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The effects of grazing management on small mammal density and diversity in Nebraska sandhills.

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THE EFFECTS OF GRAZING MANAGEMENT ON SMALL MAMMAL DENSITY AND DIVERSITY IN THE NEBRASKA SANDHILLS

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THESIS ACCEPTANCE

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INTRODUCTION

Strong relationships exist between vegetative structure and composition of a grassland and the animal composition in terms of density and diversity (MacArthur and MacArthur 1961, Wiens 1973). Recent investigations of grassland habitat management and its effect on the avifauna, indicate that the primary mechanism of habitat alteration of a mixed or short grass prairie is grazing (Owens and Myres 1973; Balda 1975; Wiens and Dyer 1975).

Grazing can have varying effects on the flora, and these are related to grazing intensity and geographic location of the site. A grazing intensity which produces an overgrazed condition one year may produce a more normal grazed condition the following year (Tolstead 1942; Ellison 1960; Wiens and Dyer 1975). In general, overgrazing will change the floristic composition to resemble that of a more xeric location (Ellison 1960), and the avifaunal composition reflects this change. If grazing effects on the vegetation are minor, the bird composition shifts only a small amount. If grazing has a substantial impact, resulting in a shift towards a xeric plant assemblage, the avian composition also changes dramatically (Owens and Myres 1973; Wiens and Dyer 1975).

Although most studies on grassland management and its effect on the animal community have dealt with birds, some studies have centered on small mammal habitat selection. A comparative study of small mammal populations in the great plains revealed some degree of selection by small mammals for an ungrazed grassland (Pefaur and Hoffman 1975). In a study of the preferred habitats of small mammals in north central Kansas, it was suggested that small mammals are more influenced by the life forms of the plants (trees vs. grasses) than any one plant species (Kaufman and Fleharty 1974). Choate and Terry (1973) commented on the preferred habitat of the northern grasshopper mouse, Onychomys leucogaster. They felt that this species selected for areas where the climax vegetation might have been disturbed. Frydendall (1969) studied small mammal habitat preference in another mixed-grass prairie of Kansas and found that certain rodent species would avoid an ungrazed area but could be found in a moderately grazed area. A similar study showed relationships between several plant assemblages and rodent species (Martin 1960).

Most North American grasslands have been studied with respect to vegetational quality and animal abundance. This study deals with the Nebraska Sandhills, an area which has not been extensively investigated with respect to small mammal communities. The few studies that have been conducted include inventories by Beed (1936), Jones (1964), and Gunderson (1973). There has been no study which investigates the effects of sandhill grassland management on small mammal density and diversity. Such a study is needed to help evaluate the management regime of any proposed sandhill wilderness area.

The present study was undertaken (1) to define the effects of two management regimes on the small mammal diversity and density, and (2) to predict the impact of these regimes on the native small mammals.

STUDY AREA

The study was conducted on two sandhill grassland sites situated in the Valentine National Wildlife Refuge, Cherry County Nebraska (Fig. 1). The refuge is characteristic of the Nebraska sandhills, consisting of hills of originally wind-blown, but subsequently stablized, sand dunes (Smith 1965). The grassland vegetation (*Andropogon* - *Calamovilifa* - *Stipa* - *Yucca*) (Kaul 1975) is unique from that of any other grassland in North America (Weaver 1965).

A grazed and an ungrazed study site were selected based on their proximity to each other and their similarity in topography and exposure. The 400 hectare (1,000 acre) ungrazed area, located in Section 22 T30NR29W. It was set aside as a Native Sandhill Grassland Monument in 1935. The 267 hectare (656 acre) grazed area was located directly south of the ungrazed site in Sections 27-28 T30NR29W and was last grazed from 1 June to 10 July 1973, by 130 head of cows and calves, representing 220 animal units per month.

