OPTIMUM CARRYING CAPACITY FOR BISON IN THEODORE ROOSEVELT NATIONAL PARK

Clayton B. Marlow

Lynn L. Irby

Jack E. Norland

OPTIMUM CARRYING CAPACITY FOR BISON IN THEODORE ROOSEVELT NATIONAL PARK

Clayton B. Marlow, Assistant Professor
Animal & Range Sciences Department

Lynn R. Irby, Associate Professor
Biology Department

Jack E. Norland, Research Assistant
Animal & Range Sciences Department

November 1984

Montana State University
Bozeman, Montana

Submitted to the National Park Service, P.O. Box 25287, Denver, Colorado 80225, in compliance with contract No. CX-1200-2-B035

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Theodore Roosevelt National Park was established in 1947 to preserve the scenic, scientific, historical and recreational values of the Little Missouri Badlands. The area chosen for the park is representative of the Missouri Plateau and the North Dakota Badlands sections of the Great Plains physiographic province. It is generally believed that plant communities within the Great Plains province developed under a regime of high intensity, short duration grazing by migratory ungulates and frequent fires. However, European settlement of the Little Missouri Badlands area altered this regime. These alterations occurred as a result of the elimination of bison, the primary migratory ungulate, and widespread fire suppression. Because the goal and purpose of Theodore Roosevelt Natural Park is to restore and protect those characteristics unique to the Little Missouri Badlands, bison were reintroduced to the park in 1956.

Although the reintroduction of bison was very successful, a major problem began to develop. Bison frequently escaped from the park and the resulting damage claims and capture costs began to encumber a disproportionately large percentage of the resource management budget. Solutions to this problem, as stated in the 1983 Natural Resources Management Plan, hinge upon determination of the optimum carrying capacity for bison in both the North (NU) and South Units (SU) of the park. Ideally, optimum carrying capacity would be that number of bison which would:

A. insure maintenance of a viable bison population;
B. enhance the recovery and stabilization of climax plant communities;
C. provide maximum visitor viewing opportunities consistent with ecological integrity;
D. reduce the potential for bison escape due to forage shortages; and
E. provide for visitor safety while viewing bison.

In 1982, personnel from the Animal and Range Sciences Department and the Biology Department at Montana State University began a field study to determine the optimum carrying capacity. This was to be accomplished by:

A. delineating primary and secondary areas of bison use;
B. determining net primary production and forage utilization for major range sites within primary and secondary use areas;
C. determining seasonal food habits of bison;
D. determining range trends under the existing bison population level; and
E. determining the maximum carrying capacity for primary ranges.

This report includes a summarization of the findings from that study and a series of management alternatives based on those results. The data set upon which these alternatives are based can be found in the Appendices. In addition, a vegetative mosaic map prepared during the investigation has been given to resource management personnel at Theodore Roosevelt National Park Headquarters. It should be noted that the "Methods" section of the report is quite detailed to allow continued resource monitoring.

METHODS AND RESULTS

Section 1.0 DESCRIPTION OF PHYSIOGRAPHIC/VEGETATION CLASSES

1.1 Methods

Initial visits to the Park indicated that delineation of primary, secondary and marginal ranges would have to be completed before any other investigations were undertaken. But to do so, it was necessary to develop a procedure for describing the landforms and vegetation communities of both units. The land in each unit of the park was classified under two schemes. One scheme involved dividing the units into physiographic/vegetational classes (PC) based on land form appearance, land form origin, and the gross structure of the associated vegetation (i.e. grassland, shrubland, wooded draw, etc.).

The second scheme was based on habitat types[1] (HT) which have been designated by other authors working in western North Dakota[2]. Habitat types are based on the premise that under a certain climate and on the land forms present, specific vegetational assembleges will develop. Consequently, identification of habitat types can be made from a combination of vegetation composition, soil type and/or landform. Vegetation assemblages on sites with little or no chance of reaching a "climax" condition, such as early stages of succession on eroded clay and sites altered by man and/or animals were classified as mapping units (MU). At several locations in both units, habitat types or mapping units were either so small or so intermixed as to make it difficult to differentiate specific assemblages. These mosaics were classified as complexes.

The actual mapping of the TRNP under both classification schemes was done from infrared photographs obtained from the Bureau of Land Management in conjunction with ocular reconnaissance in the field during 1982 and 1983. Base maps (1 to 12,000 scale) for both classification systems were prepared. An overlay of the PC map with the HT map allowed us to determine the HT/MU/complexes associated with each PC.

---

[1]Daubenmire, R. 1968. Plant Communities: A Text of Plant Synecology. Harper & Row, New York, NY. p.260-261.

[2]Kjar, Kathie. 1982. Unpublished PhD Thesis. North Dakota State University.

Soil Conservation Service. Range Site Guidelines for Badlands of North Dakota.

Whitman, Warren C. 1978. Analysis of grassland vegetation on selected key areas in southwestern North Dakota. North Dakota Regional Environmental Program.

