Morus* L.	X		T	Mulberry
Poaceae	*Agropyron repens* (L.) Beauv.	X	X	NP	Quack grass
	Agrostis stolonifera L.	X	X	NP	Red top
	Andropogon gerardii Vitman.	X	X	P	Big Blue Stem
	Andropogon scoparius Michx.	X	X	P	Little Blue Stem
	Bouteloua curtipendula (Michx.) Torr.	X	X	P	Side Oats Grama
	Bouteloua gracilis (H.B.K.) Lag.	X		P	Blue Grama
	Bromus inermis Leyss.	X	X	NP	Smooth Brome
	Bromus japonicus Thunb.	X		NP	Japanese brome
	Cenchrus longispinus (Hack.) Fernm.	X		P	Sand Bur
	Danthonia spicata (L.) Beauv.	X		P	Poverty grass
	Echinochloa crusgalli (L.) Beauv.	X	X	P	Barnyardgrass
	Elymus canadensis L.	X	X	P	Canada Wild Rye
	Elymus virginicus L.	X	X	P	Virginia Wild Rye
	Eragrostis curvula (Schrad.) Ness.	X		P	Lovegrass
	Hordeum jubatum L.	X	X	NP	Foxtail Barley
	Panicum capillare L.	X	X	P	Witchgrass
	Panicum virgatum L.	X	X	P	Switchgrass
	Phalaris arundinacea L.	X	X	P	Reed Canary Grass
	Setaria glauca (L.) Beauv.	X	X	NP	Yellow Foxtail
	Setaria italica (L.) Beauv.	X		P	Foxtail Millet
	Setaria verticillata (L.) Beauv.	X		P	Bristly foxtail
	Setaria viridis (L.) Beauv.	X	X	NP	Green Foxtail
	Sorghastrum nutans (L.) Nash.	X	X	P	Indian Grass
	Spartina pectinata Link.	X	X	P	Prairie Cord Grass
Equisetaceae	*Equisetum* species L.	X	X	P	Horsetail
Salicaceae	*Salix* L.		X	T	Willow

Apiaceae	*Daucus carota* L.	X	X	NP	Queen Annes' Lace
Ulmaceae	*Ulmus* Mirb.	X		T	Elm

Table 2. A comparison of 2003 and 2004 percentages for five different plant cover types at Spirit Mound Historic Prairie. Common letters indicate no significant differences between years within sites for each of the five cover types

Site	Year	Prairie Forbs	Non-Prairie Forbs	Prairie Grasses	Non-Prairie Grasses	Bare Ground
1	2003	11.86 ± 1.83 b	12.46 ± 2.04 a	65.99 ± 2.77 a	0.29 ± 0.29 a	4.5 ± 1.33 a
	2004	19.78 ± 2.14 a	6.12 ± 1.20 a	71.61 ± 2.34 a	0 ± 0 a	2.5 ± 0.74 a
2	2003	9.62 ± 1.74 a	47.13 ± 4.26 a	33.14 ± 3.98 a	3.02 ± 1.22 a	5.0 ± 1.38 a
	2004	10.29 ± 1.87 a	29.91 ± 3.67 b	27.50 ± 3.34 a	0.17 ± 0.17 a	4.74 ± 1.23 a
3	2003	6.41 ± 1.59 a	10.16 ± 2.56 a	41.70 ± 4.81 b	32.31 ± 4.43 a	0 ± 0 a
	2004	5.82 ± 2.33 a	9.58 ± 2.34 a	53.33 ± 4.75 a	25.49 ± 4.15 b	0 ± 0 a
4	2003	4.98 ± 1.18 b	10.58 ± 2.18 b	60.76 ± 3.56 a	3.12 ± 1.06 a	19.33 ± 3.34 a
	2004	9.85 ± 1.43 a	24.40 ± 2.10 a	55.73 ± 3.00 a	9.02 ± 2.15 a	1.00 ± 0.46 b
5	2003	2.80 ± 0.93 a	3.39 ± 1.78 b	35.48 ± 4.34 b	44.00 ± 4.62 a	5.33 ± 1.57 a
	2004	6.34 ± 1.02 a	18.97 ± 2.17 a	67.46 ± 2.57 a	5.24 ± 1.72 b	2.00 ± 0.62 a
6	2003	2.03 ± 0.64 a	3.01 ± 0.89 a	0.15 ± 0.15 a	85.58 ± 1.86 a	7.83 ± 1.51 a
	2004	4.55 ± 1.04 a	7.93 ± 1.31 a	0.67 ± 0.44 a	82.36 ± 1.88 a	4.5 ± 1.15 a

Table 3. Butterfly species recorded in Clay County[24] and whether or not they were observed at Spirit Mound Historic Prairie in Summer 2003.