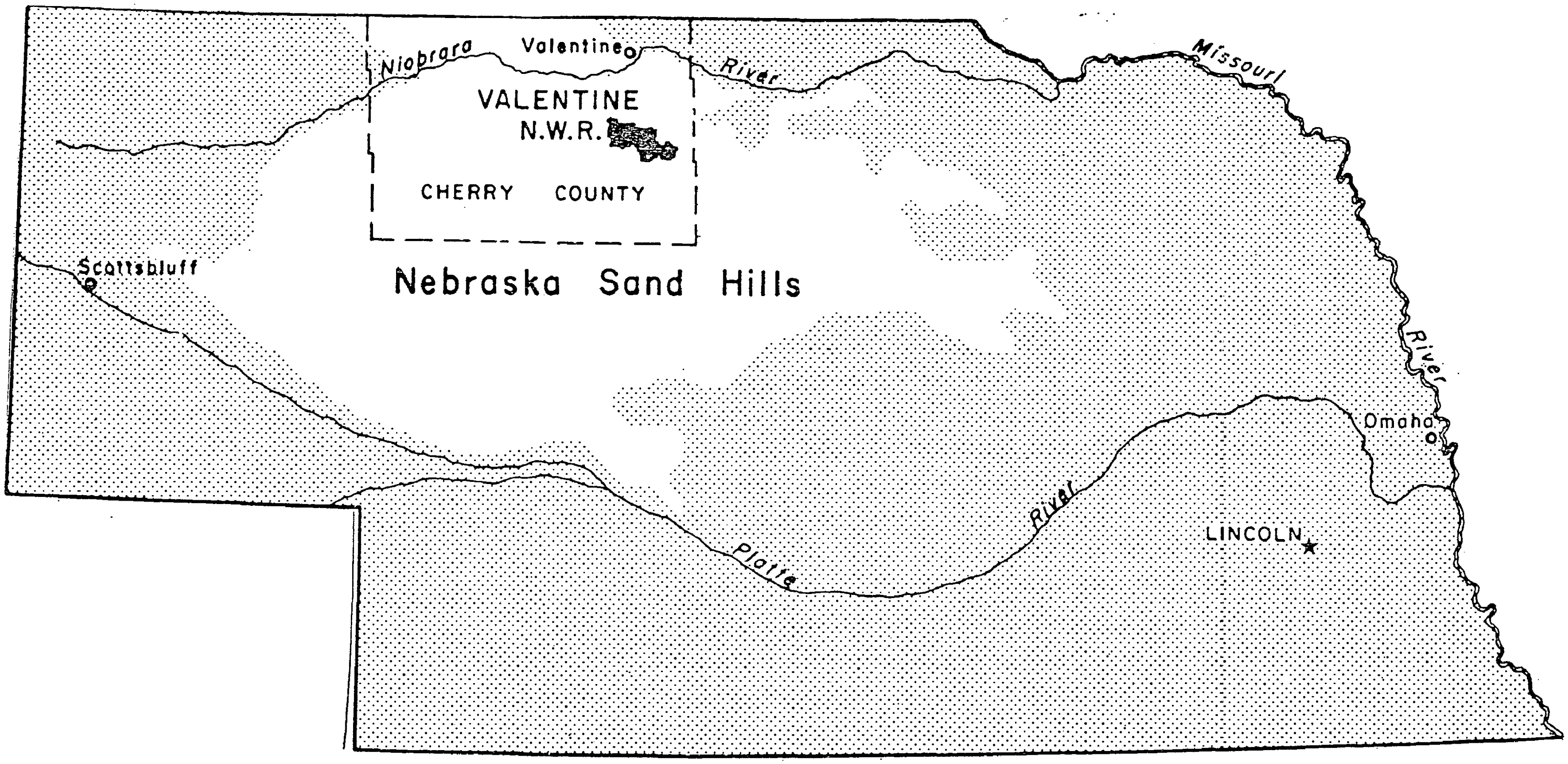

Fig. 1. Location of the Valentine National Wildlife Refuge within the Nebraska sandhills.

METHODS

Vegetative Analysis

Vegetative analysis was conducted in mid-August, 1975. Three topographic zones, hilltops, slopes, and depressions, were separately evaluated in both the grazed and ungrazed management areas. Depressions are defined as saucer-shaped basins, situated in uplands and surrounded by slopes and hilltops (Pool 1912). Eight sample plots were evaluated in each topographic zone on both management areas. Two procedures were implemented to quantitatively evaluate vegetation. Percent coverage of grasses, forbs, cacti, woody vegetation and bare ground was measured using a canopy coverage procedure described by Daubenmire (1959). Canopy coverage and density for each species, thatch thickness, and vertical density were determined using procedures developed by Wiens (1973).

Data gathered from the aforementioned procedures were used to calculate importance values, relative species diversity, community similarity, community heterogeneity, and community species richness. Importance value is the sum of relative dominance, relative density, and relative frequency for each species. Dominate plant species were considered to be those with an importance value greater than .20. Relative plant species diversity (H') was calculated using the Shannon formula: $H' = \sum_{i=1}^{s} p_i \log_e pi$ where p_i equals the proportion of all individuals which belong to the i^{th} species (MacArthur and MacArthur 1961; Pefaur and Hoffman 1975); as the H' value increases, diveristy increases. A comparison of H' values between two areas was made using a test presented in Zar (1974). Species diversity values (H') were considered significantly different at the .05 confidence level. Vegetative community similarity was determined using the Spatz-Jaccard equation (Muller-Dombois and Ellenberg 1974). Community heterogeneity was determined using a heterogeneity index developed by Weins (1973) and is used to compare horizontal uniformity of vegetation. Species richness, the total number of species in a community, was determined for each topographic zone.

Small Mammal Analysis

Small mammal data were gathered by snap trapping. Both Victor Hold Fast Mouse Traps and larger, Museum Special Snap Traps were used in order to allow sampling of as broad a range of body size as possible. Trapping was conducted during April, May, and June, 1975.

Trapping locations were selected so as to resemble each other as closely as possible. As with the vegetative study, the management areas evaluated were divided into hilltops, slope, and depression topographic zones.

Traps were placed in a grid approximately 10 meters apart. Every sixth trap was the larger museum special. The maximum number of traps for any one location was 50; the minimum was 30. A total of 3,730 trap nights were accumulated during the study (Appendix Table 1). A trap night equals one trap set one night.

Traps were first baited with a combination of rolled oats and peanut butter. After the first trap session the bait was changed to strictly rolled oats. There was no noticeable change in bait acceptance and much less time was required to set and bait the traps.

Traps were set and baited as close to sunset as possible and checked the next morning as close to sunrise as possible. Traps not sprung during the night were left set; there were only two diurnal captures. The specimens were tagged, numbered, and identified. Identification and taxonomy were based on Hall and Kelson (1959), Burt and Grossnheider (1964), Jones (1964), and Gunderson (1974).

Small mammal relative diversity was determined and tested statistically using the previously described Shannon and Zar formulas.

Relative density estimates were used. A relative density based on either biomass or population alone has certain inherent problems. Harris (1971) spoke of these when he noted "...by counting small individuals equally with large, the analysis of numbers would tend to over-emphasize the importance of small size species, whereas the consideration of biomass only, would tend to over-emphasize the importance of larger species". Therefore both types of density data were calculated.

Relative population density:

$$= \frac{\text{Number of individuals collected in a species}}{\text{Total number of individuals collected}} \times 100$$

Relative biomass diversity:

$$= \frac{\text{Total biomass of a species}}{\text{Total collected biomass}} \times 100$$

RESULTS AND DISCUSSION

Vegetation

General

A total of 48 species were recorded, 37 on the grazed area and 39 on the ungrazed area (Appendix Table 2). Based on importance values, 12 were considered dominants (Table 1), of which six occurred on all topographic zones. Nomenclature is based on McGregor (1973); common names are based on Anderson and Owensby (1969).

Each vegetative zone was found to be dissimilar from each other with the exception of grazed hilltops and ungrazed slopes (Fig. 2).

Comparison of Management and Topographic Zones

Hilltops: Little bluestem, *Andropogon scoparius*, dominated ungrazed hilltops; hairy grama, *Bouteloua hirsuta*, was most abundant on grazed hilltops (Table 1). High percentages of bare ground, small amounts of thatch and poor vertical stratification were recorded for both grazed and ungrazed sites (Table 2, Fig. 3).

Species richness was greater and species diversity was significantly higher on the ungrazed hilltop (Table 2). Of the 12 dominant species, 10 were recorded on the grazed areas as compared to 12 on the ungrazed areas (Table 1).

Slopes: Prairie sandreed grass, *Calamovilfa longifolia*, and sand lovegrass, *Eragrostis trichodes*, dominate the grazed slopes; needleandthread grass, *Stipa comata*, was highest on the ungrazed slopes (Table 1). Of the dominant species, Kentucky bluegrass, *Poa pratensis*, was not found on ungrazed slopes; small soapaweed, *Yucca glauca*, was not found on grazed slopes. Species richness was higher on the ungrazed slopes than on any other topographic zone evaluated; species diversity (H') of this zone, however, was low (Table 2). A possible explanation for this discrepancy is that H' values are determined using both number of species and the number of individuals of each species, whereas species richness is a function only of the number of species in an area.

Some vertical stratification was found on ungrazed slopes, but not on grazed slopes (Fig. 3). Grass and forb coverage was much higher on the ungrazed than on the grazed slopes (Table 3).