Hansen, Paul L., Ricky B. Hopkins, George R. Hoffman. 1980. An Ecological Study of the Habitat Types and Their Animal Components at Theodore Roosevelt National Park, North Dakota. University of South Dakota. 182 pp.

1.2 Results

A total of 14 PC's were identified. Table 1 shows the acreage covered by each class in both units. Seven classes were found in only one unit, while seven were found in both units. Figures 1 and 2 indicate where in the landscape each of the classes are found. The prairie dog towns are not shown in the figures because they can occur on any suitable site in the park. A general description of each type follows:

1. Breaks: consist of areas noticeably devoid of vegetation or if vegetation does exist, are situated on steep slopes.
2. Cottonwood Forests: gallery forests along perennial water courses dominated by plains cottonwood (Populus deltoides). Large expanses in the NU are devoid of a dense shrub understory and have instead a dense cover of grass and forbs.
3. Wooded Draws: woody stringers dominated by either green ash (Fraximus pennsylvanica) or aspen (Populus tremuloides). The wooded draws are uniformly scattered over both units of the park.
4. Upland Grasslands: level to rolling grasslands found on the plains above the river valley. These lands are typical of the northern Great Plains.
5. Old River Terraces: level grasslands 200 to 500 feet above the river which are situated on terraces formed before the rapid down cutting of the river.
6. Grassland Flats: large flat grassed alluvial deposits found 100 to 200 feet above the river valley.
7. Bottom Grasslands: large flat grassed alluvial deposits found on higher floodplains of the Little Missouri and its larger tributaries.

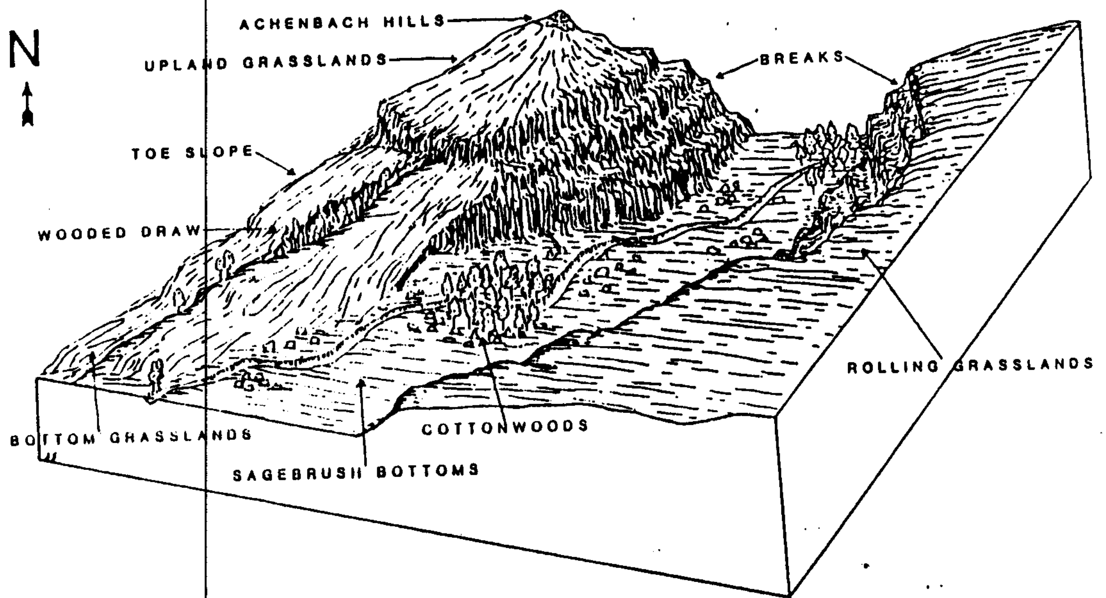


Figure 1. A VIEW OF PHYSIOGRAPHIC-VEGETATIVE CLASSES WITHIN AN IDEALIZED LANDFORM OF THEODORE ROOSEVELT NATIONAL PARK, NORTH UNIT.