Family	Common Name	*Scientific Names*	Observed at Spirit Mound
Pieridae	Checkered White	*Pontia protodice* Boisduval & LeConte	
	Cabbage White	*Pieris rapae* Linnaeus	Yes
	Olympia Marble	*Euchloe olympia* W.H. Edwards	
	Clouded Sulphur	*Colias philodice* Godart	Yes
	Orange Sulphur	*Colias eurytheme* Boisduval	
	Cloudless Sulphur	*Phoebis sennae eubule* Linnaeus	
	Little Yellow	*Eurema lisa* Boisduval & LeConte	
	Dainty Sulphur	*Nathalis iole* Boisduval	Yes
Lycaenidae	Gray Copper	*Lycaena dione* Scudder	Yes
	Bronze Copper	*Lycaena hyllus* Cramer	
	Gray Hairstreak	*Strymon melinus franki* Hübner	
	Reakirt's Blue	*Hemiargus isola* Reakirt	
	Eastern Tailed-Blue	*Everes comyntas* Godart	
	Summer Azure	*Celastrina neglecta* W. H. Edwards	
	Melissa Blue	*Lycaeides melissa* W. H. Edwards	
Nymphalidae	American Snout	*Libytheana carinenta bachmanii* Cramer	
	Variegated Fritillary	*Euptoieta claudia* Cramer	Yes
	Great Spangled Fritillary	*Speyeria cybele* Fabricius	Yes
	Regal Fritillary	*Speyeria idalia* Drury	Yes
	Meadow Fritillary	*Boloria bellona* Fabricius	
	Silvery Checkerspot	*Chlosyne nycteis* Doubleday	Yes
	Pearl Crescent	*Phyciodes tharos* Drury	
	Question Mark	*Polygonia interrogationis* Fabricius	
	Eastern Comma	*Polygonia comma* Harris	

	Mourning Cloak	*Nymphalis antiopa* Linnaeus	
	Red Admiral	*Vanessa atlanta rubria* Fruhstorfer	Yes
	Painted Lady	*Vanessa cardui* Linnaeus	Yes
	Common Buckeye	*Junonia coenia* Hübner	
	Red-spotted Purple	*Limenitis arthemis astyanax* Fabricius	
	Viceroy	*Limenitis archippus* Cramer	
	Mountain Emperor	*Asterocampa celtis antonia* Edwards	
	Little Wood-Satyr	*Megisto cymela* Cramer	
	Common Wood-Nymph	*Cercyonis pegala* Fabricius	
	Monarch	*Danaus plexippus* Linnaeus	Yes
Hesperiidae	Silver-Spotted Skipper	*Epargyreus clarus* Cramer	
	Common Checkered Skipper	*Pyrgus communis* Grote	
	Common Sootywing	*Pholisora catullus* Fabricius	
	Least Skipper	*Ancyloxypha numitor* Fabricius	
	Fiery Skipper	*Hylephila phyleus* Drury	
	Sachem	*Atalopedes campestris* Boisduval	
	Tawny-edged Skipper	*Polites themistocles* Latreille	
	Crossline Skipper	*Polites origenes rhena* Fabricius	
	Arogos Skipper	*Atrytone arogos iowa* Boisduval & LeConte	
	Delaware Skipper	*Anatrytone logan lagus* Edwards	

Figure 1a. Aerial photograph showing different land-use site divisions at Spirit Mound Historic Prairie. East Mound is referred to as East Central in the rest of this document. Map is oriented with North at the top.