Depressions: Kentucky bluegrass was the most important species on the grazed depressions; prairie sandreed grass dominated ungrazed areas (Table 1). Grass coverage was higher in grazed and ungrazed depressions than in any other topographic zone; bare ground was the lowest (Table 2).

Species richness in this zone was lower than in any other zone; species diversity between the grazed and ungrazed areas were significantly different (Table 2). Eight of the dominant species were found on the ungrazed areas; ten were recorded on the grazed areas (Table 1). Some vertical stratification is suggested (Fig. 3b).

Responses of Vegetative Species to Grazing

Various grass species respond differently to grazing (Fig. 4).

These results support studies done by Tolstead (1942) and Weaver (1965).

Two additional trends were found: (1) woody vegetation appears to be encouraged by grazing (Table 2) and (2) grazing increases the vertical density of vegetation (Fig. 3).

Table 1. Importance value of plant species dominating in at least one topographic zone. Dominate plants are those with an importance value greater than .20. UNG. = Ungrazed management GRA. = Grazed management.

SPECIES	TOPOGRAPHIC ZONE						AVERAGE IMPORTANCE VALUE	
	HILLTOP		SLOPE		DEPRESSION			
	UNG.	GRA.	UNG.	GRA.	UNG.	GRA.	UNG.	GRA.
Ambrosia psilostachys	.26	.16	.25	.02	.06	.05	.20	.14
Andropogon hallii	.23	.15	.11	.21	.10	.05	.15	.14
Andropogon acoparius	.39	.17	.33	.13		.05	.27	.12
Bouteloua hirsuta	.20	.39	.14	.21			.13	.21
Calamovilfa longifolia	.26	.27	.27	.47	.78	.33	.40	.36
Carex spp.	.06	.09	.07	.16	.37	.18	.25	.17
Eragrostis trichodes	.02	.14	.17	.47	.14	.26	.10	.29
Rosa arkansana	.04	.15	.07	.25		.08	.05	.16
Poa pratensis				.09	.45	.75	.12	.27
Sporobolus cryptandrus	.17	.20	.06	.19	.12	.43	.11	.27
Stipa comata	.17		.44	.17	.34	.25	.31	.13
Yucca glauca	.25	.13	.16				.15	.04

	UNG. DEPR.	UNG. SLOPE	UNG. HILLTOP	GRA. DEPR.	GRA. SLOPE	GRA. HILLTOP
UNGRAZED DEPRESSION	--					
UNGRAZED SLOPE	4.9	---				
UNGRAZED HILLTOP	3.8	24.5	---			
GRAZED DEPRESSION	16.3	9.1	6.7	---		
GRAZED SLOPE	12.7	15.3	17.4	12.5	---	
GRAZED HILL	6.1	39.8	16.7	7.2	19.4	---

Fig. 2. Comparison of plant communities using the Spatz-Jaccard Similarity index. Values less than 25.0 indicate dissimilarity, values between 25.0 and 50.0 suggest similarity.

Table 2. Vegetative characteristics of grazed and ungrazed sandhill areas. trace 0.5 cm
[a] = probability above .05 that H' is different.

VEGETATIVE CHARACTERISTIC	TOPOGRAPHIC ZONE						AVERAGE	
	HILLTOP		SLOPES		DEPRESSION			
	UNG.	GRA.	UNG.	GRA.	UNG.	GRA.	UNG.	GRA.
Vertical density	2.6	3.5	3.7	5.3	5.5	8.6	3.9	5.8
Mean quart. dist.	5.7	5.6	6.0	5.5	4.6	4.1	5.4	5.1
Thatch thickness (cm)	tr	tr	tr	1.0	1.5	1.5	tr	tr
Percent coverage								
grass	27	35	27	50	74	67	42	51
forbs	32	19	22	29	6	10	20	19
cactus	2	1	1	1	0	1	1	1
woody vegetation	3	4	4	12	0	1	3	6
bare ground	50	56	41	50	27	23	39	43
Species richness	27	24	32	20	11	18	39	37
Species diversity (H')	1.74	1.58[a]	1.54	1.29[a]	0.71	1.06[a]	3.59	3.14[a]
Heterogeneity index	1.40	1.48	1.06	1.23	1.01	1.52	1.11	1.43