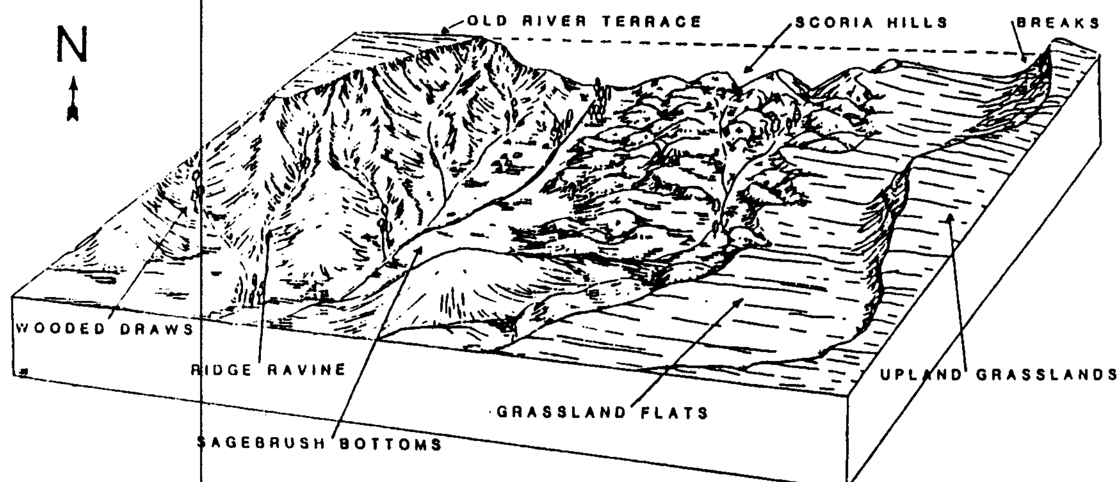


Figure 2. A VIEW OF PHYSIOGRAPHIC-VEGETATIVE CLASSES WITHIN AN IDEALIZED LANDFORM OF THEODORE ROOSEVELT NATIONAL PARK, SOUTH UNIT.

Table 1. Number of acres classified in the different physiographic/ vegetational classes for both units (river channels included).

Physiographic Vegetation Classes	Acreage SU	Acreage NU
Breaks	8842	7176
Sagebrush Bottoms	2903	2252
Wooded Draws	1048	923
Upland Grasslands	2497	1036
Prairie Dog Town	416	119
Cottonwood Forests	219	1284
River Bottom	216	423
Grassland Flats	4816	0
Rolling Grassland	0	22135
Bottom Grassland	0	2213
Ridge & Ravine	16999	0
Toe Slopes	0	4834
Old River Terraces	2502	0
Achenbach Hills	0	192

8. Toe Slopes: gradually sloping lands formed by slumping and alluvial deposition. The land is covered with grass, shrubs, and trees.

9. Rolling Grasslands: level to rolling grasslands found on the plains above the river valley which were glaciated in early times.

10. Achenbach Hills: hills found 650 feet above the river which are covered by grass and shrubs. The large boulder fields on the slopes of the hills are the debris of a once solid cap of bedrock.

11. Ridge & Ravine: lands highly dissected by watercourses and covered by various grasses, shrubs, and trees.

12. Scoria Hills: lands influenced by scoria (a clinker formed from the baking of clays adjacent to burning coal veins) which produces a differential weathering of the land. This weathering produces a very rugged and varied topography which is covered by various grasses and shrubs.

13. Sagebrush Bottoms: floodplains dominated by silver sagebrush (*Artemisia cana*) along with a substantial grass cover.

14. Prairie Dog Towns: lands which have been or are being influenced by prairiedogs. At the edges of towns, plants are still characteristic of the former plant community. Nearer the center, vegetation is absent or dominated by unpalatable perennial plant species.

There were 15 habitat types (HT) recognized as occurring within the TRNP. Seven mapping units (MU) were also recognized. In addition to the HT's and MU's, four complexes were defined (Table 2). Table 3 lists similar HT's reported for western North Dakota by other researchers. Forage production estimates from those descriptions in closest agreement with our observations were used in the calculation of carrying capacity. Several MU's had no comparable designations by other researchers and were defined by us. Characteristics of these undescribed MU's follow.

Table 2. List of each vegetational complex and the proportion of each HT or MU that comprises the complex.

Achenbach Hills Complex -

.4	Agropyron smithii - Stipa comata
.3	Stipa comata - Bouteloua gracilis
.15	Andropogon scoparius
.05	Andropogon scoparius - Juniperus horizontalis
.05	Brush
.05	Andropogon gerardii

Petrified Forest Complex -

.4	Agropyron smithii - Stipa comata
.3	Agropyron smithii - Stipa viridula
.1	Andropogon scoparius
.05	Andropogon gerardii
.15	Stipa comata - Bouteloua gracilis

Rolling Scoria Complex -

.25	Andropogon scoparius
.2	Agropyron smithii - Stipa viridula
.2	Stipa comata - Bouteloua gracilis
.15	Agropyron smithii - Stipa comata
.1	Andropogon scoparius - Juniperus horizontalis
.1	Agropyron smithii - Bouteloua gracilis - Distichlis stricta

Steep Scoria Complex -

.3	Andropogon scoparius
.25	Andropogan scoparius - Juniperus horizontalis
.15	Agropyron smithii - Stipa viridula
.15	Stipa comata - Bouteloua gracilis
.1	Artemisia tridentata - Atriplex confertifolia
.05	Agropyron smithii - Bouteloua gracilis - Distichlis stricta

INTRODUCED GRASSES MU - disturbed areas replanted to introduced grasses to reduce erosion hazards. The grasses most often used were crested wheatgrass (*Agropyron cristatum*) or smooth brome (*Bromus inermis*). Production was estimated by comparing these units with other areas which had similar stands of vegetation.

