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Vegetative Comparison of Two Gravel Ridge Prairies with Different Grazing Histories in Polk County, Minnesota

Kelly Wolfe
College of Saint Benedict/Saint John's University

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Kelly S. Wolfe
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Approved by:

Stephen G. Saupe

Dr. Stephen G. Saupe, Associate Professor of Biology

James M. Poff

Dr. James M. Poff, Professor of Biology

Marianna D. Wood

Dr. Marianna D. Wood, Assistant Professor of Biology

Charles F. Rodell

Dr. Charles F. Rodell, Chair, Department of Biology

Margaret L. Cook

Dr. Margaret Cook, Director, Honors Thesis Program

Mark Thamert, OSB.

Fr. Mark Thamert, Director, Honors Program

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Abstract. The vegetation of a gravel ridge running the length of two native prairie remnants, the Stipa Wildlife Management Area (WMA) and the Tympanuchus WMA, in northwestern Minnesota was compared during June, July, and August 1993. The Stipa WMA was grazed by confined domestic cattle from 1958 to 1977, while the Tympanuchus WMA has been relatively undisturbed. The vegetative composition of each area was compared qualitatively by compiling a plant species list for each ridge. Quantitative vegetative comparisons were conducted by recording abundance and cover values for individual plant species in twenty-five 0.5 m^2 random sample plots on each ridge during the first two weeks of August. The calculated Shannon-Wiener diversity index values showed the Tympanuchus WMA ridge vegetation to be more diverse than the Stipa WMA ridge vegetation. Also, 10 plant species predicted to decrease with grazing were found with significantly greater frequency and in higher abundance on the Tympanuchus WMA ridge, while 4 species categorized as weedy invaders under conditions of grazing were found with greater frequency and in higher abundance on the Stipa WMA ridge. Data collected on species expected to increase under heavy grazing pressure, however, were inconclusive. As predicted, the vegetation on the grazed native prairie gravel ridge was less diverse than that on the undisturbed native prairie ridge and consisted of more weedy, introduced plant species and fewer plant species palatable to large grazers.

INTRODUCTION

North American grasslands were formed in the beginning of a drying trend at the Miocene-Pliocene transition seven to five million years ago (Anderson 1990). These grasslands contain a diverse array of vegetation types, ranging from the arid grasslands and shortgrass prairies of the semi-desert Southwest to the eastern tallgrass prairies of Indiana and Wisconsin (Anderson 1990). The True Prairie originally extended from Manitoba to Texas and from the forest margins of Indiana and Wisconsin halfway across the Dakotas and Kansas. From here, the drier and more sparse Great Plains spanned westward across central North America to the Rocky Mountains (Weaver 1954). Today much of the Great Plains are utilized for rangeland, but only a small percentage of the North American native prairie remains intact. A few relatively large expanses are preserved through the efforts of organizations such as The Nature Conservancy, but most remnant prairie is now comprised of small patches scattered among agricultural fields under cultivation or land utilized for intensive domestic cattle grazing.

Grasslands worldwide can be characterized by their climate with periodic droughts, repeated fires, level or gently rolling landscape, and dominance by grazing animals (Sauer 1950). Grassland vegetation is dominated by grasses and includes many forbs, while large shrubs and trees are noticeably absent. It has been proposed that grasses are adapted to drought conditions because of their ability to die down to underground organs, exposing only dead vegetation aboveground. This same adaptation protects grassland plants from fire and also prevents mortality of some grassland species due to grazing (Gleason 1922). Growing points beneath the soil surface permit regrowth after intensive grazing pressure and protect growing points during dormant seasons, when aboveground palatable tissues are removed (Tainton and Mentis 1984).

Grazing by North American bison (*Bison bison*) helped shape North American grasslands. These animals freely roamed wide expanses of land, grazing individual areas only lightly. Climax grassland can retain its essential natural composition when grazed lightly (Weaver 1954) and, in fact, some researchers maintain that grassland vegetation and herbivores have a mutualistic relationship, with grasses and grazers having co-evolved under long-term, periodic grazing (Owen 1980, McNaughton 1983).

Many plants, particularly grasses, have evolved adaptations that permit, and even encourage, high levels of consumption. In fact, grasses may disappear and be replaced by dicots in the absence of grazers (Owen 1980). Animal disturbance in tallgrass prairie is important for maintaining vegetative species richness and spatial heterogeneity (Gibson 1989). McNaughton (1983, 1986) observed that plants have the capacity to compensate for herbivory and may even compensate to the point that fitness is increased, while Owen and Wiegert (1976) claim that consumers can maximize plant fitness.

Despite the fact that grazers are a defining characteristic of grasslands, many researchers have found that herbivory is detrimental to individual plants and plant populations. Lacey and Van Poollen (1981) found that herbage production was significantly higher on sites protected from moderate grazing. These findings rest on the assumption that herbage production can be used as a measure of plant vigor (Vogel and Van Dyne 1966, Bjugstad and Whitman 1970) and plant fitness. Grazing reduced heterogeneity in the Flooding Pampa, Argentina (Facelli et al. 1989) and

Herrera (1981) observed that, although grazing may promote grass growth, it reduces seed production. Thompson and Utley (1982) claim that North American prairies are maintained by periodic drought and fire and, while they are exploited by grazers, their existence does not depend on grazing.

Some experimental results demonstrate no positive or negative effect of herbivory on plants (McNaughton and Chapin 1985), while others show that an individual plant's response to herbivory varies according to the biotic and abiotic conditions it experiences (Maschinski and Whitman 1989). When grazed lightly, climax grassland can retain its essential natural composition. It is only when a large number of grazing animals are confined to a small range, that grazing and trampling become so excessive that normal plant cover cannot be maintained (Weaver 1954).

The post-grazing vegetative effects of heavy domestic cattle grazing and trampling in a relatively small, confined area of native prairie were studied in this project. It is hoped that the information collected in this study will be used in a future project to determine the long-term effects of heavy grazing on vegetative composition of native prairie and the effectiveness of current management practices in prairie restoration efforts. Since much of today's remaining prairie consists of small remnant patches, the effects of intensive use and management techniques merit study. The future of wildlands management lies in developing the ability to sustain entire ecosystems within remnant patches of land in a relatively undisturbed state. Examination and comparison of remnant prairies with regard to post-grazing vegetation should provide some insight into current management effects.

Polk County, located in northwestern Minnesota, contains many remnants of native prairie. In addition, many acres of former agricultural land are currently being managed to restore native prairie plant species. In this study I compared two native prairie areas, both currently managed with periodic, controlled burning: one has never been grazed by domestic cattle, and the other was heavily grazed by confined domestic cattle for nearly 20 years (1958-1977). The purpose of this study was to collect qualitative and quantitative data to compare the formerly grazed and ungrazed prairie study sites. The main goal was to determine the current relative state and health of the native prairie vegetation on the grazed prairie site and the effectiveness of its restoration to native prairie status. Another goal was to provide this information with the hope that it will be used in the future to monitor the vegetative restoration of the grazed prairie site.

McNaughton (1983) found that herbivore activity on the Serengeti grasslands was a source of plant community heterogeneity, while Facelli et al. (1989) noted reduced heterogeneity due to grazing in the Flooding Pampa, Argentina. It should be noted that the Serengeti evolved under high grazing pressure, while the Flooding Pampa evolved under low grazing pressure (Facelli et al. 1989). The prairie in northwestern Minnesota, located near the forest-grassland border, probably evolved under moderate bison grazing pressure and, thus, I expected that intensive cattle grazing would slightly reduce heterogeneity of the native vegetation. Heterogeneity was judged qualitatively and quantitatively by looking at community diversity and vegetative composition of both areas.