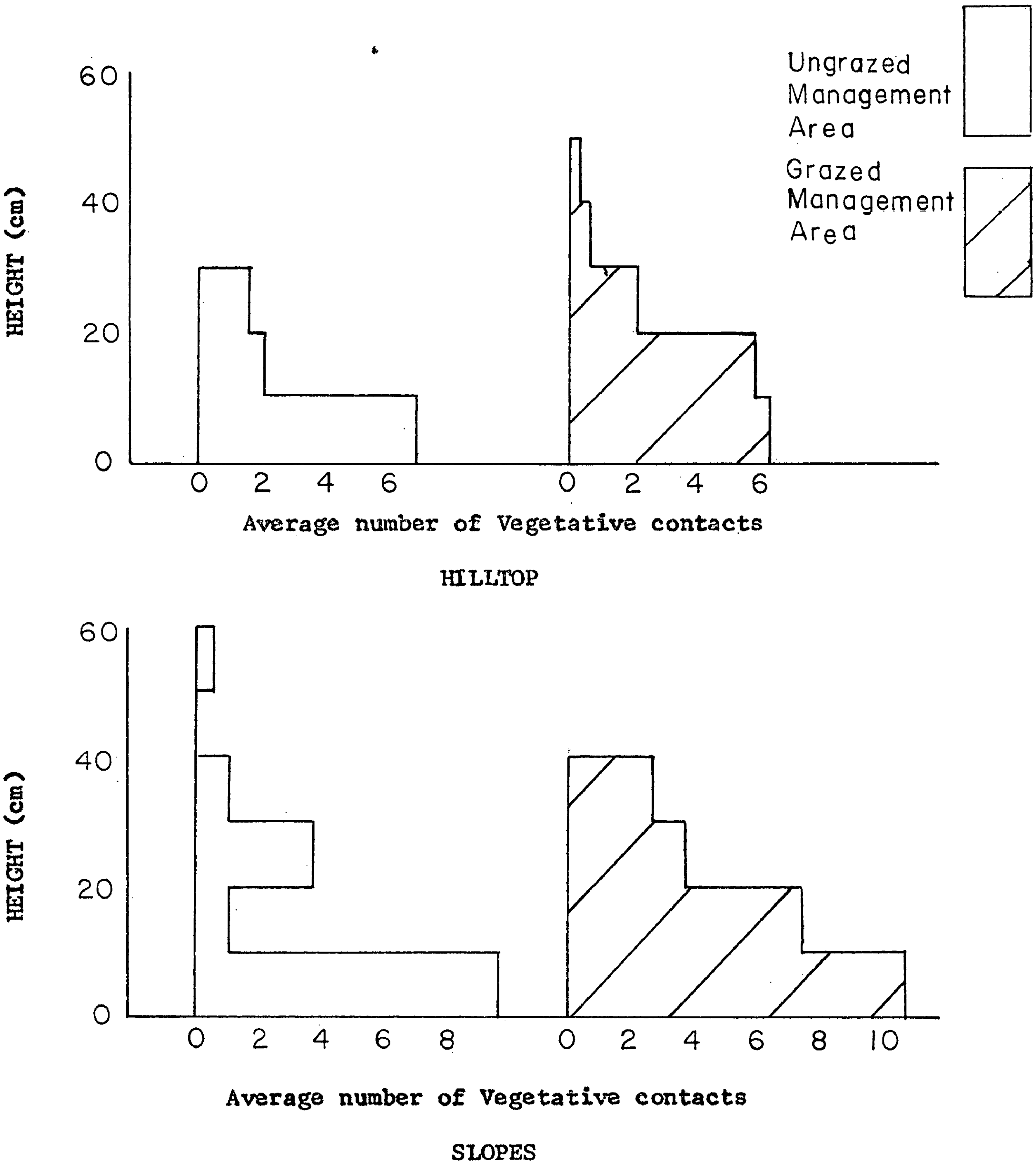

Fig. 3. Vertical density of plants on grazed and ungrazed hilltops and slopes in the Nebraska Sandhills.

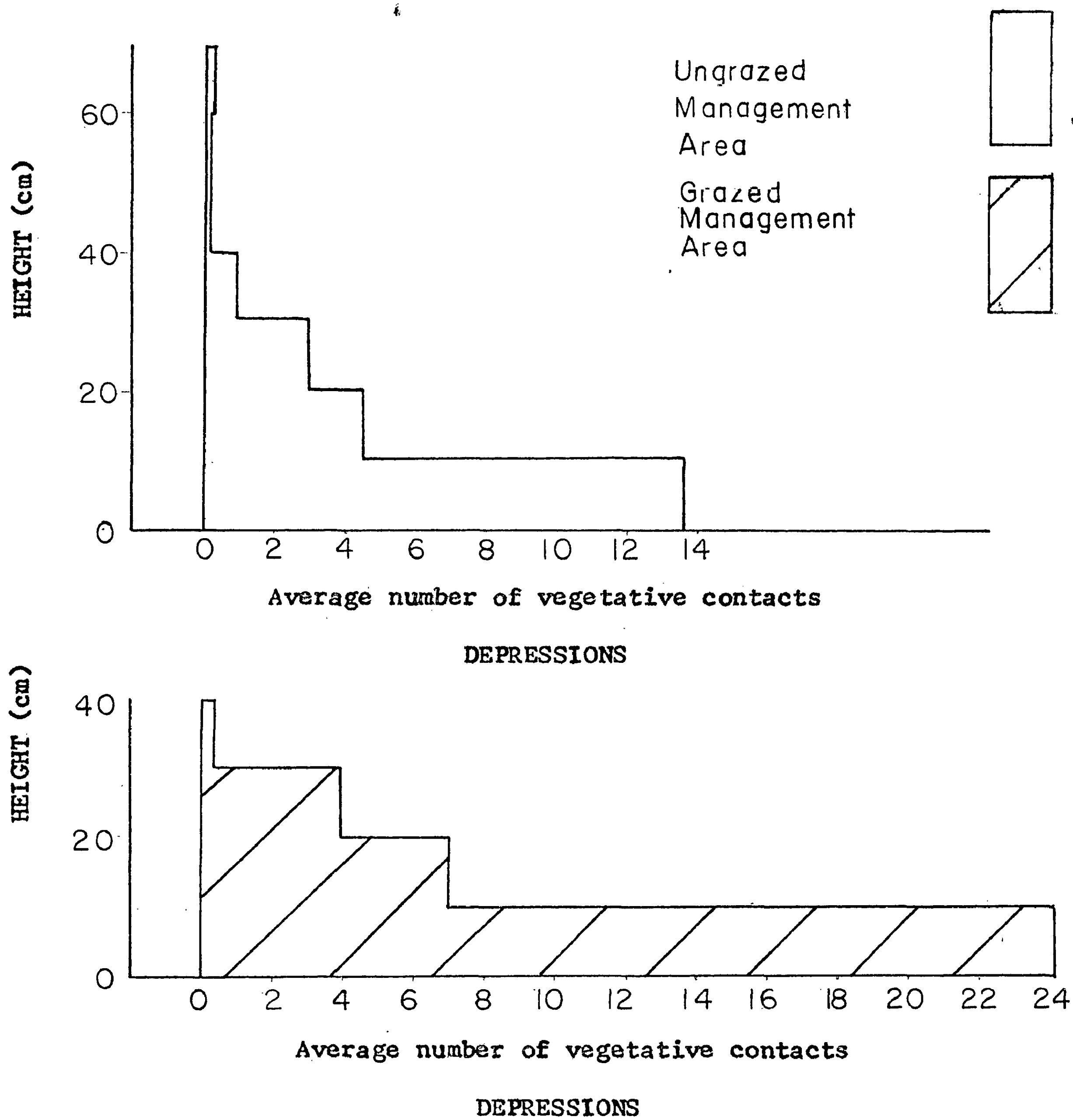

Fig. 3A. Vertical density of plants on a grazed and ungrazed upland depression in the Nebraska sandhills.