PRAIRIE DOG TOWNS MU - vegetation drastically altered by prairie dogs. We assumed that 20% of all prairie dog towns were either dominated by annuals, unpalatable perennials, and/or bare ground and that 40% of the production was utilized by prairie dogs, leaving only 40% of the remaining production on towns available to bison. Because most towns occurred on areas that would have been covered by the *Agropyron smithii* - *Stipa viridula* HT, 40% of the production of this HT was used as the base for the prairie dog towns.

RIVER BOTTOMS MU - areas subject to frequent flooding. Production estimates were unreliable and not included in any further analysis.

WILLOWS MU - areas dominated by densely growing willow (*Salix* spp.) with little other plant growth. No production estimates were available.

MAN-MANAGED MU - those lands whose vegetation was altered by ongoing human activities (roadsides, campgrounds, etc). The high variability in forage composition and production in this MU made estimation of production impractical.

Table 3. Comparison of habitat type (HT) and mapping unit (MU) names used in this study with other systems developed in North Dakota.[2]

Agropyron smithii - Stipa viridula HT	
Hirsch:	Agropyron smithii - Stipa viridula*
Whitman:	Agropyron - Stipa viridula - Bouteloua and Agropyron - Stipa viridula - Mixed
SCS:	Clayey range site#
Agropyron smithii - Stipa comata HT	
Hirsch:	Agropyron smithii - Stipa comata*
Whitman:	Agropyron - Stipa - Bouteloua
Hansen et al.:	Agropyron smithii - Carex filifolia
SCS:	Silty range site#
Stipa comata - Bouteloua gracilis HT	
Hirsch:	Stipa comata - Bouteloua gracilis*
Whitman:	Stipa - Calamovilfa - Carex
Hansen et al.:	Stipa comata - Carex filifolia
SCS:	Sandy range site#
Artemisia cana HT	
Hirsch:	Artemisia cana*# (species production estimated by authors)
Hansen et al.:	Artemisia cana - Agropyron smithii
Andropogon scoparius - Juniperus horizontalis HT	
Hirsch:	Andropogon scoparius - Juniperus horizontalis*
Hansen et al.:	Juniperus horizontalis - Andropogon scoparius
SCS:	Very shallow range site#
Artemisia tridentata - Atriplex confertifolia HT	
Hirsch:	Artemisia tridentata - Atriplex confertifolia*
SCS:	Shallow clay range site#
Artemisia tridentata - Bouteloua gracilis HT	
Hirsch:	Artemisia tridentata - Bouteloua gracilis*
Hansen et al.:	Artemisia tridentata - Agropyron smithii
SCS:	Shallow clay range site# (this site and the immediately preceding have the same production)
Andropogon scoparius HT	
Hirsch:	Andropogon scoparius*
Whitman:	Andropogon - Stipa - Bouteloua
Hansen et al.:	Andropogon scoparius - Carex filifolia
SCS:	Shallow range site#
Andropogon gerardii HT	
Hirsch:	Andropogon gerardii*
Whitman:	Andropogon - Stipa - Sporobolus# (Production from site at the Dickinson Experiment Station)
Agropyron smithii - Bouteloua gracilis - Distichlis spicata var. stricta HT	
Hirsch:	Agropyron smithii - Bouteloua gracilis - Distichlis spicata var. stricta*
SCS:	Thin claypon range site#
Grassed Sand Floodplains HT	
SCS:	Sandy range site*#
Hardwood Draws HT (No production available)	
Hansen et al.:	Fraximum pennsylvanica - Prunus virginiana and Fraximum pennsylvanica - Symphoricarpos occidentalis*
Girard:	(Has a similar HT proposed)
Juniperus scopulorium - Oryzopsis mircantha HT (No production available)	
Hansen et al.:	Juniperus scopulorium - Oryzopsis mircantha*
Girard:	(Has a similar HT proposed)
Populus deltoides - Juniperus scopulorium HT (No production available)	
Girard:	Populus deltoides - Juniperus scopularium (proposed)*
Populus tremuloides - Betula occidentalis HT	
Hansen et al.:	Populus tremuloides - Betula occidentalis*
Girard:	(Has a similar HT proposed)
Marsh MU	
SCS:	Wetland range site*#
Brush MU (No production available)	
Hansen et al.:	Symphoricarpos occidentalis* (this includes only a few sites, the rest may have been dominated by Prunus virginiana or Prunus americana)

Table 3. Continued

Introduced Grass MU
    Classified and production estimated by authors

Prairie Dog Towns MU
    Classified and production estimated by authors

Willows MU (No production available)
    Classified by authors

Man-Managed MU
    Classified by authors

*Denotes the description which was used by researchers for the habitat type or mapping unit.

#Denotes that author whose production figures were used.

Acreage and production for each HT, MU, and complex for which data were available appear in Appendices A and B. All production was estimated in pounds/acre and adjusted for a normal year. Normal year production was based on the average production at sites in western North Dakota over several years.