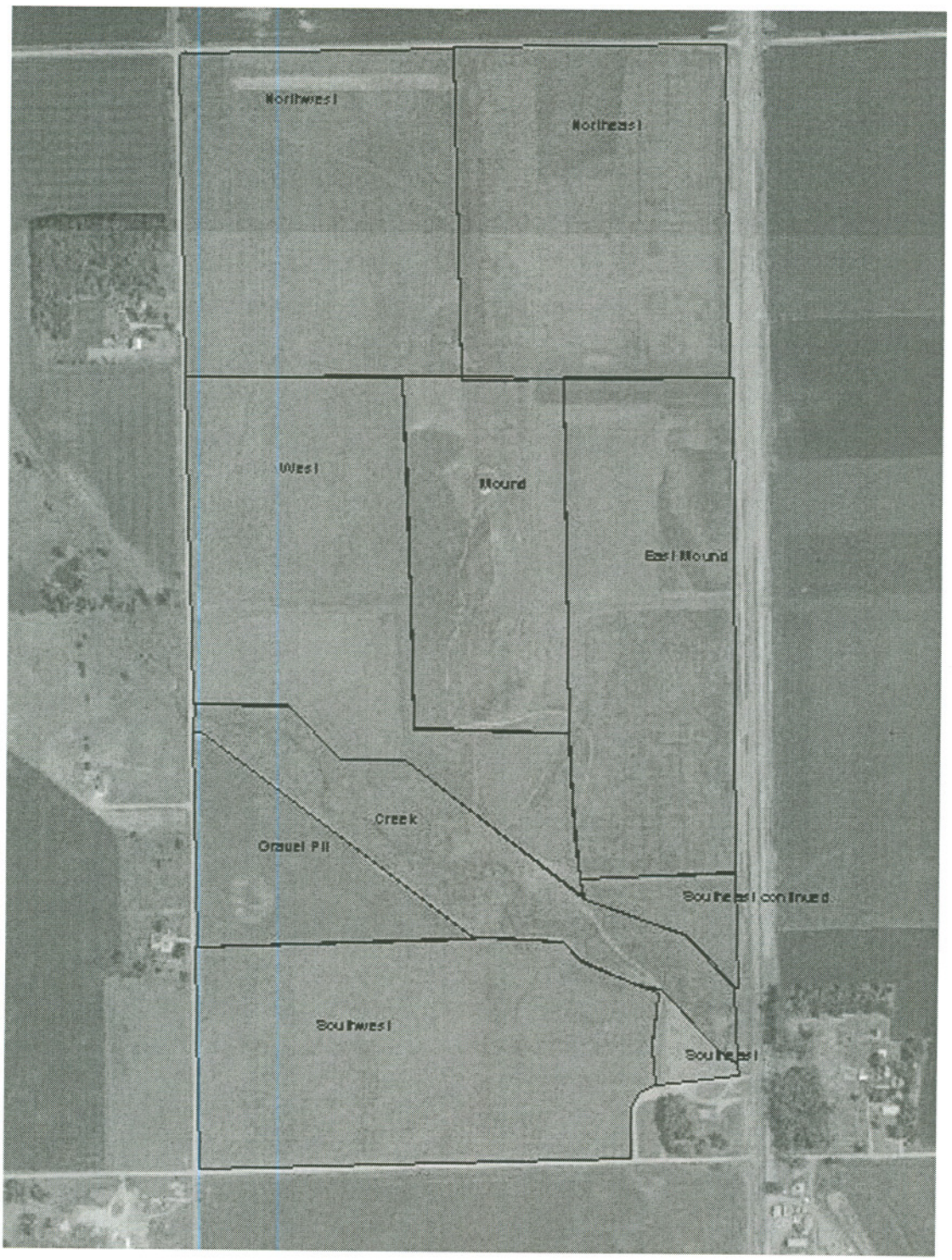


Figure 1b. Approximate plant sampling transect locations at Spirit Mound Historic Prairie. Transects 14 and 15 were added in 2004.

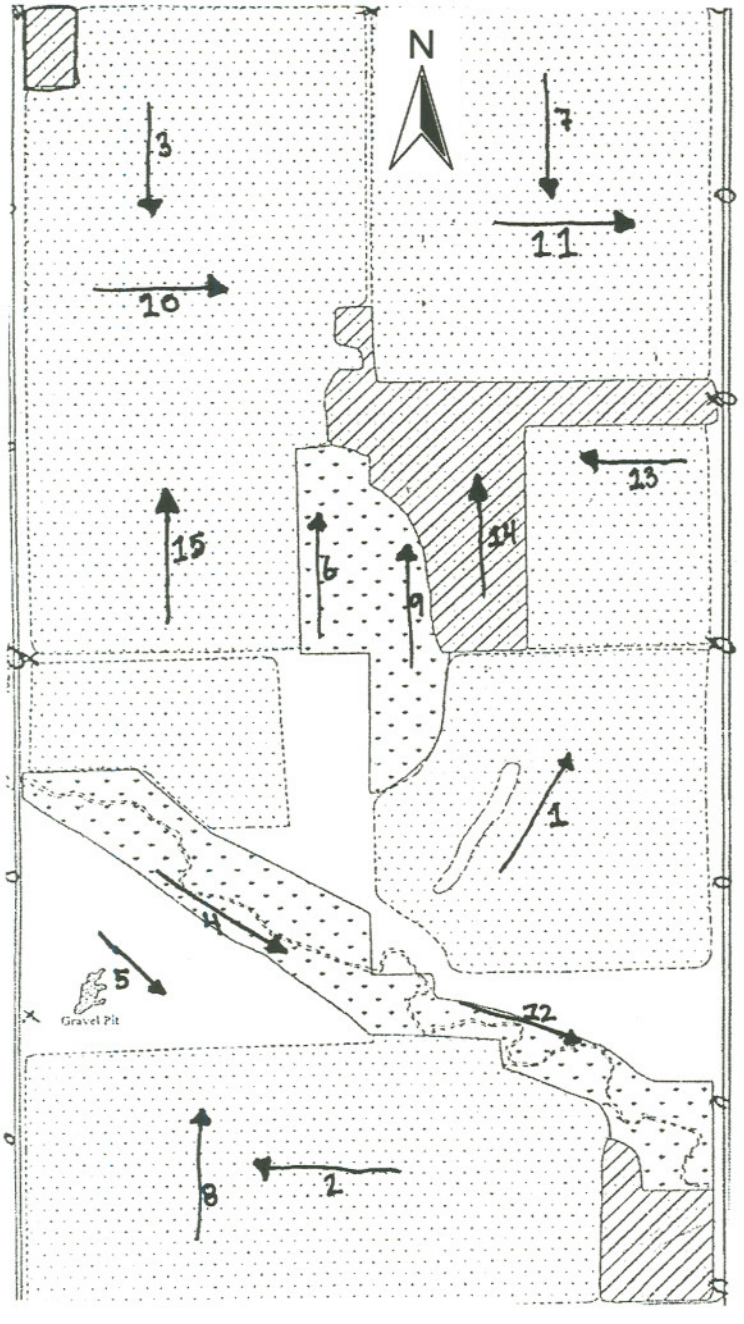


Figure 1c. Approximate soil sampling locations at Spirit Mound Historic Prairie in October 2003. Map is oriented with north at the top.