Under conditions of pasture overgrazing, the degree of overgrazing can be recognized by three types of plant indicators. Plant species preferred by grazers are referred to as "decreasers", those that are not eaten and benefit from the disappearance of palatable species are "increasers", and those weedy plants that move into bare patches caused by plants weakened from the effects of grazing are "invaders" (Weaver 1954). In this study I predicted that species characterized as increasers or weedy invaders (Weaver 1954, Johnson and Nichols 1970) would be found more frequently and in higher abundance on the grazed prairie area, while decreasers would be less abundant and found less frequently on the grazed area.

METHODS

Study Area:

The study was conducted on two prairie remnants in northwestern Minnesota, the Stipa Wildlife Management Area (WMA) and the Tympanuchus WMA, both characterized by their dry prairie plant species. In this type of prairie, *Andropogon gerardii* is always present, although not dominant, while mid-height and short grasses, such as *Stipa spartea*, *Schizachyrium scoparium*, *Bouteloua curtipendula*, and *Koelaria macrantha* are dominant (Aaseng et al. 1993).

The Stipa WMA is a 64.8-hectare (160-acre) expanse of prairie located approximately 18 km northeast of Crookston in SE 1/4, Section 11, Gentilly Township, Polk County (Figures 1 and 2). It is surrounded by cropland on all four sides and its history includes domestic beef cattle and dairy cattle grazing from 1958 to 1977, when Elmer and Viola Ricard owned it. Its use before 1958 is unknown, but in October 1977 it was purchased by the Minnesota Department of Natural Resources (DNR) as a prairie wildlife management area. The area was named for *Stipa comata* (Needle-and-thread grass), which is common on native, dry, gravel ridge prairie, although none was evident at the time of purchase (Terrance Wolfe, DNR Wildlife Manager, personal communication).

I limited my study of the Stipa WMA to a gravel ridge running the length of the

WMA (approximately north to south) created by glacial Lake Agassiz. This ancient beach ridge formed an easily identifiable study area. The ridge is at an elevation of approximately 305 m above sea level, and the study area was defined as approximately 533 m long by 34 m wide. This gravel ridge is part of a system of ridges along western Minnesota that were formed by wave action along the beaches of glacial Lake Agassiz, which finally receded from the area that is now northwestern Minnesota, eastern North Dakota, Manitoba, and Ontario approximately 9300 years ago (Bluemle 1993 unpublished report).

Since 1977 the entire Stipa WMA has undergone controlled burn management to restore native prairie vegetation and eliminate some of the annual, weedy invader plant species that have become common. Often only one half of the ridge is burned because the top of the ridge is used as a firebreak. The burn history of the ridge includes: a burn of the entire ridge in May 1981; a burn of the southern half in May 1983; burns of the western half in April 1984, May 1986, and April 1987; burns of the eastern half in May 1989 and April 1990; a burn of the northwestern portion in April 1991; a burn of the southwestern portion in April 1992; and a burn of the eastern half on 13 April 1993. No other forms of management, including haying, mowing, or seeding of native vegetation, have taken place on the Stipa WMA (DNR Wildlife Managers, personal communication).

The native prairie plant populations seem to be making a comeback and stabilizing all over the Stipa WMA (DNR Wildlife Managers, personal communication), and I studied them by identifying the types and abundances of plant species currently on the ridge, with the hope that this information could be used in a future project to determine the effectiveness of native prairie restoration using only burn management.

Because the scope of this project rendered it impossible to compare the current state of the Stipa WMA vegetation to its condition in 1977 or its condition in the future, I compared the Stipa ridge vegetation to that on a similar gravel ridge on the Tympanuchus WMA.

The Tympanuchus WMA is located approximately 32 km south of the Stipa WMA on the same glacial beach ridge system. It is approximately 15 km southeast of Crookston, and the ridge I studied is located in NW 1/4, Section 28, Kertsonville Township, Polk County (Figures 1 and 2). It is surrounded by cropland and pasture, and it was purchased by the Minnesota DNR in 1967 as a prairie wildlife management area with potential prairie chicken (*Tympanuchus cupido*) habitat (DNR Wildlife Managers, personal communication).

The study area on the Tympanuchus WMA is approximately 305 m long by 26 m wide and the ridge is at an elevation of approximately 290 m above sea level. The Tympanuchus WMA ridge may not be located on exactly the same beach ridge as the Stipa ridge, but it is part of the same system of beach ridges found running north and south in northwestern Minnesota. These ridges are characteristically composed of 1.5 to 8 m of gravel and sand (Bluemle 1993 unpublished report) and, thus, I concluded that the Stipa ridge and Tympanuchus ridge should basically contain the same soil and gravel composition, along with a similar long-term history.

The exact recent history of the Tympanuchus WMA ridge is unknown, although its gravel nature probably prevented plowing and it is thought to never have been grazed by domestic animals. Since 1967 the area has been managed using only controlled burning: no haying, mowing or seeding has occurred. The burn history of the ridge includes: a complete burn in May 1975; another in March 1981; a wildfire burn of the entire WMA in April 1985; a complete burn of the ridge in 1986; and others in May 1989 and October 1991.

Qualitative data:

The comparison of vegetation on both ridges began qualitatively with the creation of a plant species list for each ridge. This was compiled by visiting each ridge weekly or bi-weekly throughout June, July, and August 1993 in order to obtain the correct plant identifications for all species on both ridges, note flowering plant species, and estimate the relative abundance and cover of each species. The Stipa WMA ridge was visited 17 times throughout the summer, beginning on 26 May 1993 and concluding on 27 August, with one extra trip conducted on 2 October. Trips to the Tympanuchus WMA ridge were often conducted on different days, with 17 total trips made, beginning on 26 May and ending on 25 August. This ridge was also visited on 2 October.

Plant species were identified using the following references: Range Plant Handbook (United States Department of Agriculture Forest Service 1937); Peterson and McKenny (1968); Johnson and Nichols (1970); Niering and Olmstead (1979); Stubbendieck, Hatch, and Kjar (1982); and Gleason and Cronquist (1991). The likelihood of the identified species being found in northwestern Minnesota dry gravel prairie was verified using species lists compiled by authors who had conducted similar surveys of Minnesota and North Dakota prairie flora (Henderson date unknown unpublished report; Sperling 1979 unpublished report, Dana 1986 unpublished releves for MN DNR Natural Heritage Program, Facey 1986). Species nomenclature followed the Manual of Vascular Plants of Northeastern United States and Adjacent Canada (Gleason and Cronquist 1991).

Quantitative data:

The ridges were semi-quantitatively compared using a modified quadrat method of sampling terrestrial vegetation during the period of peak biomass (approximately the first two weeks of August). Twenty-five 0.5 m^2 (1 m X 0.5 m) sample plots were located semi-randomly across each ridge along the length of the ridge. This was done by placing twenty-five numbered, evenly-spaced stakes (approximately 12 m apart on the Tympanuchus WMA ridge and 21 m apart on the Stipa WMA ridge) in the center of the ridge, down the length of each ridge. The average width of each ridge, in paces, was determined (17.3 paces for the Tympanuchus and 22.2 paces for the Stipa) and each pace was numbered across the ridge. For each numbered center stake on the Tympanuchus ridge a number corresponding to the pace across the ridge (one through seventeen) was chosen randomly and represented the site of the sample plot corresponding to that center stake (Figure 3). The random pattern of the Tympanuchus plots was scaled up in size and inverted from east to west, then used for the sample plot placement on the Stipa ridge (Figure 4). In this way, the same number of plots were sampled on the top of each ridge and on the extreme east or west sides.