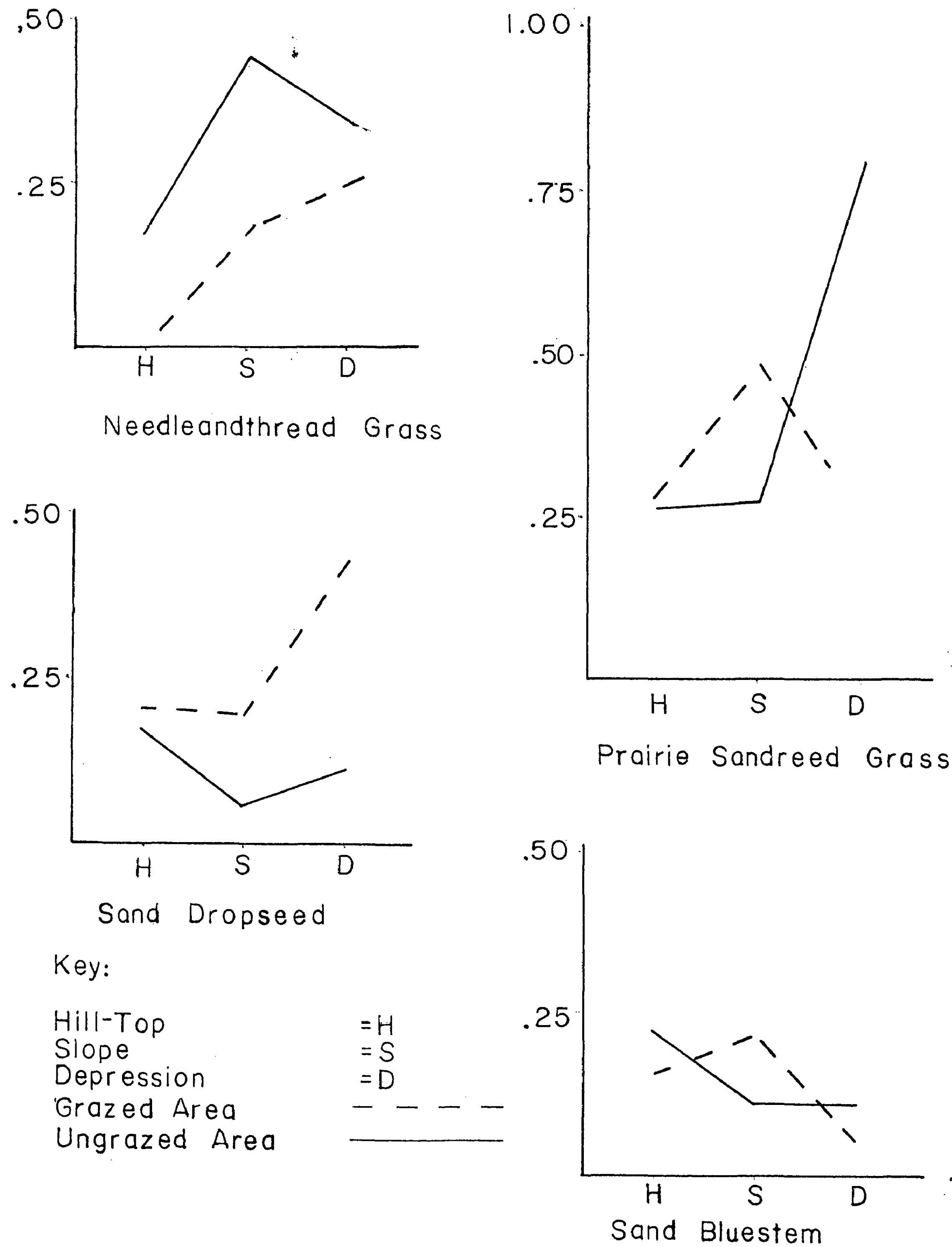

Fig. 4. Changes in importance values on grazed and ungrazed Nebraska Sandhill areas. Number on vertical axis represents importance value.

RESULTS AND DISCUSSION

Small Mammals

General

A total of 286 individuals, representing ten species, were captured on the two management areas. Of this total, three individuals were excluded from the small mammal analysis. Two thirteen-lined ground squirrels, Spermophilus tridecemlineatus, were not considered because of their diurnal captures. One meadow jumping mouse, Zapus hudsonius, was excluded, because its presence on the ungrazed upland prairie was believed to be transitory due to its strong affinity to riparian communities (Jones 1964).

The remaining captures were divided among eight species; prairie vole, Microtus ochrogaster, meadow vole, Microtus pennsylvanicus, Ord's kangaroo rat, Dipodomys ordii, plains pocket mouse, Perognathus flavescens, western harvest mouse, Reithrodontomys megalotis, plains harvest mouse, Reithrodontomys montanus, northern grasshopper mouse Onychomys leucogaster, and prairie deer mouse, Peromyscus maniculatus (Table 3).

On the ungrazed management area 148 individuals were captured, while on the grazed management area, 134 individuals were obtained. This represents a trapping success of 7.9% for the ungrazed and 7.2% for the grazed areas.

Densities

Relative population density (Appendix Table 2) suggests that two species have a significant difference between management areas. Ord's Kangaroo rat data indicates significantly higher (P= .05 confidence level) population density on the grazed management area. Its population density was higher on the grazed hilltops than on ungrazed hilltops. This most likely reflects the relatively open area (Table 2) that this species prefers (Jones 1964).

Western harvest mouse shows a significantly higher population density on the ungrazed management area, a habitat which is consistent with results presented in earlier studies (Brown 1946; Jones 1964; Kaufman and Fleharty 1974). These studies indicated that this species favors areas where the plant production was high or in their words "lush". Plant data (Table 2), suggest that the ungrazed study area was more diverse and rich in species than the grazed area.

Population densities for all other species did not differ significantly from their counterparts on the other management area, however, some trends are suggested by the data. Grasshopper mice are more abundant on the grazed area. A study of this species reported that grasshopper mice are most common where the climax vegetation has been disturbed. They also showed a relationship with sand lovegrass (Choate and Terry, 1973). My data would support this observation (Table 1).

The plains harvest mouse has been reported to favor short-grass prairies (Kaufman and Fleharty, 1974). My data would suggest that this species is most common on the grazed area, a more xeric plant community than the ungrazed (Table 1). Wiens and Dyer (1975) have

Table 3. General small mammal characteristics of grazed and ungrazed sandhill areas. [a]= probability above .97 that H' is different.

TRAPPING CHARACTERISTICS	TOPOGRAPHIC ZONES						TOTAL	
	HILL		SLOPE		DEPR.			
	UNG.	GRA.	UNG.	GRA.	UNG.	GRA.	UNG.	GRA.
Total trap nights	930	920	220	240	730	690	1880	1850
Trapping success (%)	10.1	10.0	10.0	3.3	4.1	4.9	7.9	7.2
Total trapped biomass (grms)	1826	2347	426	185	516	759	2777	3290
Species richness	8	8	5	4	7	7	8	8
Species diversity (H')	1.43	1.35[a]	0.52	0.24[a]	0.67	0.77[a]	1.72	1.69

reported a similar shift in avifauna towards xeric tolerating species when a shift in vegetation is toward a xeric plant group. This same phenomenon may be occuring on the grazed management area. Where a more xeric plant community exists, those small mammals that favor this type of prairie are more commonly found. The remaining species were all more abundant on the ungrazed management area. This could be due to the more diverse plant community creating more lush vegetation. Of the eight species tested for relative biomass density (Appendix Table 2), six species differed significantly in their total species biomass between the two management areas.

Habitat and Dietary Relationships

Microtines (voles) account for only 7% of the biomass on the grazed area, but over twice that on the ungrazed (Fig 5). The topographic zone where they were most abundant was the relatively moist depressions.