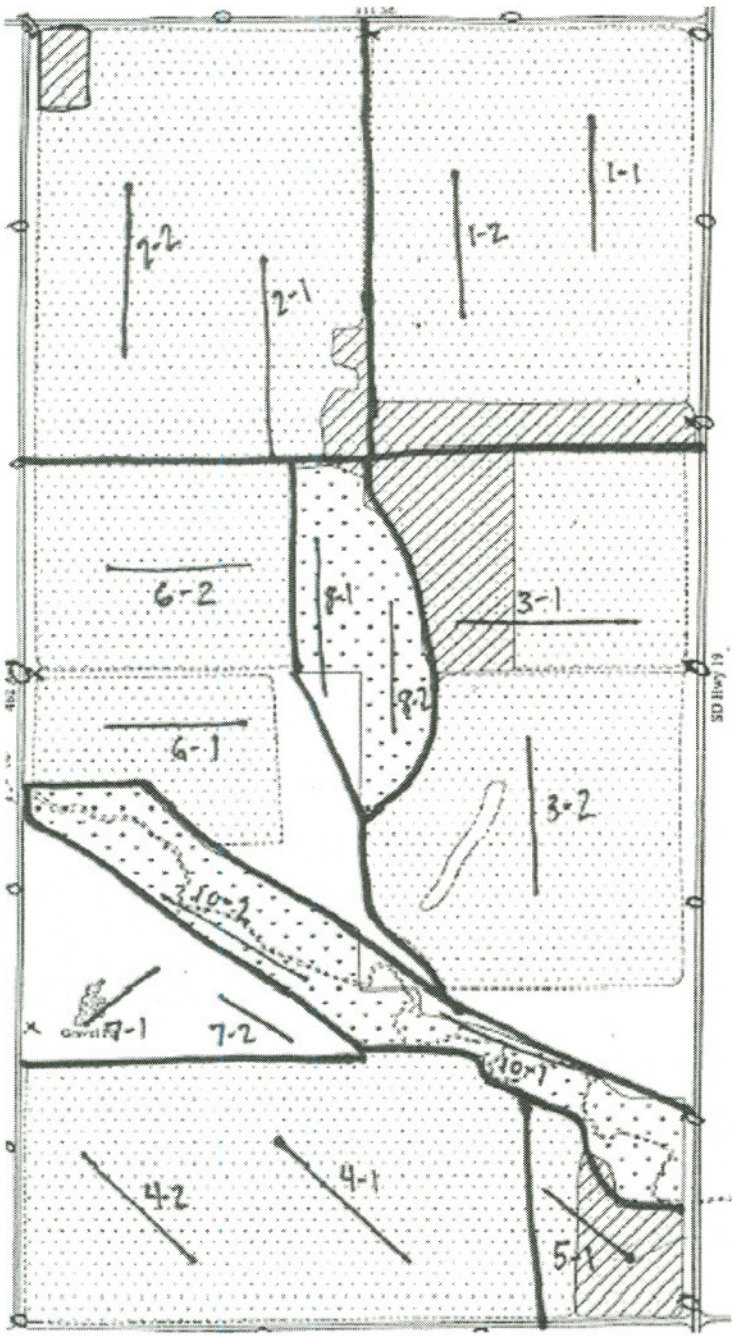
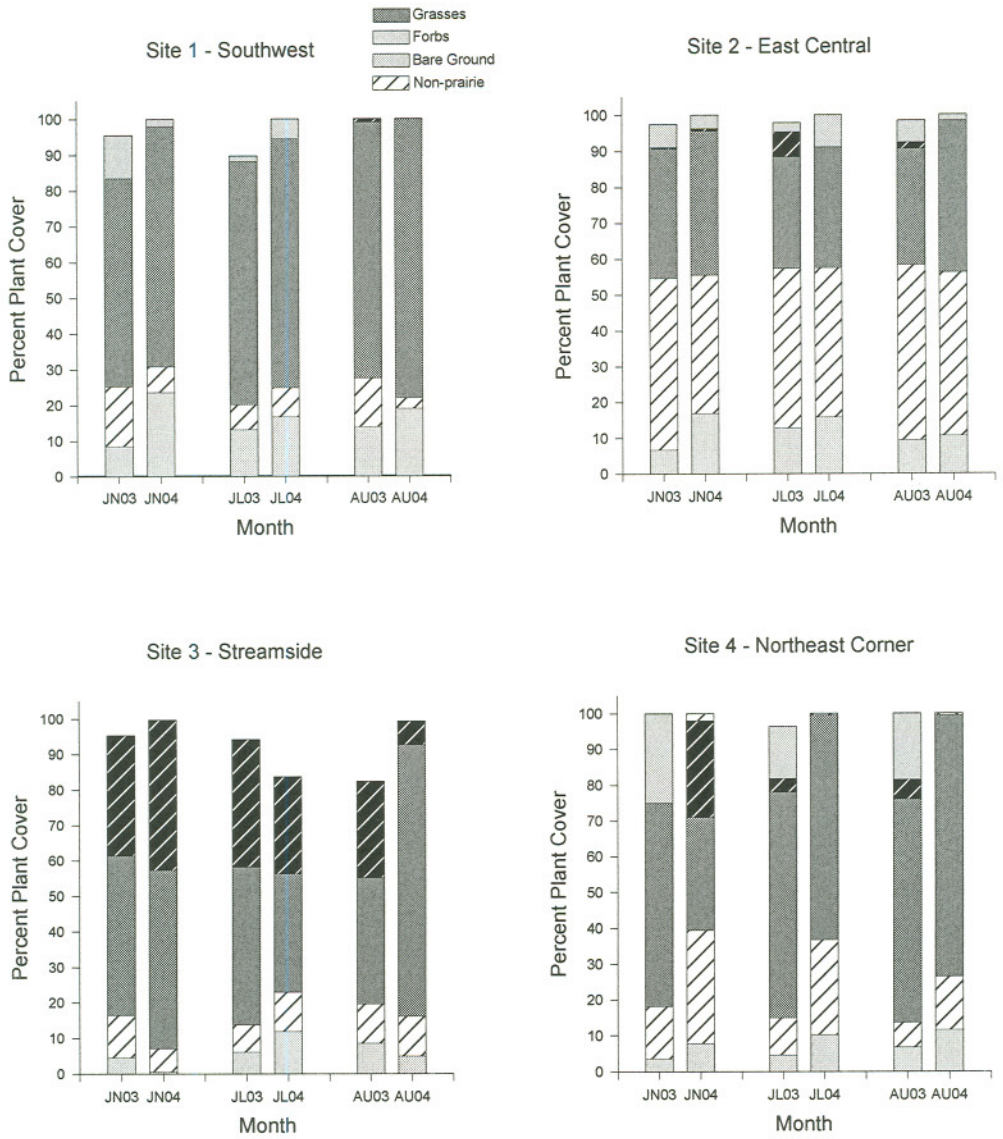
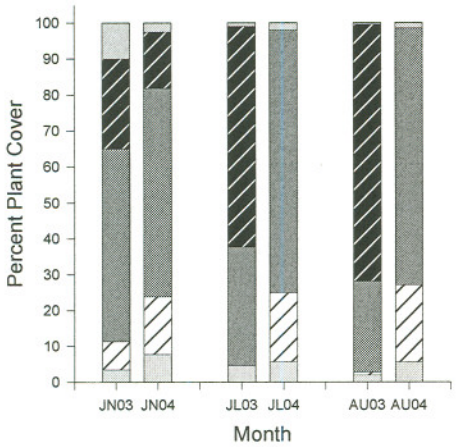