Section 2.0 BISON DISTRIBUTION AND POPULATION CHARACTERISTICS

2.1 Methods

Direct Observation -

Bison herds were observed for at least eight hours per day for several consecutive days during 1982-83. Because of travel and time constraints, data were only collected in the SU. During the observation periods, the following data were recorded at 15-minute intervals:

1. the location of the herd (plotted on a topographic map);
2. the number of animals older than 5 months that were using a particular physiographic/vegetation type and landform class;
3. the type of activity in which the animals were engaged ("feeding" was any activity that was or resembled grazing or browsing. "Resting" was any time when bison were reclining on the ground. "Other" included all other activities such as social interaction, standing, grooming, moving, etc.). which

Observations were limited to large cow herds when possible. Four mature cows with individually recognizable horn configurations were used to determine home range size and herd constancy. Age and sex ratios were calculated from observations in August and September, the period when bison tended to congregate in the largest herds and the period when bulls were most likely to associate with cow herds.

Fecal Counts -

To determine primary, secondary and nonuse areas a fecal transect system was developed. Each transect was 500 meters long and 1 meter wide, and all bison chips were counted within the 1 m by 500 m belt transect. Placement of transects was done in a stratified, random manner. Each unit was divided into sections, 9 in the South Unit and 5 in the North (see 1:12,000 scale map for actual delineations). Within each section, transects were randomly placed in each of the physiographic/vegetational classes (Figures 1 & 2). The number of transects placed in each class was proportional to the amount of area of each class in the section. All classes had at least three transects. Fecal chip density was determined from one counting period during the summer of 1983.

2.2 Results

2.2a Physiographic/Vegetational Class (PC) Use:

During July 1982 - July 1983, 132 days were spent in direct observation of herds (Table 4). A total of 5281 herd location/activity notes were recorded. The average herd size under observation was 71. These data covered only daylight hours and only cow herds in the SU.

Fecal transects, 52 in the NU and 100 in the SU, included defecations by all age and sex classes at all times of the day. Counts in the summer of 1983 represented an accumulation of fecal material from the previous 2 (or more) years and potentially were a less reliable index of time spent feeding in an area than direct observation.

The high correlation between fecal transects and direct observation estimates of bison use by PC ($R^2 = 0.95$) and the lack of significant differences ($p > 0.05$) in observed grazing activity among PC's indicated:

1. PC use patterns observed in 1982-83 were unlikely to have been aberrant.
2. Deletion of bulls from direct observation did not seriously bias results.
3. The relatively inexpensive fecal transect approach is an adequate measure of PC use.

Table 4. The eleven time periods with starting and ending dates along with the number of observation days in the period that were from the direct observations.

	Period	Start		End	Number of Observation Days
1.	April	3/28/83	to	4/14/83	14
2.	May	5/ 1/83	to	5/19/83	14
3.	June	6/27/83	to	7/ 7/83	14
4.	August 1	8/ 3/82	to	8/15/82	10
5.	August 2	8/16/82	to	8/31/82	13
6.	September 1	9/ 1/82	to	9/15/82	11
7.	September 2	9/16/82	to	9/30/82	11
8.	October 1	10/ 2/82	to	10/15/82	10
9.	October 2	10/16/82	to	10/28/82	11
10.	November	11/10/82	to	11/26/82	14
11.	December	12/ 4/82	to	12/15/82	10

The major difference between results obtained from herd transects and results from direct observation occurred in prairie dog towns. Evidently destruction of fecal piles in towns by prairie dogs could cause underestimates of use on fecal transects.

The yearly level of bison use of each PC is shown for both units of the park in Table 5. In the SU, the most extensive classes (breaks, grassland bottoms, ridge and ravine, and scoria hills) had very little use while those classes which covered five percent or less of the total land area had varying levels of use. Forested areas had significantly ($P < 0.001$) lower levels of use than would be expected based on their vegetative productivity and limited size. The most heavily used classes were relatively flat areas dominated by grasses (old river terraces, upland grasslands, prairie dog towns, and sage-brush bottoms).

Classes with an open grassland aspect (upland grassland, grassland bottoms, Achenbach hills, and toe slopes) were the most heavily used in the NU while the breaks and sagebrush bottoms received very little use. The most notable difference between the two units was the higher level of use of forested classes in the NU. Cottonwood communities in the NU are in a more advanced stage of succession than those in the South. Advanced succession in a Northern Plains cottonwood community means fewer shrubby species and more grasses and forbs. Consequently, NU cottonwood stands were more open on average than SU stands. It is possible that the successional endpoint of this class would be something similar to the old river terraces in the SU.

Seasonal use of each physiographic/vegetation class (Figure 3a - 3j). was available only for the SU where herds were under observation. From late March until early July, bison appeared to prefer old river terraces and cottonwood forests. Prairie dog towns were used extensively during August and September. During late October and November, bison were usually found in the scoria hill, upland grassland, wooded draw, and sagebrush bottom classes. In early winter (December) the old river terraces and upland grasslands were used most often.