Sampling of the quadrats took place from 2 August to 17 August 1993. In each quadrat I identified all plant species containing enough aboveground biomass to be identifiable at that time of year; estimated their relative abundance using a scale devised by Braun-Blanquet (1972), noted their approximate cover using the Daubenmire cover scale index (Daubenmire 1959) as modified by Bailey and Poulton (1968); and assigned each to a category from the Braun-Blanquet scale of cover and abundance (Braun-Blanquet 1972). The species that could not be identified were counted as a species present for the plot, but were labelled as unknowns.

The sample plot data were used to compare the relative frequency of increaser, decreaser, and weedy invader species on each ridge. Species were designated increasers, decreasers, or weedy invaders from descriptions in Weaver (1954) and Johnson and Nichols (1970). Frequency is defined by Bonham (1989) as the probability of finding a particular species within a quadrat of given size randomly located within a sample area. It was calculated for each species by dividing the number of plots the species was found in on each ridge by the number of plots on each ridge, and it was expressed as a percentage of the number of observations. The average number of species found in each individual plot on each ridge was statistically analyzed using a t-test to determine whether the observed difference was significant. The average relative abundance and the total relative cover for each species also was calculated and used to compare the increasers, decreasers, and weedy invaders on each ridge. For ease in handling the data, no comparisons in cover and abundance (from the Braun-Blanquet scale) were made. A diversity index value was calculated for each ridge using the Shannon-Wiener diversity index. Importance values for calculating the Shannon-Wiener function were based on percent cover for each species rather than number of individual plants.

Voucher specimens:

Throughout the course of the field research for this study, voucher specimens of most species found on each ridge were collected. These were used to positively identify unknown species and to verify the presence of all or most species listed. Herbarium specimens were prepared from the collected plants for my private collection and duplicates were given to the College of St. Benedict / St. John's University herbarium. Numerous slides of each area were taken throughout the summer, also, to trace the vegetation changes seen from June to August and to serve as vouchers for some of the species observed on each ridge.

Climate data:

Climate data from the University of Minnesota Northwest Experiment Station weather station in Crookston were obtained. These data were analyzed in order to determine whether the monthly weather conditions during the course of this study were significantly different from the 104-year average. Mean temperature and total precipitation for the months May, June, July, and August 1993 were examined using t-tests for a single observation and the mean of a sample to determine whether they were significantly different from the 104-year average monthly values (Wilson and Shay 1960).

RESULTS

Qualitative data:

A plant species list containing 110 species was compiled and can be found in Appendix A. Most of the collected and photographed plants could be at least tentatively identified to genus, although three were left at family, and twelve others were identified to genus but not to specific epithet. Eighty-three species were noted on the Stipa WMA ridge, while 89 species were found on the Tympanuchus. Of these, 30 species were found on the Stipa ridge which were not found on the Tympanuchus, and 27 species were noted on the Tympanuchus ridge but not on the Stipa.

Quantitative data:

Sixty-three species were observed in the 0.5 m^2 sample plots on both ridges. Thirty-eight species were found on the Stipa WMA ridge sample plots and 52 on the

Tympanuchus WMA ridge sample plots. These numbers include only those plants that could be identified to genus; those listed as unknowns were used solely to determine the number of different species per individual plot.

The number of different species found per sample plot on the Stipa ridge ranged from 3 to 14 species (mean = 8.32, standard deviation = 2.51). On the Tympanuchus ridge, the number of species per plot ranged from 8 to 19 (mean = 13, standard deviation = 2.84). The difference between the means of 8.32 and 13 species was found to be statistically significant ($p = 0.0001$). The Shannon-Wiener diversity value for the Stipa ridge was 0.9623, while the Tympanuchus value was 1.3451. The difference seems to be significant, but a statistical test of significance was not performed.

Species found with the greatest frequency and in the highest abundance on both ridges are listed in Tables 1 and 2. Species were not compared separately for both frequency and abundance values. In Tables 1 and 2 species are arranged by decreasing frequency, and abundance corresponded with this ranking relatively well. Because the abundance values shown represent averages, it was possible to perform t-tests on the data to statistically compare species on both ridges. Note that fewer species were found in great frequency on the Stipa ridge (12 species with a frequency of 16% or greater) than on the Tympanuchus ridge (23 species with a frequency of 16% or greater). The top three species on the Stipa ridge, however, were all greater in frequency (96%, 92%, and 80%, respectively) than the top species on the Tympanuchus ridge (76%).

Ten species categorized as decreasers were found with relatively great frequency and in high abundance on the Tympanuchus ridge. Eight of these species, *S. scoparium*, *Amorpha canescens*, *Elymus trachycaulus*, *A. gerardii*, *Helianthus rigidus*, *Liatris punctata*, *Pediomelum esculentum*, and *Koelaria pyramidata*, were not found in any sample plots on the Stipa ridge. *Senecio plattensis* had a significantly higher abundance (1.48) on the Tympanuchus ridge than on the Stipa ridge (0.08) ($p = 0.0001$). The final decreaser species, *Dalea purpurea*, was more abundant (0.32) on the Tympanuchus ridge than on the Stipa ridge (0.12), but these abundance levels were not significantly different ($p = 0.23$).

Four species categorized as weedy invaders were found with great frequency and in high abundance on the Stipa WMA ridge. *Bromus inermis* and *Ambrosia coronopifolia* were not found in any Tympanuchus ridge sample plots. *Artemisia frigida* had a significantly higher abundance of 1.80 on the Stipa ridge than on the Tympanuchus ridge (0.08) ($p = 0.0001$), while *Cirsium floodmanii* had an abundance of 0.40 on the Stipa ridge and 0.16 on the Tympanuchus ridge ($p = 0.23$).

The increaser species data are not as simple to interpret as that of the decreasers and weedy invaders. *Melilotus* spp. (*M. alba* and *M. officinalis*) were found with a frequency of 68% and an abundance of 1.36 on the Stipa ridge, while they were not found in any Tympanuchus sample plots. *Aster ericoides* had an abundance significantly higher on the Stipa than the Tympanuchus ridge ($p = 0.0018$). *Achillea millefolium* had a slightly higher abundance on the Stipa ridge than the Tympanuchus ridge, but the difference was not significant ($p = 0.63$). *Artemisia ludoviciana* was found in higher abundance on the Tympanuchus ridge than on the Stipa (0.36 and 0.24, respectively), as was *Bouteloua gracilis*, but these differences also were not significant ($p = 0.64$ and 0.24, respectively). *S. comata*, *Solidago missouriensis*, and *Solidago rigida*, however, each had a higher abundance on the Tympanuchus ridge and these values were significant ($p = 0.0004$, 0.031, and 0.032, respectively).

Climate data:

The average daily temperature during May in 1993 was 12.8° C. This was not significantly different than the 104-year average for May of 12.7° C ($p = 0.80$). The 1993 average temperatures for June, July, and August (15.8, 18.2, and 19.0° C, respectively), however, were all significantly cooler than the 104-year average temperatures for those months (18.0, 20.9, and 19.6° C, respectively) ($p = 0.00001$ for each t-test). The total precipitation in May 1993 was 4.01 cm, which was significantly lower than the 104-year average precipitation for May of 6.53 cm ($p = 0.00001$). The total precipitation for June and August (9.42 and 7.77 cm, respectively) was not significantly different from the 104-year average for those months (9.02 and 7.42 cm) ($p = 0.39$ and 0.41), while July's total precipitation (12.04 cm) was significantly higher than the 104-year average (7.62 cm) ($p = 0.00001$).