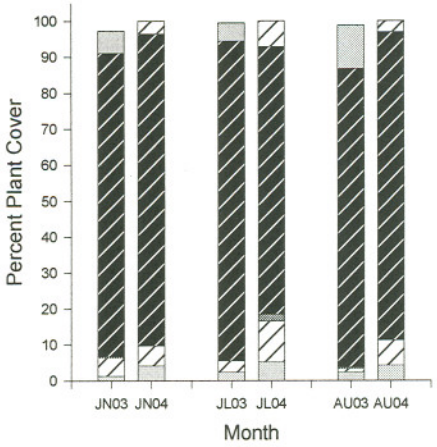
Figure 2. Percent plant cover in different research sites at Spirit Mound Historic Prairie.



Site 5 - Northwest Corner



Site 6 - On the Mound



Site 7-West Mound

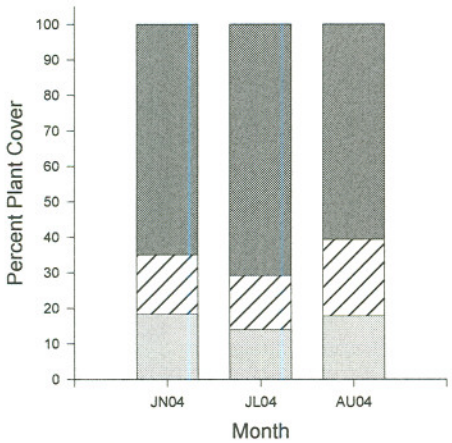


Figure 3. Plant biomass production in 2003 and 2004 at Spirit Mound Historic Prairie.