Heteromyids (plains pocket mouse, Ord's kangaroo rat) contributed 49% of the biomass, 47% of the individuals to the ungrazed area. They constituted 74% of the biomass and 60% of the population on the grazed area (Fig. 5). The topographic zone where they were most productive was grazed hilltops.

Cricetine rodents (western and plains harvest mouse, grasshopper mouse, and deer mouse) constituted 32% of the biomass, 41% of the individuals on the ungrazed. While on the grazed, they accounted for 39% of the biomass, and 31% of the individuals. The "topo" zone most accountable for these species was the ungrazed hilltops.

Harris (1971) has developed a hypothesis which can be corroborated by my data. Microtines are almost pure grazers and would require abundant forage. Also, microtines are surface "tunnelers" and require extensive vertical and horizontal cover. It is not unexpected to find the ungrazed depressions as their most preferred habitat, since this "topo" zone has the highest percent coverage of grass of all the evaluated areas (Table 2).

Heteromyids are primarily seed eaters (Baker 1971) and are the predominant rodent group in a desert community (Harris 1971). This may be because of the increased seed production in a desert community. In this study heteromyids were found to be most dense on grazed hilltops. This site most closely resembles a desert community (Table 2). Assuming increased seed production and smaller amounts of foliage, grazed hilltops would be strongly favored by heteromyids.

Cricetid rodents have developed less specificity in their diets. While primarily seed eaters, cricetids will turn to insects and other animal food when the seed supply has been over-exploited. This omnivory has allowed them to occupy a niche between the microtines and the heteromyids. Their diet and antomical make-up suggest such a compromise (Harris 1971). My data indicate this group to be most common on the ungrazed hilltops. This topographic zone could be

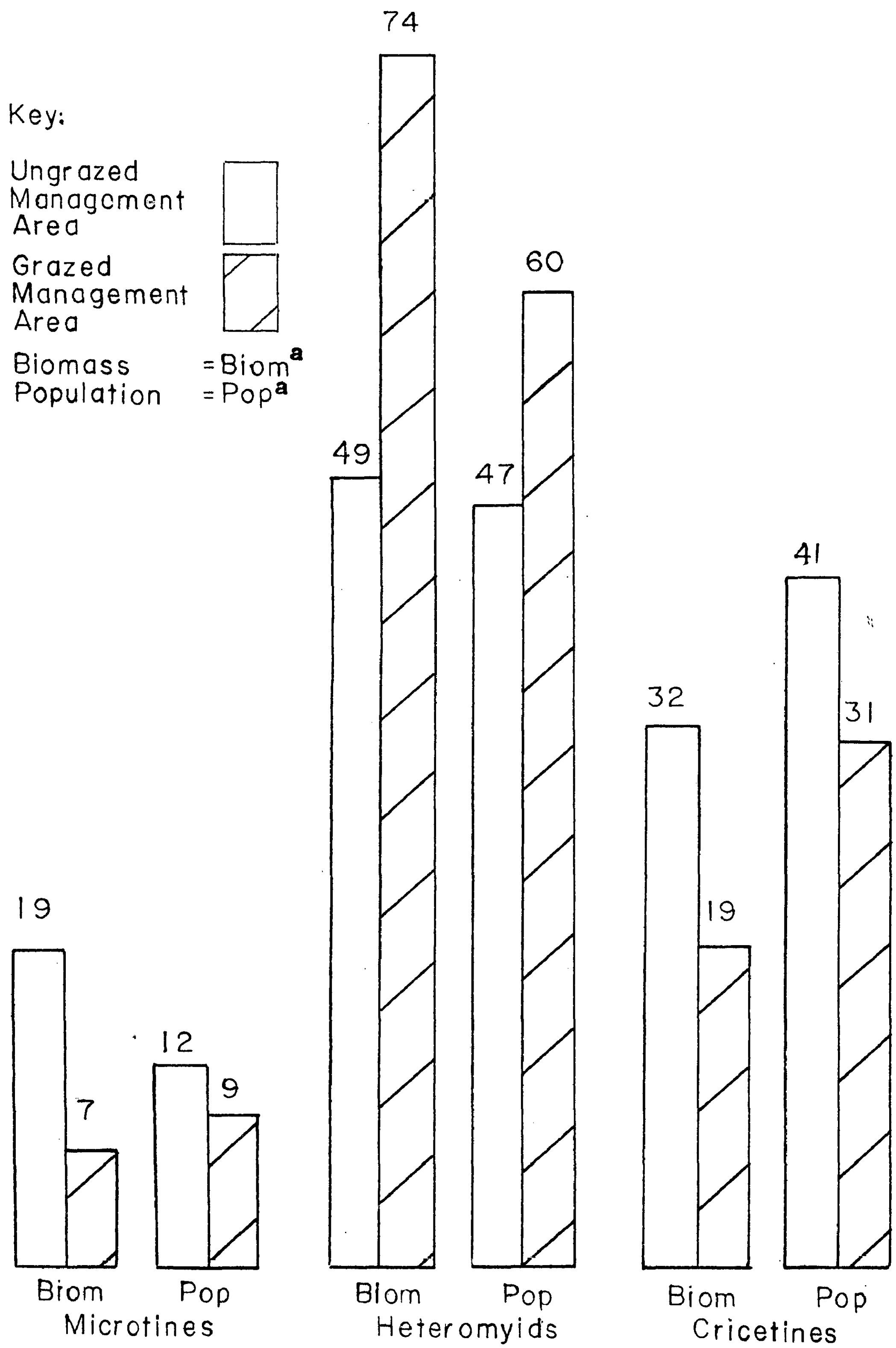

Fig. 5. The percentages of biomass and population contributed by the three major rodent groups on grazed and ungrazed sandhill areas. [a] see text

termed an intermediate between the densely covered ungrazed depressions and the more open, xeric, grazed hilltops. Cricetids may select for this type vegetation.

Species Diversity

The H' values for the ungrazed were higher than the grazed (Table 3). This would agree with previous studies where the highest values were recorded on the ungrazed sites (Pefaur and Hoffman 1975). However, there was no significant difference between the two H' values.

A comparison of H' values for the different topographic zones is presented in Table 3. The ungrazed hilltop recorded the highest value and the difference was judged highly significant (.01 confidence level) from the grazed hilltop value. Interestingly, the two locations recorded the same species richness (8) for small mammals. As H' values are a function of the number of species and the proportion of individuals within species, the differing H' values suggest that the proportions were unequal within species, and resulted in unequal H' values.