DISCUSSION

Qualitative data:

The number of species noted on the Stipa WMA ridge does not seem to be significantly different than the number found on the Tympanuchus WMA ridge. However, the fact that 30 species were found on the Stipa but not on the Tympanuchus ridge, and 27 were found on the Tympanuchus but not the Stipa ridge does seem to be significant. In fact, these data seem to indicate that heavy cattle grazing for approximately 20 years did have a significant effect on the Stipa WMA ridge vegetation. Specific differences between the vegetation on the two gravel ridges can be seen more clearly when the individual species comprising the species lists are studied.

Quantitative data:

The three species found with greatest frequency on the Stipa WMA ridge each were found more frequently than *S. comata* on the Tympanuchus WMA ridge, where it was the most frequently found species. Also, each ridge contained approximately the same number of plant species, although only 38 of these species were found in any sample plots on the Stipa ridge while 52 were found in the Tympanuchus ridge sample plots. This seems to indicate that the Tympanuchus ridge contains a more heterogeneous mix of plant species than the Stipa ridge. Only a few species, such as *B. inermis, A. ericoides, Poa* spp, *Melilotus* spp, and *A. frigida*, dominate the Stipa ridge vegetation, while a larger number of plant species are found with more moderate frequency and in an average level of abundance on the Tympanuchus ridge. The calculated diversity index values also indicate that the Tympanuchus ridge vegetation is more diverse than the Stipa ridge vegetation. This supports the hypothesis that the grazed prairie area will show less vegetative community diversity than the ungrazed area. This is also similar to what Facelli et al. (1989) found in the Flooding Pampa, Argentina, in that the grazed community in their study was less diverse on a large scale than the ungrazed community. They concluded that excessive grazing imposes a heavy stress on an area which overrides subtle environmental differences that would otherwise create vegetative community heterogeneity.

The prediction that decreaser species would be found less frequently and in lower abundance on the grazed area was supported by the sample plot data. Eight decreaser species found with high frequency on the Tympanuchus ridge were not found in any Stipa ridge sample plots, and *S. plattensis* was found in significantly higher abundance on the Tympanuchus than on the Stipa ridge. No decreaser species were found on the Stipa ridge with a frequency greater than 4%. Note that *S. scoparium, A. gerardii, H. rigidus, L. punctata*, and *K. pyramidata*, although not found in any sample plots, do appear on the species list for the Stipa ridge.

Weedy invader species, as expected, were found more frequently on the Stipa WMA ridge. *B. inermis, A. coronopifolia*, and *A. frigida* all had significantly higher abundances on the Stipa ridge. In fact, *B. inermis* and *A. coronopifolia* were not found in any Tympanuchus sample plots. Also, no weedy invaders were found on the Tympanuchus ridge with a frequency greater than 12%.

The frequencies and abundances of increaser species did not follow the prediction. Two species (*Melilotus* spp and *A. ericoides*) were found in significantly higher abundance on the Stipa ridge than the Tympanuchus ridge, as expected. But three species (*S. comata, S. missouriensis,* and *S. rigida*) had a significantly higher abundance on the Tympanuchus ridge. *S. comata* and *S. missouriensis* were at least found on the Stipa ridge, whereas *S. rigida* does not even appear on the Stipa ridge species list.

It should be noted that the three quantitative vegetative characteristics that I used -- frequency, abundance, and cover -- are somewhat subjective and cannot always be clearly interpreted. Frequency is not an absolute value and is dependent on shape, size, and number of sample plots. Extremely high or low frequency values are not reliable for interpretation and frequency values determined at different points in time cannot be compared. Abundance refers to an arbitrarily estimated range in numerical values, of which the designated classes are relative and may not be consistent. The estimation of abundance, then, is subject to personal bias based on a species' aesthetic appeal or familiarity. Aboveground vegetative cover was recorded for each species in this study, and these values will vary depending on the time of season in which field research occurs. (Bonham 1989).

The quantitative data in this study were collected with these shortfalls in mind. The number of sample plots on each ridge was chosen because 25 was a manageable number of plots to sample, yet large enough to prevent any species from being found in 100% of the plots. The 0.5 m^2 plot size provided a plot large enough to adequately represent the sample area, while not containing an overwhelming number of species to identify. The sampling was conducted in a two-week period, when aboveground biomass of most plant species should not have changed drastically. I also tried to be aware of my personal bias for or against certain species, thus preventing any skewed data.

Climate data:

The weather in Polk County did not completely conform to the 104-year average in 1993. June, July, and August were significantly cooler than normal, while May was drier and July was rainier than usual. These differences should have had no effect on the results of this study, since it was conducted during one field season, but if this study is repeated in the future these significant differences should be taken into account as a possible reason for variation in vegetative composition.

CONCLUSION

Three of the four predictions for the comparison of two areas with different grazing histories were supported by the collected data. The vegetative community diversity was lower on the grazed area (Stipa WMA), probably due to the stress of annual, long term domestic cattle grazing. Species predicted to decrease under grazing conditions due to their palatability were found with greater frequency and in higher abundance on the ungrazed area (Tympanuchus WMA). Weedy invader species that spread into bare patches created by grazing were discovered with greater frequency and in higher abundance on the grazed area. Increaser species expected to benefit from the removal of palatable species, however, were found with relatively great frequency and abundance on both the grazed and ungrazed areas.

Because the Stipa and Tympanuchus WMAs are not located in precisely the same area, it is difficult to conclude that the cattle grazing on the Stipa WMA is the source of all variation between the two ridges. Both areas were, however, created by the action of glaciers and the waves of glacial Lake Agassiz. Both ridges are currently managed in a similar manner, with only periodic burning. Also, the ridges are only approximately 32 km apart and are both surrounded by similar cropland and native prairie vegetation seedbanks.

It is also difficult to conclude whether the Stipa WMA ridge vegetation is recovering its community diversity and original composition since grazing has been discontinued. This type of conclusion could have been drawn had pre-grazing data for the Stipa WMA existed or had a third gravel ridge with a history of intensive grazing but no current management been sampled. With these data, a continuum of vegetative condition ranging from grazed with no management to never grazed could have been created. Presumably, the Stipa ridge vegetation would have been located somewhere along the continuum and a conclusion could have been drawn about the stage of recovery of its vegetation. A potential third study area with the necessary characteristics could not, however, be located in the vicinity. Because most decreaser species found on the Tympanuchus ridge are still present on the Stipa ridge, it seems that either the native vegetative composition is returning or was never completely disturbed. General observations by the area wildlife managers indicate that native species such as *S. comata* and *S. spartea* have returned and are increasing under the fire management regime.