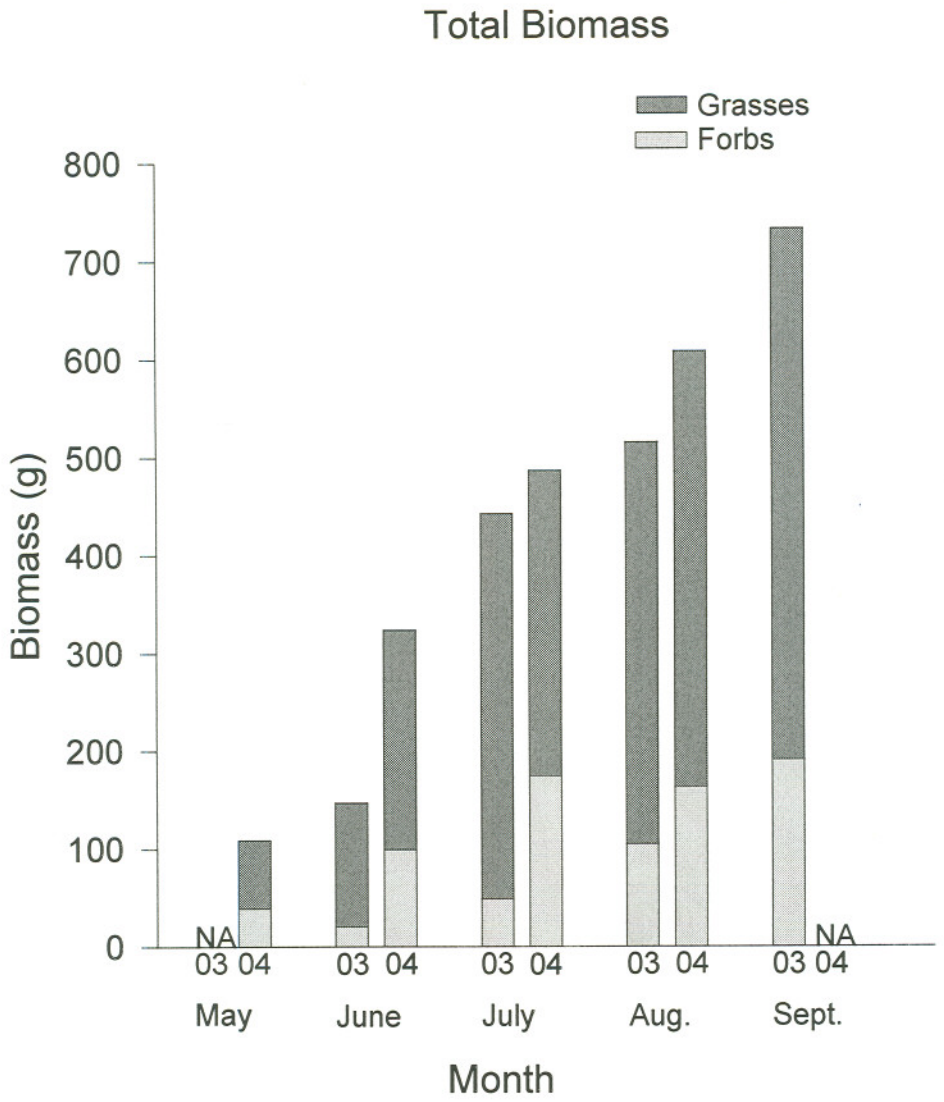
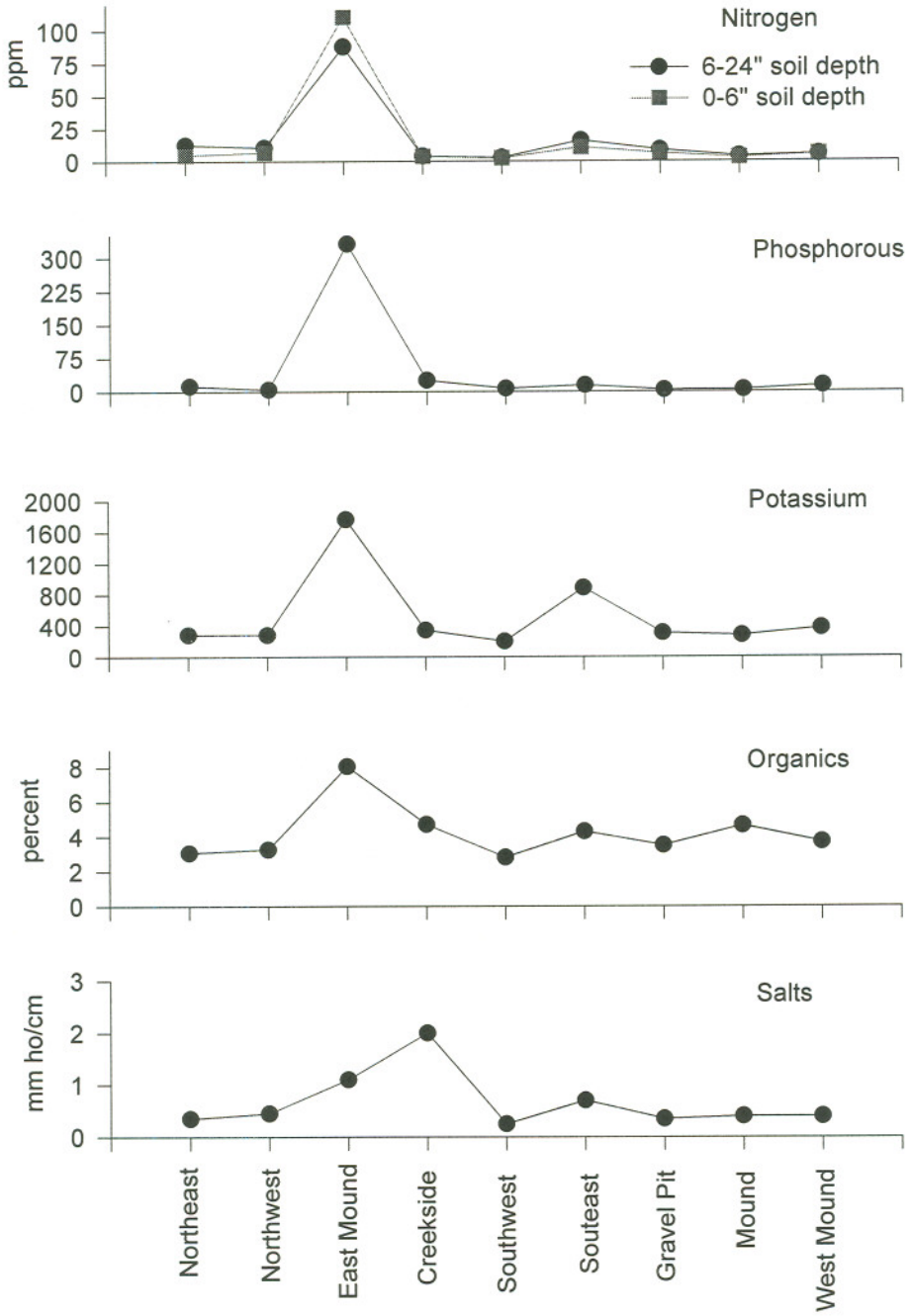