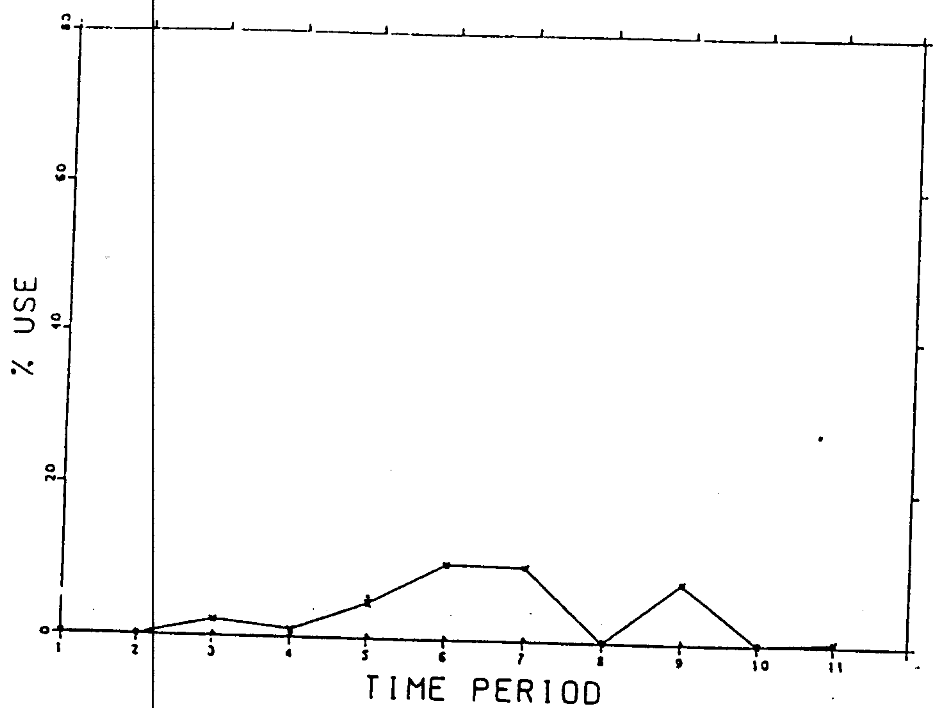
Table 5. Fecal chip density and availability of physiographic/vegetation classes in TRNP (Norland 1984).

Physiographic Vegetation Type	South Unit Area Percent (Total Unit)	South Unit Fecal Density (Chips/ transect)	North Unit Area Percent (Total Unit)	North Unit Fecal Density (Chips/ transect)
Breaks	17.3[a]	1.5[b]	37.2[a]	1.0[b]
Cottonwood Forests	0.7[a]	0.3[b]	4.6[c]	2.3[c]
Wooded Draws	3.0[a]	2.2[b]	3.9[c]	4.0[c]
Upland Grassland	5.5[a]	17.8[b]	6.3[a]	33.5[b]
Old River Terrace	5.8[a]	41.9[b]	Not Present	
Grassland Bottoms	11.8[c]	8.7[c]	4.5[a]	14.8[b]
Toe Slopes	Not Present		19.1[a]	31.6[b]
Rolling Grasslands	Not Present		11.6[c]	15.4[c]
Ridge and Ravine	19.2[a]	9.6[b]	Not Present	
Scoria Hills	29.7[a]	8.7[b]	Not Present	
Achenbach Hills	Not Present		1.9[a]	11.6[b]
Sagebrush Bottoms	5.5[c]	6.4[c]	10.3[a]	9.5[b]
Prairie Dog Towns	1.5[a]	23.5[b]	0.5[a]	50.7[b]

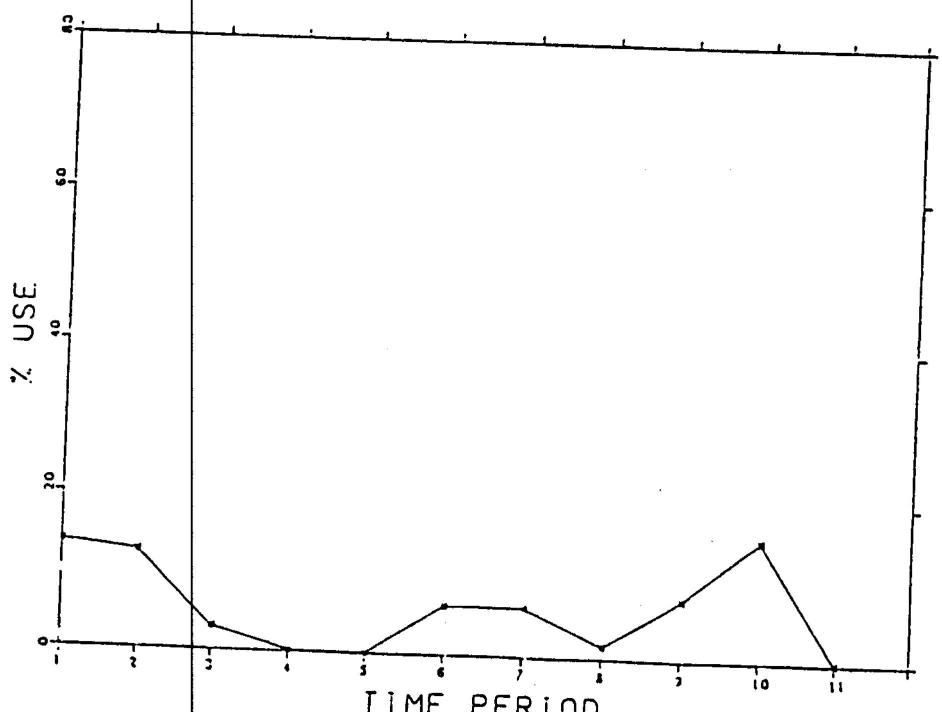
[a,b,c]Pairs with different superscripts are significantly different at the 0.05 level.