I predict that if the current management of the Stipa WMA continues, the vegetation will eventually return to a state similar to that of native prairie -- with greater community diversity, more decreaser plant species, and fewer of the weedy invader plant species. Most of the desirable decreaser species are present on the ridge and so the seedbank for native vegetation is still present. Those species not found on the Stipa ridge are present on other native gravel prairie ridges in the area and it is possible, through wind dispersal, that the seeds may someday reach the Stipa ridge. Early spring burning also should help to restore a desirable native vegetation state. The flowering of some grasses, including *A. gerardii, S. scoparius, B. curtipendula*, and *Muhlenbergia racemosa*, has been found to increase after a spring burn, while *Poa pratensis* flowering decreases (Glenn-Lewin et al. 1990). Increased flowering should cause these desirable, native species to increase in abundance, while decreased flowering of *P. pratensis* would hopefully reduce the abundance of this introduced species. Flowering in the forbs *A. canescens* and *Solidago canadensis* also increases after a spring burn (Glenn-Lewin et al. 1990), again possibly causing an increase in abundance of these desirable native prairie plants. It is generally thought that cool season, undesirable grasses and weedy forbs are hurt by early spring burning, which in turn benefits warm season, desirable grasses and native prairie forbs. Thus, continued management of the Stipa WMA ridge with periodic early spring burning should continue to restore the native gravel ridge prairie vegetation disturbed by intensive grazing to a state similar to that of the Tympanuchus WMA ridge vegetation which has never been grazed by domestic cattle.

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Fig. 1 Location of Polk County in Minnesota

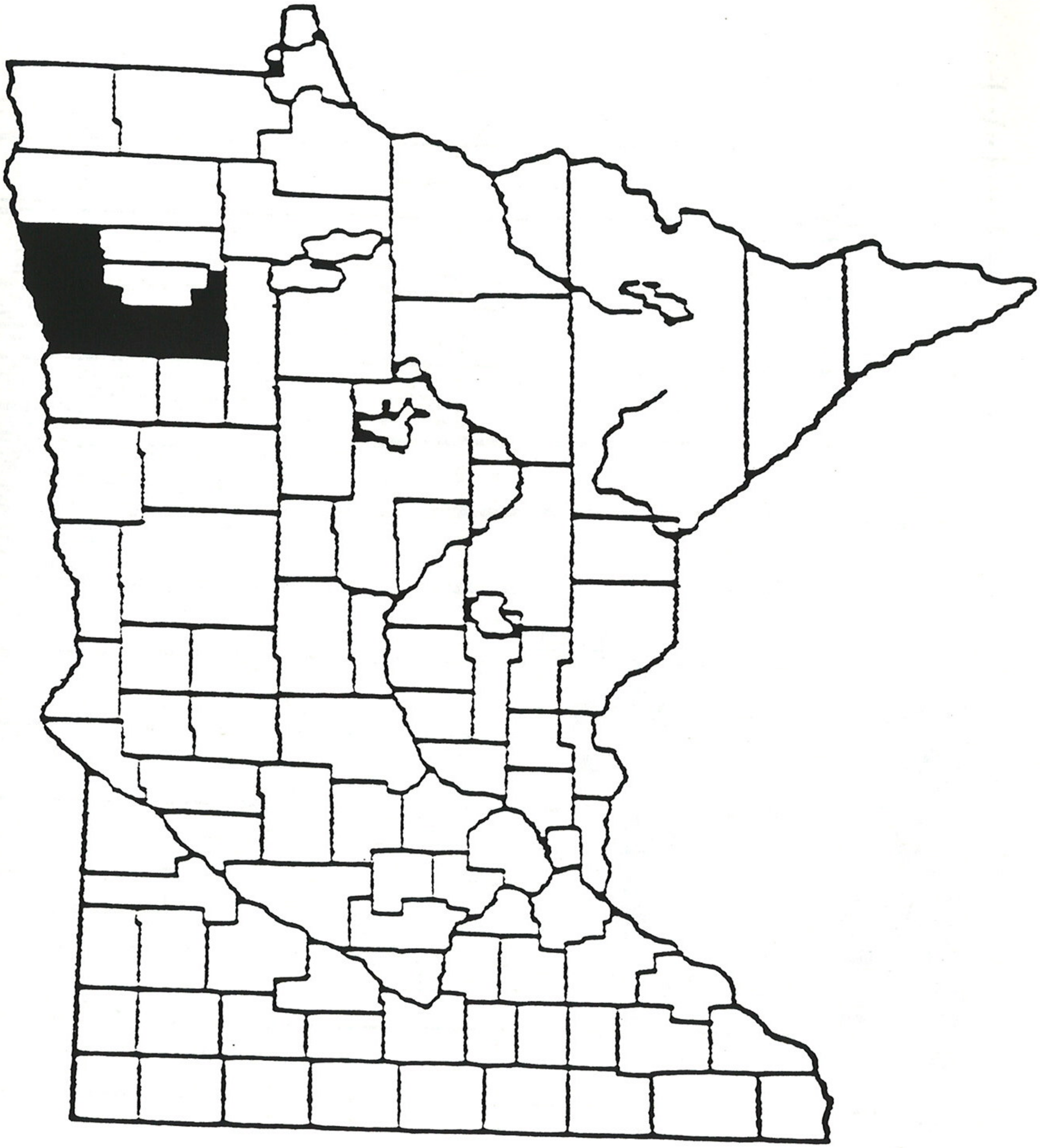

Fig. 2 Location of the Stipa Wildlife Management Area (WMA) and Tympanuchus Wildlife Management Area in Polk County, Minnesota.