Figure 4: Soil nutrients at Spirit Mound Historic Prairie. Samples were taken in October, 2003.



Appendix I: Seed Mixes (lbs./acre) planted at Spirit Mound Historic Prairie.[8,27]

Common Name	Scientific Name	40-Acre Xeric Mix*	227-Acre Mesic Mix	10-Acre Mesic/Xeric Mix (Trail Mix)	10-Acre Wetland Mix	10-Acre Xeric Plugs Prairie Plugs (plugs/acre)
Leadplant	*Amorpha canescens*	0.05	0.01	0.1	0.0	0.0
Ironweed	*Vernonia faciculata*	0.0	0.2	0.0	0.3	0.0
Silver Sage	*Artemisia ludoviciana*	0.05	0.01	0.01	0.0	32.7
Butterfly Milkweed	*Asclepias tuberosa*	0.1	0.01	0.5	0.0	32.7
Swamp Milkweed	*Asclepias incarnata*	0.0	0.0	0.0	0.25	0.0
Whorled Milkweed	*Asclepias verticillata*	0.0	0.0	0.0	0.0	32.7
Sky Blue Aster	*Aster azureus*	0.01	0.0	0.01	0.0	32.7
Smooth Blue Aster	*Aster laevis*	0.1	0.01	0.1	0.0	0.0
Silky Aster	*Aster sericeus*	0.02	0.0	0.1	0.0	32.7
New England Aster	*Aster novae-angliae*	0.0	0.01	0.1	0.05	0.0
Milkvetch	*Astragalus canadensis*	0.05	0.0	0.1	0.0	0.0
Partridge Pea	*Cassia chamaecrista*	0.25	0.0	0.5	0.0	0.0
White Prairie Clover	*Dalea candida*	0.25	0.0	0.5	0.0	0.0
Purple Prairie Clover	*Dalea purpurea*	0.5	0.0	0.5	0.0	0.0
Roundheaded Bushclover	*Lespedeza capitata*	0.05	0.01	0.05	0.0	0.0
Purple Coneflower	*Echinacea angustifolia*	0.2	0.1	0.2	0.0	32.7
Grey-headed Coneflower	*Ratibida pinnata*	0.0	0.6	0.5	0.0	0.0
Upright Yellow Coneflower	*Ratibida columnifera*	0.5	0.0	0.0	0.0	32.7
Stiff Sunflower	*Helianthus rigidus*	0.1	0.01	0.05	0.0	32.7
Yellow Ox-Eye	*Heliopsis helianthoides*	0.2	0.5	0.2	0.0	0.0
Rough Blazingstar	*Liatris aspera*	0.05	0.01	0.1	0.0	32.7