Delineation of primary, secondary, and marginal ranges was based on the magnitude of difference between the availability of a class and its level of use as indicated by fecal transects. Classes in which use was significantly ($P<0.05$) greater than expected were grouped as primary range. Secondary ranges were defined as classes with no significant differences between area and use level. Marginal ranges had significantly lower levels of use than would be expected given their availability. Table 6 displays the different range types for both units.

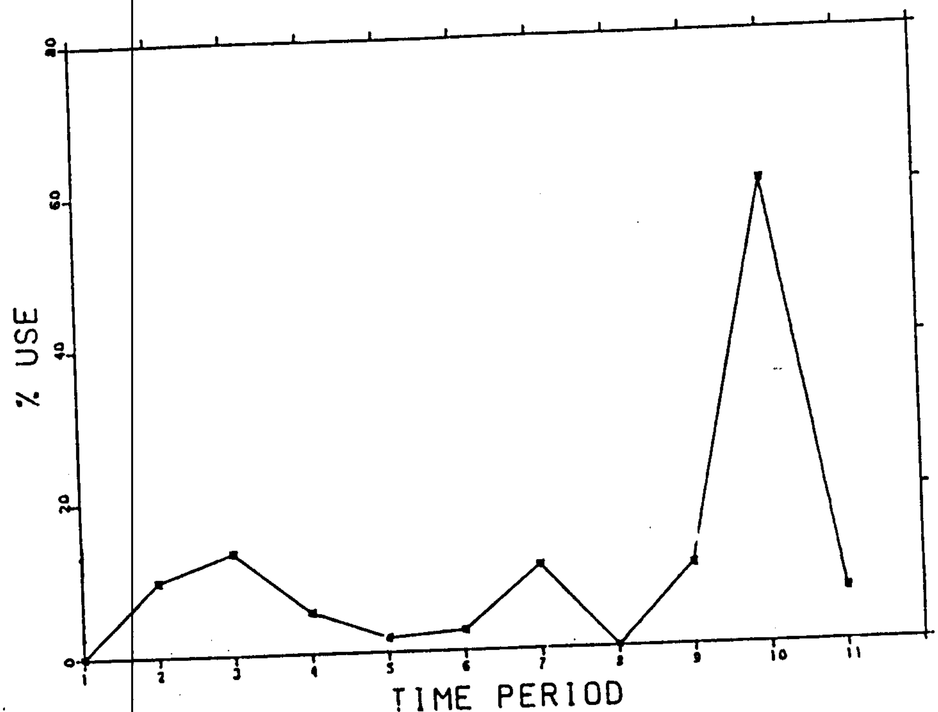
Figure 3. Seasonal use of physiographic/vegetation classes in the South Unit of Theodore Roosevelt National Park. Use is based on direct observation and time periods are given in Table 9.