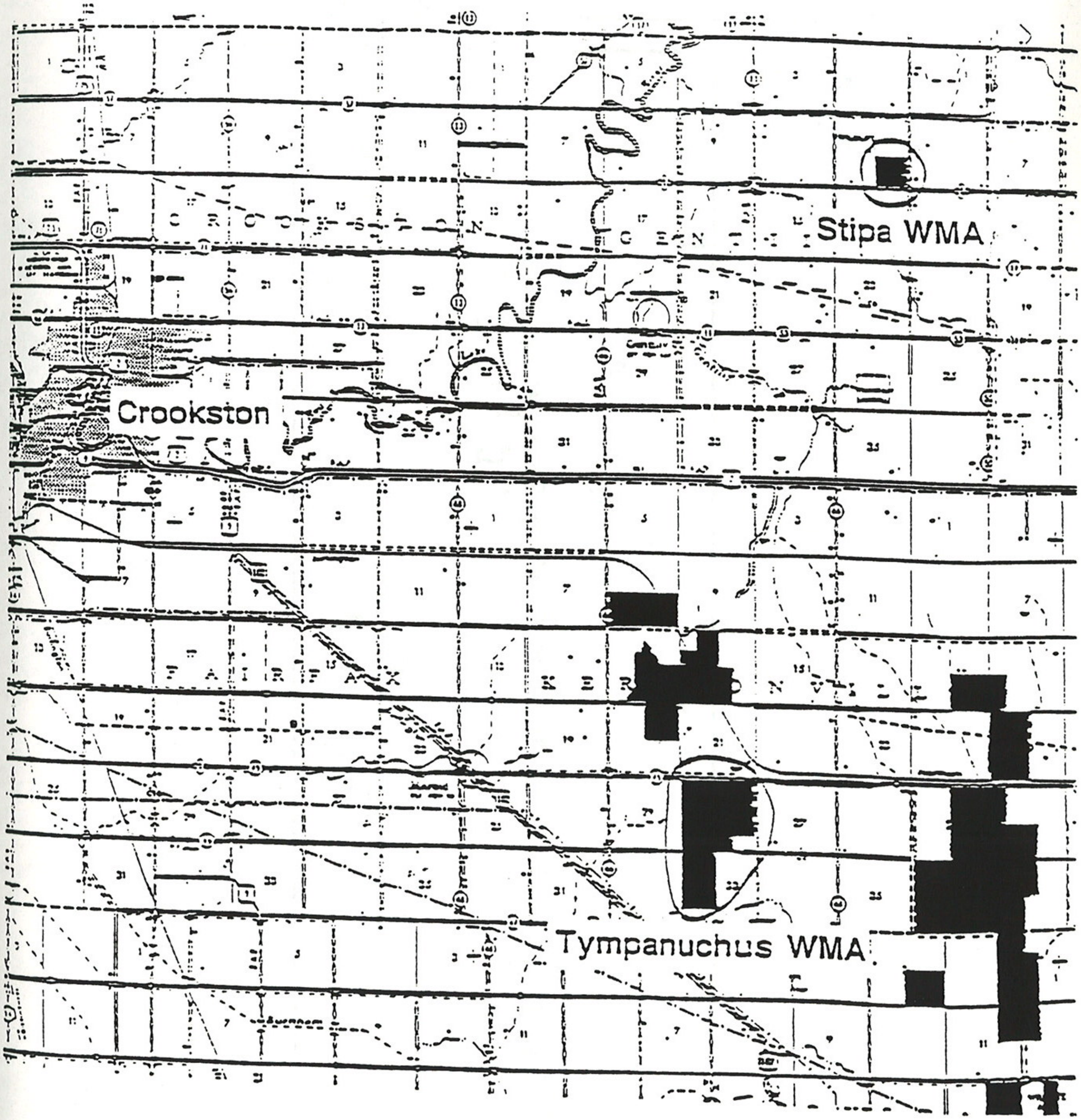

Fig. 3 Schematic diagram of sample plot placement on the Tympanuchus Wildlife Management Area ridge. (Not shown to scale.)

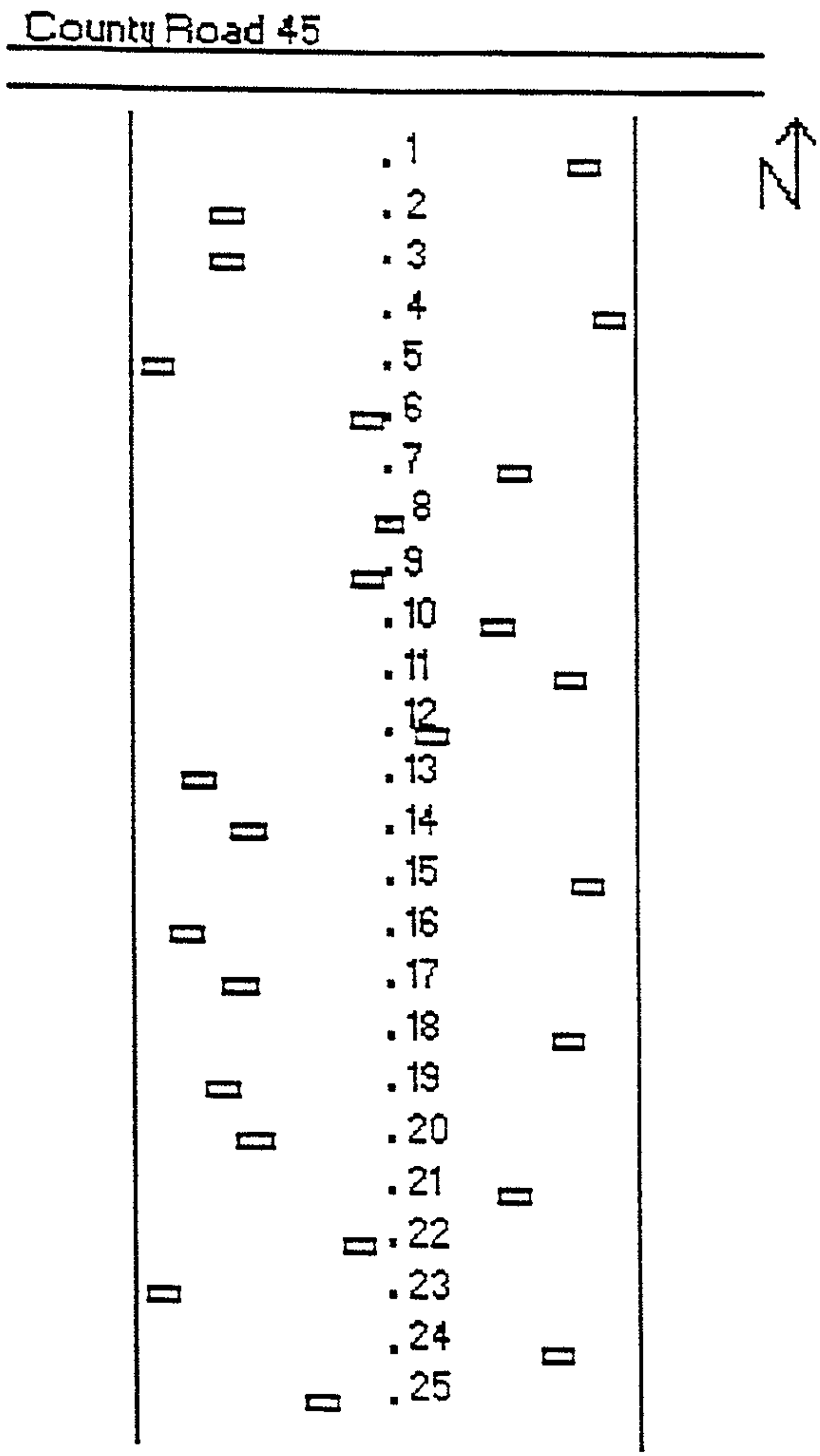

Fig. 4 Schematic diagram of sample plot placement on the Stipa Wildlife Management Area ridge. (Not shown to scale.)