Beebalm	*Monarda fistulosa*	0.2	0.08	0.2	0.1	0.0
Large-flowered Beard-tongue	*Penstemon grandiflorus*	0.05	0.0	0.1	0.0	0.0
Prairie Phlox	*Phlox pilosa*	0.05	0.0	0.1	0.0	0.0
Prairie Cinquefoil	*Potentilla arguta*	0.1	0.0	0.2	0.0	0.0
Black-eyed Susan	*Rudbeckia hirta*	0.2	0.1	0.3	0.0	0.0
Grey Goldenrod	*Solidago nemoralis*	0.05	0.0	0.1	0.0	32.7
Stiff Goldenrod	*Solidago rigida*	0.1	0.3	0.2	0.0	32.7
Showy Goldenrod	*Solidago speciosa*	0.05	0.01	0.1	0.0	32.7
Spiderwort	*Tradescantia bracteata*	0.05	0.0	0.05	0.0	32.7
Hoary Vervain	*Verbena stricta*	0.2	0.0	0.4	0.0	32.7
Blue Vervain	*Verbena hastata*	0.0	0.04	0.0	0.2	0.0
Joe-pye Weed	*Eupatorium maculatum*	0.0	0.0	0.0	0.250	0.0
Boneset	*Eupatorium perfoliatum*	0.0	0.0	0.0	0.250	0.0
Sneezeweed	*Helenium autumnale*	0.0	0.0	0.0	0.250	0.0
Bur Marigold	*Bidens cernua*	0.0	0.0	0.0	0.250	0.0
Flat-topped Aster	*Aster umbellatus*	0.0	0.0	0.0	0.2	0.0
Wild Licorice	*Glycyrrhiza lepidota*	0.0	0.0	0.0	0.01	0.0
Monkey Flower	*Mimulus ringens*	0.0	0.0	0.0	0.05	0.0
Cup Plant	*Silphium perfoliatum*	0.0	0.5	0.0	0.5	0.0
Compass Plant	*Silphium laciniatum*	0.0	0.05	0.0	0.0	0.0
Prairie Smoke	*Geum triflorum*	0.0	0.0	0.0	0.0	32.7
Pasque Flower	*Anemone patens*	0.0	0.0	0.0	0.0	32.7
Big Bluestem	*Andropogon gerardii*	0.1	1.0	0.1	1.0	0.0
Little Bluestem	*Andropogon scoparius*	2.5	0.5	2.19	0.0	32.7
Side-oats Grama	*Bouteloua curtipendula*	1.7	0.5	2	0.0	32.7
Canada Wild Rye	*Elymus canadensis*	0.2	1.0	0.2	0.0	0.0
Indian Grass	*Sorghastrum nutans*	0.2	1.69	0.2	0.0	0.0
Rough Dropseed	*Sporobolus aspera*	0.1	0.1	0.1	0.0	32.7

Prairie Dropseed	*Sporobolus heterolepis*	0.1	0.1	0.1	0.0	32.7
Porcupine Grass	*Stipa spartea*	0.1	0.1	0.1	0.0	32.7
Switchgrass	*Panicum virgatum*	0.0	0.01	0.01	0.1	0.0
Prairie Cordgrass	*Spartina pectinata*	0.0	0.0	0.0	4	0.0

*40-acre xeric mix: 3.53 lbs. forb seed/acre, 5 lbs. grass seed/acre; 227-acre mesic mix: 2.56 lbs. forb seed/acre, 5 lbs. grass seed/acre; Trail mix: 5.37 lbs. forb seed/acre, 5 lbs. grass seed/acre; Wetland mix: 2.66 lbs. forb seed/acre, 5.1 lbs. grass seed/acre.

Appendix II: Field guides used in this study.

Jackson, L. and L. Dittmer. 1997. Prairie Seedlings Illustrated: An Identification Guide. Volume 1: Twenty selected grasses and forbs. University of Northern Iowa, Cedar Falls, Iowa.

Johnson, J.R., and G.E. Larson. 1999. Grassland Plants of South Dakota and the Northern Great Plains. South Dakota State University, Brookings, South Dakota.

Ladd, D. 1995. Tallgrass Prairie Wildflowers. Globe Pequot Press. Guilford, Connecticut.

Marrone, G.M. 2002. Field Guide to Butterflies of South Dakota. South Dakota Game, Fish, and Parks, Pierre, South Dakota.

Peterson, R.T., and M. McKenny. 1996. A Field Guide to Wildflowers of Northeastern/North Central North America. Houghton Mifflin Company, New York, New York..

Van Bruggen, T. 1983. Wildflowers, Grasses, and Other Plants of the Northern Plains and Black Hills. University of South Dakota, Vermillion, South Dakota.

Vance, F.R., R. Jowsey, J.S. McLean, and F.A. Switzer. 1999. Wildflowers of the Northern Great Plains Third Edition. University of Minnesota Press, Minneapolis, Minnesota.