The slope H' values for both ungrazed and grazed areas were quite low. These values are primarily due to small sample size (Table 3) resulting in few individuals trapped. However, there was a high degree of difference between the two H' values. Of interest is the large, although untested, difference in trap success (Table 3).

Ungrazed depressions recorded a lower H' value than the grazed counterpart, and were found to be significantly different. A factor which might help explain this reversal of trends is that plant species diversity is lower on ungrazed depressions (Table 2) than on grazed depressions. There is some evidence to suggest a correlation between small mammal diversity and plant diversity (Harris 1971).

EFFECTS OF MANAGEMENT

The data suggest that grazing on the Valentine refuge will have an effect on the small mammals of the area. The most noticeable effect is on rodent biomass (Table 3), which increases on the grazed area. This is due primarily to the selection for the larger kangaroo rats on the grazing management areas.

Whereas kangaroo rats increase in grazed areas, several species decline in this type of management unit. My data would indicate that western harvest mice and prairie deer mice prefer ungrazed areas. They made up 15% and 21% respectively of the small mammal community of the ungrazed areas and only 7% and 16% of the grazed small mammal community.

Species diversity, both plant and small mammal, was higher on the ungrazed management areas. A trend of decreasing diversity was manifested from hilltops to slopes to depressions, suggesting a correlation between plant and small mammal diversity.

A less obvious effect of grazing management is the reproduction of a vegetative mosaic. It is believed that bison, Bison bison, produced a mosaic of grazed and ungrazed vegetation, (Koford 1958), and that small mammals have adapted to this periodic grazing. Small mammals could, depending on their requirements, select either grazed or ungrazed areas in a mosaic, depending upon their niche requirements. It is assumed that replacement of bison by other large ungulates has not yet displaced any of the native sandhill small mammals. Light intensity grazing is in harmony with this ecosystem and, in fact, its exclusion may allow non-native animals to increase at the expense of sandhill natives. Therefore; those sandhill areas which are established to preserve this grassland and its native small mammals must be grazed either by native ungulates or a suitable substitute.

SUMMARY

Small mammal density and diversity were evaluated on grazed and ungrazed areas of the Valentine National Wildlife Refuge, Cherry County, Nebraska during April, May, and June of 1975. Data for eight species of small mammals were obtained by snap trapping on hilltops, slopes and upland depressions within each management unit. Vegetation was also sampled in each area and used as a basis for describing habitat variations. Small mammal density, based on percent of total captures, indicates a significant difference between grazed and ungrazed for only two species. Kangaroo rat (Dipodomys ordii) density was greater on the grazed area (28%) than on the ungrazed areas (15%). Western harvest mouse (Reithrodontomys megalotis) appeared to favor ungrazed areas (15%) over grazed areas (7%). Selectivity for open areas by kangaroo rats and for more diverse vegetation by western harvest mice are characteristic habitats for the species indicated. Density, expressed as a percent of total biomass, for six of the eight species, was found to be significantly different between grazed and ungrazed areas (19% on the ungrazed, 25% on the grazed areas). Small mammal diversity (1.69 grazed, 1.72 ungrazed) was found to increase with increasing plant diversity (3.14 grazed, 3.59 ungrazed). The combined results of this study suggest that grazing decreases both plant and animal diversity but that small mammal species composition and density changes with management practices.

Appendix Table 1. Dates and characteristic of trapping locations of the small mammal analysis. T. L. = trapping locations.

UNGRAZED				GRAZED			
T.L.	DATE	TOPOGRAPHIC ZONE	TOTAL TRAP NIGHTS	T.L.	DATE	TOPOGRAPHIC ZONE	TOTAL TRAP NIGHTS
1	18 April	Slope	30	A	18 April	Depression	40
1	19 April	Slope	30	A	19 April	Depression	40
1	31 May	Slope	40	A	18 May	Depression	50
1	1 June	Slope	40	A	19 May	Depression	50
2	18 April	Depression	40	B	18 April	Slope	40
2	19 April	Depression	40	B	19 April	Slope	40
2	18 May	Depression	50	B	31 May	Slope	40
2	19 May	Depression	50	B	1 June	Slope	40
3	3 May	Hilltop	40	C	3 May	Hilltop	36
3	4 May	Hilltop	40	C	4 May	Hilltop	36
3	31 May	Hilltop	40	C	31 May	Hilltop	40
3	1 June	Hilltop	40	C	1 June	Hilltop	40
4	3 May	Depression	35	D	17 June	Hilltop	44
4	4 May	Depression	35	D	18 June	Hilltop	44

Appendix Table 1. (con't)

UNGRAZED				GRAZED			
T.D.	DATE	TOPOGRAPHIC ZONE	TOTAL TRAP NIGHTS	T.L.	DATE	TOPOGRAPHIC ZONE	TOTAL TRAP NIGHTS
4	31 May	Depression	40	E	16 May	Depression	30
4	1 June	Depression	40	E	17 May	Depression	30
5	17 May	Hilltop	50	F	16 May	Hilltop	40
5	18 May	Hilltop	50	F	17 May	Hilltop	40
6	16 May	Depression	50	G	3 May	Depression	40
6	17 May	Depression	50	G	4 May	Depression	40
7	16 May	Hilltop	40	G	31 May	Depression	40
7	17 May	Hilltop	40	G	1 June	Depression	40
8	17 May	Slope	40	H	17 May	Slope	40
8	18 May	Slope	40	H	18 May	Slope	40
9	16 June	Hilltop	50	I	16 June	Hilltop	50
9	17 June	Hilltop	50	I	17 June	Hilltop	50
10	16 June	Hilltop	50	J	16 June	Hilltop	50
10	17 June	Hilltop	50	J	17 June	Hilltop	50
11	17 June	Depression	50	K	16 June	Depression	50
11							

Appendix Table 1. (con't)

T.D.	DATE	TOPOGRAPHIC ZONE	TOTAL TRAP NIGHTS
11	18 June	Depression	50
12	18 June	Depression	50
12	19 June	Depression	50
13	18 June	Hilltop	50
13	19 June	Hilltop	50
14	18 June	Depression	50
14	19 June	Depression	50
15	20 June	Hilltop	50
15	21 June	Hilltop	50
16	20 June	Hilltop	45
16	21 June	Hilltop	45
17	20 June	Depression	45
17	21 June	Depression	45
	TOTAL		1880

T.L.	DATE	TOPOGRAPHIC ZONE	TOTAL TRAP NIGHTS
K	18 June	Depression	50
L	18 June	Hilltop	50
L	19 June	Hilltop	50
M	18 June	Hilltop	50
M	19 June	Hilltop	50
N	18 June	Depression	50
N	19 June	Depression	50
O	20 June	Hilltop	50
O	21 June	Hilltop	50
P	20 June	Hilltop	50
P	21 June	Hilltop	50
Q	20 June	Depression	45
Q	21 June	Depression	45
	TOTAL		1850

APPENDIX TABLE 2

Appendix Table 2. Importance values of plants from grazed and ungrazed sandhill areas.