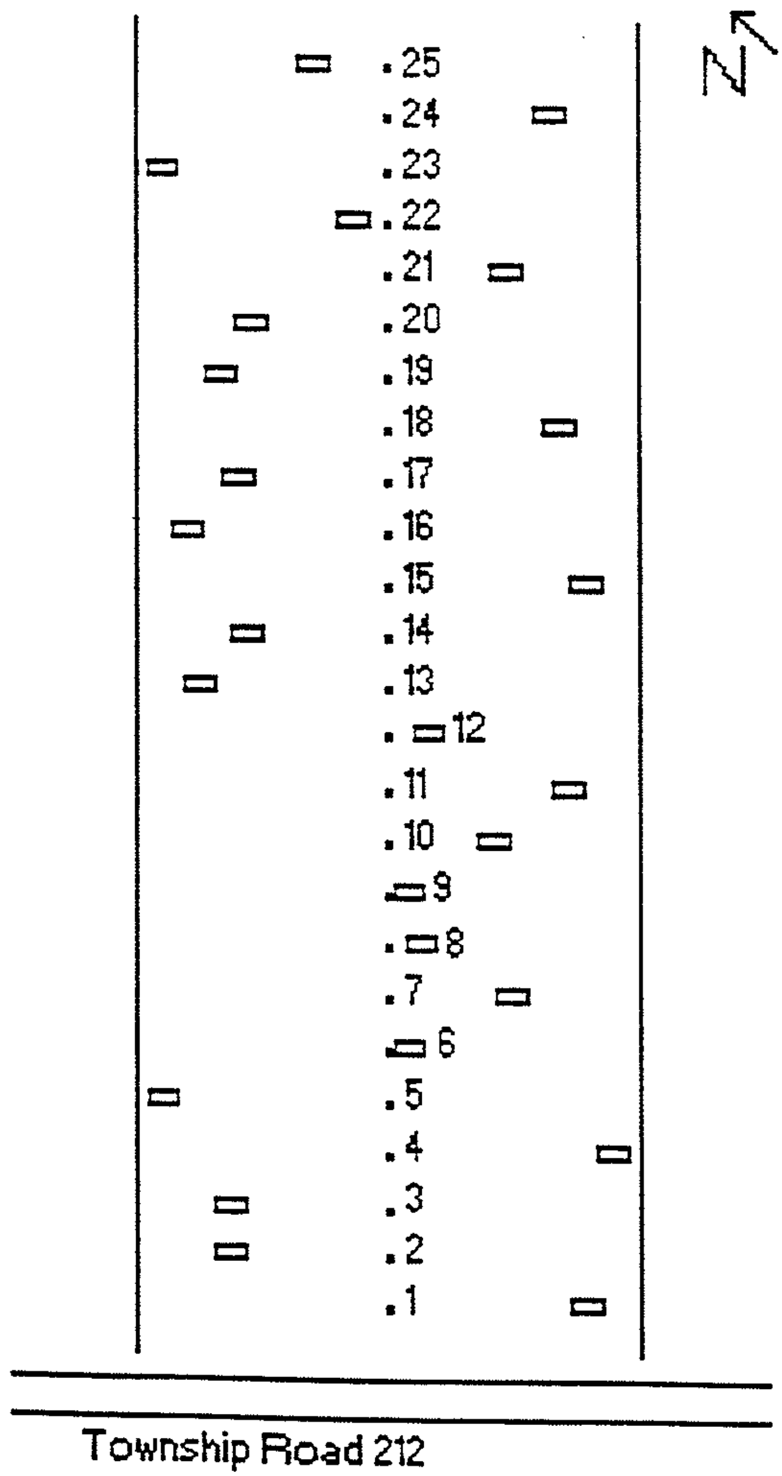

Table 1. Species found with the greatest frequency and in the highest abundance on the Stipa Wildlife Management Area ridge.

Species	Grazing Classification*	Frequency (%)	Mean Abundance
Bromus inermis Leysser.	W	96	3.92
Aster ericoides L.	I	92	3.56
Poa spp.^	U	80	2.28
Melilotus spp.#	I	68	1.36
Artemisia frigida Willd.	I/W	64	1.80
Medicago lupulina L.	U	48	1.16
Achillea millefolium L.	I	44	0.88
Stipa comata Trin. and Rupr.	I	28	0.84
Cirsium floodmanii (Rydb.) Arthur.	W	24	0.40
Symphoricarpos occidentalis Hook.	U	24	0.60
Ambrosia coronopifolia T. & G.	W	20	0.44
Solidago canadensis L.	U	16	0.44
Artemisia ludoviciana Nutt.	I	12	0.24
Solidago missouriensis Nutt.	I	12	0.36
Astragalus adsurgens Pallas.	U	8	0.28

* I = Increases under grazing pressure
D = Decreases under grazing pressure
W = Weedy invader with grazing pressure
U = Not classified as an increaser, decreaser, or weedy invader
Classified according to Weaver (1954) and Johnson and Nichols (1970)

^ Poa pratensis L. and Poa compressa L.

Melilotus officinalis (L.) Pallas. and Melilotus alba Medikus.

Table 2. Species found with the greatest frequency and in the highest abundance on the Tympanuchus Wildlife Management Area ridge.

Species	Grazing Classification*	Frequency (%)	Mean Abundance
Stipa comata Trin. and Rupr.	I	76	2.64
Aster ericoides L.	I	72	2.16
Senecio plattensis Nutt.	D	64	1.48
Campanula rotundifolia L.	U	64	1.72
Schizachyrium scoparium (Mich.) Nash.	D	52	1.92
Amorpha canescens Pursh.	D	44	0.96
Elymus trachycaulus (Link.) Gould.	D	44	1.00
Andropogon gerardii Vitman.	D	40	1.20
Solidago missouriensis Nutt.	I	40	1.28
Poa pratensis L.^	I	40	1.28
Rosa spp.#	U	40	0.92
Achillea millefolium L.	I	36	0.72
Helianthus rigidus (Cass.) Desf.	D	32	0.92
Liatris punctata Hook.	D	32	1.12
Panicum leibergii (Vasey.) Scribn.	U	32	0.68
Solidago rigida L.	I	28	0.76
Pediomelum esculentum (Pursh.) Rydb.	D	28	0.40
Koelaria pyramidata (Lam.) P. Beauv.	D	28	0.72
Helictotrichan hookeri (Scribn.) Henr.	U	24	0.60
Anemone patens L.	U	24	0.76
Dalea purpurea Vent.	D	16	0.32
Bouteloua gracilis (HBK.) Lagasca.	I	16	0.56
Symphoricarpos occidentalis Hook.	U	16	0.48

* I = Increases under grazing pressure
D = Decreases under grazing pressure
W = Weedy invader with grazing pressure
U = Not classified as an increaser, decreaser, or weedy invader
Classified according to Weaver (1954) and Johnson and Nichols (1970)

^ No Poa compressa L. was found on the Tympanuchus WMA ridge

\# The species in this genus is (are) listed by only the genus name in the species list

Appendix A. Complete species list for both the Tympanuchus WMA and the Stipa WMA.

Family	Scientific name	Common name	Location Tympanuchus	Stipa
Apiaceae	Thaspium trifoliatum (L.) A. Gray.	Smooth meadow-parsnip	X	
Apiaceae	Zizia aurea (L.) Koch.	Common golden alexander		X
Asteraceae	Achillea millefolium L.	Common yarrow	X	X
Asteraceae	Agoseris glauca (Pursh.) D. Dietr.	False dandelion	X	
Asteraceae	Ambrosia coronopifolia T. & G.	Western ragweed		X
Asteraceae	Antennaria neglecta Greene.	Field pussy toes		X
Asteraceae	Antennaria plantaginifolia (L.) Richardson.	Plantain pussytoes	X	
Asteraceae	Artemisia campestris L. (sub-spp. caudata)	Wormwood	X	X
Asteraceae	Artemisia frigida Willd.	Prairie or Thin-leaf sagewort	X	X
Asteraceae	Artemisia ludoviciana Nutt.	White sage	X	X
Asteraceae	Aster ericoides L.	Many-flowered aster	X	X
Asteraceae	Aster laevis L.	Smooth aster	X	X
Asteraceae	Cirsium floodmanii (Rydb.) Arthur.	Prairie or Floodman's thistle	X	X
Asteraceae	Echinacea angustifolia DC.	Purple coneflower	X	X
Asteraceae	Erigeron glabellus Nutt.	Fleabane	X	X
Asteraceae	Erigeron spp.	Fleabane	X	X
Asteraceae	Gaillardia aristata Pursh.	Common blanket flower	X	X
Asteraceae	Grindelia squarrosa (Pursh.) Dunal.	Curly-top gum-weed	X	X
Asteraceae	Helianthus maximilianii Schrader.	Maximilian sunflower	X	X
Asteraceae	Helianthus rigidus (Cass.) Desf.	Stiff sunflower	X	X
Asteraceae	Liatris punctata Hook.	Dotted blazing star	X	X
Asteraceae	Rudbeckia hirta L.	Black-eyed susan	X	X
Asteraceae	Senecio plattensis Nutt.	Prairie ragwort	X	X
Asteraceae	Solidago canadensis L.	Common goldenrod	X	X
Asteraceae	Solidago missouriensis Nutt.	Missouri goldenrod	X	X
Asteraceae	Solidago nemoralis Aiton.	Gray goldenrod	X	
Asteraceae	Solidago ptarmicoides (Nees) B. Boivin.	Goldenrod	X	
Asteraceae	Solidago rigida L. (var. rigida)	Stiff goldenrod	X	
Asteraceae	Solidago spp.	Goldenrod	X	X
Asteraceae	Taraxacum officinale Weber.	Common dandelion		X
Asteraceae	Tragopogon dubius Scop.	Goat's beard	X	X
Boraginaceae	Lithospermum canescens (Michx.) Lehm.	Hoary puccoon	X	X
Boraginaceae	Lithospermum incisum Lehm.	Narrow-leaved puccoon		X
Brassicaceae	Lepidium densiflorum Schrader.	Prairie pepperweed		X
Brassicaceae	Thlaspi arvense L.	Field penny-cress		X
Brassicaceae	Unknown			X
Brassicaceae	Unknown			X
Campanulaceae	Campanula rotundifolia L.	Harebell	X	X
Campanulaceae	Lobelia nuttallii Roemer & Schultes.	Nuttall's lobelia	X	X
Caprifoliaceae	Symphoricarpos occidentalis Hook.	Wolfberry	X	X
Caryophyllaceae	Silene lotifolia Poiret. or Silene vulgaris (Moench.) Garcke.	White campion / Bladder-campion		X
Chenopodiaceae	Kochia scoparia (L.) Schrader.	Kochia	X	X
Cuscutaceae	Cuscuta coryli Engelm. or Cuscuta megalocarpa Rydb. or Cuscuta pentagona Engelm.	Dodder	X	X
Cyperaceae	Carex eleocharis L. Bailey	Needleleaf sedge	X	X
Cyperaceae	Carex filifolia Nutt. or Carex heliophila Mack.	Threadleaf sedge	X	
Equisetaceae	Equisetum hyemale L. (var. affine)	Common scouring rush	X	X

Appendix A. Complete species list - page 2.

Family	Scientific name	Common name	Location: Tympanuchus	Stipa
Fabaceae	Amorpha canescens Pursh.	Lead plant	X	
Fabaceae	Amorpha nana Nutt.	Dwarf indigo	X	
Fabaceae	Astragalus adsurgens Pallas.	Standing milk-vetch	X	X
Fabaceae	Astragalus agrestis Douglas.	Field milk-vetch	X	X
Fabaceae	Astragalus canadensis L.	Canada milk-vetch	X	X
Fabaceae	Astragalus crassicarpus Nutt.	Buffalo bean	X	
Fabaceae	Dalea candida Michx.	White prairie clover	X	
Fabaceae	Dalea purpurea Vent. (var. purpurea)	Purple prairie clover	X	X
Fabaceae	Glycyrrhiza lepidota L. (var. lepidota)	American licorice	X	
Fabaceae	Medicago lupulina L.	Black medick		X
Fabaceae	Melilotus alba Medikus.	White sweet clover	X	X
Fabaceae	Melilotus officinalis (L.) Pallas.	Yellow sweet clover	X	X
Fabaceae	Pediomelum argophyllum (Pursh.) Grimes.	Silverleaf scurfpea	X	X
Fabaceae	Pediomelum esculentum (Pursh.) Rydb.	Common breadroot scurfpea	X	
Fabaceae	Unknown		X	
Iridaceae	Sisyrinchium campestre Bickn. or Sisyrinchium montanum Greene	Blue-eyed grass	X	X
Lamiaceae	Monarda fistulosa L.	Horsemint or Bea-balm	X	
Liliaceae	Allium stellatum Ker Gawler.	Wild onion	X	X
Liliaceae	Allium textile (A. Nels & J. F. Macbr.)	Prairie onion	X	
Liliaceae	Lilium philadelphicum L. (var. andinum)	Wild lily or Wood lily	X	
Liliaceae	Zigadenus elegans Pursh.	Death-camas	X	
Linaceae	Linum sulcatum Riddell ?	Yellow flax	X	X
Onagraceae	Gaura coccinea Pursh.	Scarlet gaura	X	X
Onagraceae	Oenothera biennis L.	Common evening-primrose		X
Onagraceae	Oenothera serrulata Nutt.	Tooth-leaved evening primrose	X	
Poaceae	Andropogon gerardii Vitman.	Big blue stem	X	X
Poaceae	Bouteloua gracilis (HBK.) Lagasca.	Blue gramma grass	X	X
Poaceae	Bromus inermis Leysser.	Smooth brome	X	X
Poaceae	Elymus trachycaulus (Link) Gould.	Slender wheatgrass	X	
Poaceae	Elytrigia repens (L.) Nevski.	Quack-grass	X	X
Poaceae	Helictotrichan hookeri (Scribn.) Henr.	Spike oats	X	X
Poaceae	Koelaria pyramidata (Lam.) P. Beauv.	Junegrass	X	X
Poaceae	Muhlenbergia cuspidata (Torr.) Rydb.	Plains muhly grass	X	
Poaceae	Panicum leibergii (Vasey) Scribn.	Leiberg's panic grass	X	X
Poaceae	Panicum spp. (wilcoxianum?)			X
Poaceae	Panicum virgatum L.	Switchgrass	X	
Poaceae	Poa compressa L.	Canada bluegrass		X
Poaceae	Poa pratensis L.	Kentucky blue grass	X	X
Poaceae	Schizachyrium scoparium (Michx.) Nash.	Little blue stem	X	X
Poaceae	Stipa comata Trin. and Rupr.	Needle-and-thread grass	X	X
Poaceae	Stipa spartea Trin.	Porcupine grass	X	X
Poaceae	Stipa viridula Trin.	Green needle-grass		X
Polemoniaceae	Phlox pilosa L.	Prairie phlox	X	X
Polygonaceae	Polygonum spp.			X
Ranunculaceae	Anemone canadensis L.	Canada anemone	X	X
Ranunculaceae	Anemone cylindrica A. Gray.	Thimbleweed	X	X
Ranunculaceae	Anemone patens L.	Pasque flower	X	X
Ranunculaceae	Delphinium virescens Nutt.	Prairie larkspur	X	
Ranunculaceae	Thalictrum venulosum Trelease.	Northern meadowrue	X	X

Appendix A. Complete species list - page 3.

Family	Scientific name	Common name	Location: Tympanuchus	Location: Stipa
Rosaceae	Geum triflorum Pursh.	Prairie smoke	X	X
Rosaceae	Potentilla argentea L.	Silvery cinquefoil	X	X
Rosaceae	Potentilla arguta Pursh.	Tall potentilla	X	
Rosaceae	Potentilla spp.			X
Rosaceae	Rosa macounii Greene	Wild rose	X	X
	or Rosa arkansana T. C. Porter	Dwarf prairie rose		
	or Rosa blanda Ait.	Wild rose		
Rosaceae	Spiraea alba Duroi.	Meadowsweet	X	X
Rubiaceae	Galium boreale L.	Northern bedstraw	X	X
Rubiaceae	Galium spp. L.	Bedstraw		X
Santalaceae	Comandra umbellata (L.) Nutt.	Bastard toadflax	X	X
Saxifragaceae	Heuchera spp.	Alumroot	X	
Scrophulariaceae	Penstemon albidus Nutt.	Prairie white beard-tongue	X	
Scrophulariaceae	Penstemon gracilis Nutt.	Slender beard-tongue	X	X
Scrophulariaceae	Veronicastrum virginicum (L.) Farw.	Culver's root	X	
Violaceae	Viola pedatifida G. Don	Prairie violet	X	
Violaceae	Viola spp.	Violet		X
Unknown	Unknown	Bindweed		X

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