SPECIES	TOPOGRAPHIC ZONES						AVERAGE IMPORTANCE VALUES	
	HILL		SLOPE		DEPR.			
	UNG.	GRA.	UNG.	GRA.	UNG.	GRA.	UNG.	GRA.
Ambrosia psilostachys	.26	.16	.25	.20	.06	.05	.20	.14
Artemisia ludoviciana		.08	.02			.16	.01	.07
Artemisia campestris	.02	.13	.03				.02	.04
Aster sp.			.05			.03	.02	.01
Agropyron smithii						.13		.04
Andropogon hallii	.23	.15	.11	.21	.10	.05	.15	.14
Andropogon scoparius	.39	.17	.33	.13		.05	.27	.12
Bouteloua gracilis						.04		.01
Boutelous hirsuta	.20	.39	.14	.21			.13	.21
Calamovilfa longifolia	.26	.27	.27	.47	.78	.33	.40	.36
Carex spp.	.06	.09	.07	.16	.37	.18	.25	.17
Eragrostis trichodes	.02	.14	.17	.47	.14	.26	.10	.29
Haplopappus spinulosus			.02				.01	

Appendix Table 2. (con't)

SPECIES	TOPOGRAPHIC ZONE: HILL UNG.	HILL GRA.	SLOPE UNG.	SLOPE GRA.	DEPR. UNG.	DEPR. GRA.	AVERAGE IMPORTANCE VALUES UNG.	AVERAGE IMPORTANCE VALUES GRA.
Helianthus annuus	.02		.06	.04			.03	.01
Helianthus rigidus	.15	.12	.14				.11	.05
Hymenopappus tenuifolius	.08		.03	.06			.04	.01
Koeleria cristata	.17	.17	.05	.06		.12	.08	.12
Lygodesmia sp.			.06				.02	
Lathyrus sp.	.04	.08	.03				.03	.03
Muhlenbergia pungens	.03	.13	.03				.02	.04
Opuntis sp.	.02	.05				.03	.01	.03
Ross arkansana	.04	.15	.07	.25		.08	.05	.16
Panicum virgatum		.05		.14	.14	.03	.04	.08
Panicum wilcoxianum	.09		.13				.08	
Poa pratensis				.09	.45	.75	.12	.27
Prunus besseyi	.04		.02	.07			.02	.02
Sorghastrum avenaceum			.03				.01	

Appendix Table 2. (con't)

SPECIES	TOPOGRAPHIC ZONE						AVERAGE IMPORTANCE VALUES	
	HILL		SLOPE		DEPR.			
	UNG.	GRA.	UNG.	GRA.	UNG.	GRA.	UNG.	GRA.
Sporobolus cryptandrus	.17	.20	.06	.19	.12	.43	.11	.27
Stipa comata	.17		.44	.17	.34	.25	.31	.13
Solidago nemoralis	.03	.09	.02				.02	.03
Yucca sp.	.25	.13	.16				.15	.04
Erigeron sp.		.03						.01
Lithospermun carolinense	.02		.03	.03			.02	.01
Petaiste municandium				.03				.01
Psorales sp.		.03						.01
Panicum scribnerianum	.04				.04	.03	.02	.01
Ascelepias sp.		.03						.01
Toxicodendron sp.			.03	.03			.01	.01
Equstitum sp.	.02						.01	
Tradescantia sp.	.03						.01	
Euphorbia missurica	.09		.03	.03			.04	.01
Chenopodium sp.			.03					.01

Appendix Table 2. (con't)

SPECIES	TOPOGRAPHIC ZONE						AVERAGE IMPORTANCE VALUES	
	HILL		SLOPE		DEPR.			
	UNG.	GRA.	UNG.	GRA.	UNG.	GRA.	UNG.	GRA.
Physalis hederaefolia					.07		.02	
Chrysopis villosa			.03				.01	
Other forbs								
A		.03						.01
B		.03						.01
C		.03						.01

Appendix Table 3. Small mammal relative densities for an ungrazed sandhill area.
* = Specimen destroyed in trap.

SPECIES	UNGRAZED AREA						TOTAL	
	HILL		SLOPE		DEPR.			
	POP. & DEN.	BIOM. & DEN.	POP. & DEN.	BIOM. & DEN.	POP. & DEN.	BIOM. & DEN.	POP. & DEN.	BIOM. & DEN.
Microtus ochrogaster	4.7	6.4	2.0	3.5	4.0	7.5	10.8	17.4
Microtus pennsylvanicus	0.7	0.8			0.8	1.0	1.4	1.8
Dipodomys ordii	12.2	29.4	0.7	2.3	0.7	*	13.5	31.7
Perognatbus flavescena	21.0	10.9	6.1	2.8	6.8	3.2	33.8	16.9
Reithrodontonys megalotis	10.0	5.9	1.4	1.0	3.4	3.0	14.9	4.9
Reithrodontonys montanus	0.7	0.4			1.4	0.8	2.0	1.2
Onchomys leucogaster	2.7	2.6					2.7	2.6
Peromyscus maniculatus	11.5	9.4	6.1	6.1	3.4	3.1	21.0	18.6
Total	63.5	65.7	16.2	15.7	20.1	18.6	100	100

Appendix Table 3 (con't). Small mammal Relative densities for a grazed sandhill area.

SPECIES	GRAZED						TOTAL	
	HILL		SLOPE		DEPR.			
	POP. % DEN.	BIOM. % DEN.	POP. % DEN.	BIOM. % DEN.	POP. % DEN.	BIOM. % DEN.	POP. % DEN.	BIOM. % DEN.
Microtus ochrogaster	2.2	1.8	0.8	1.4	4.5	1.9	7.5	5.0
Microtus pennsylvanicus	0.8	0.3			0.8	1.4	1.5	1.7
Dipodomys ordii	20.2	46.1	1.5	2.7	6.7	14.4	28.4	63.2
Perognathus flaveseens	21.6	8.4	3.0	1.2	7.5	17.	32.1	11.3
Reithrodontonys megalotis	3.7	1.5			3.7	1.7	7.5	3.2
Reithrondontonys montanus	2.2	0.9			2.2	0.6	4.5	1.5
Onchomys leucogaster	2.2	2.8			0.8	1.4	3.0	4.2
Peromyscus maniculatus	14.1	9.6	0.8	0.4			14.8	10.0
Total	67.1	71.3	6.0	5.6	26.1	23.1	100	100

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