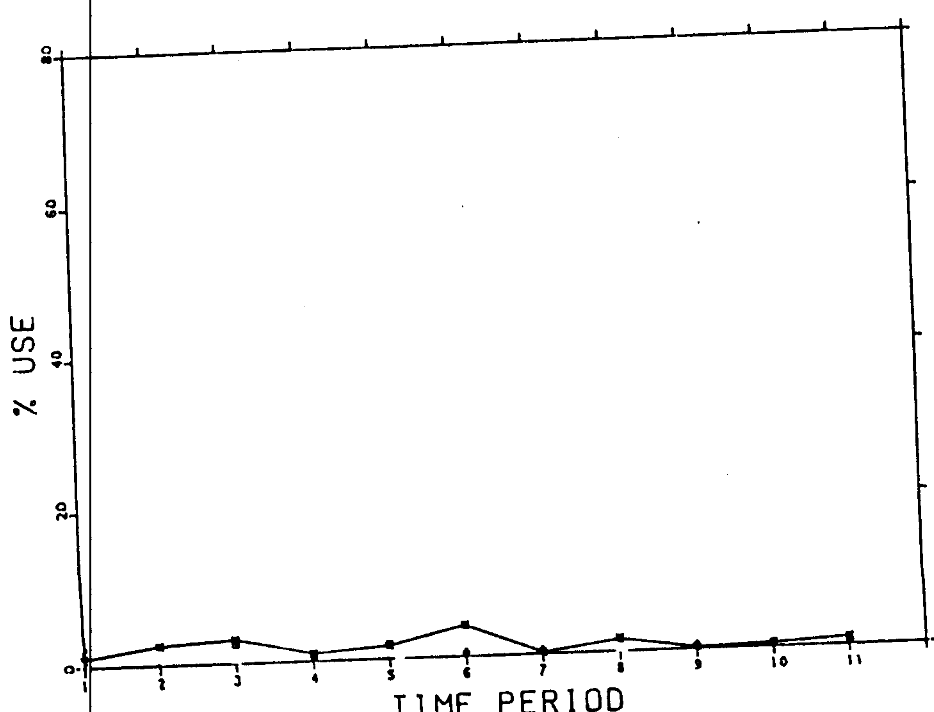
a. Cottonwood Forests



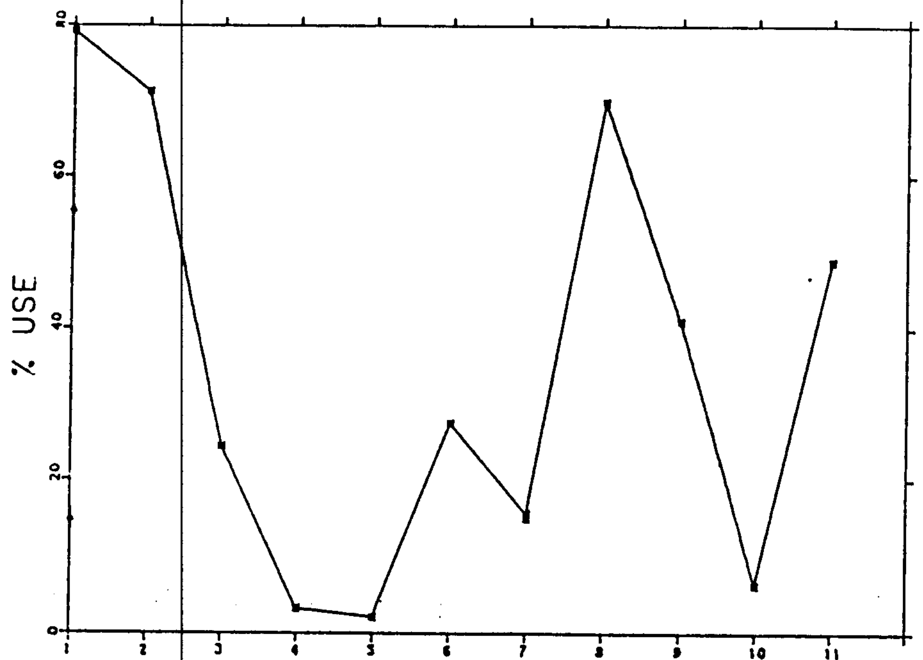
b. Ridge & Ravine



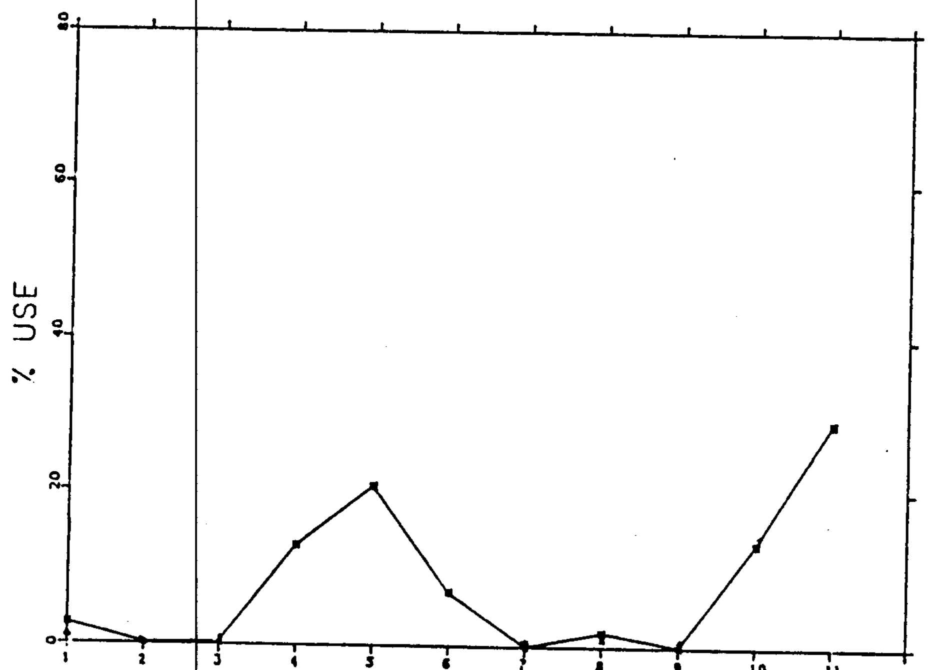
c. Scoria Hills



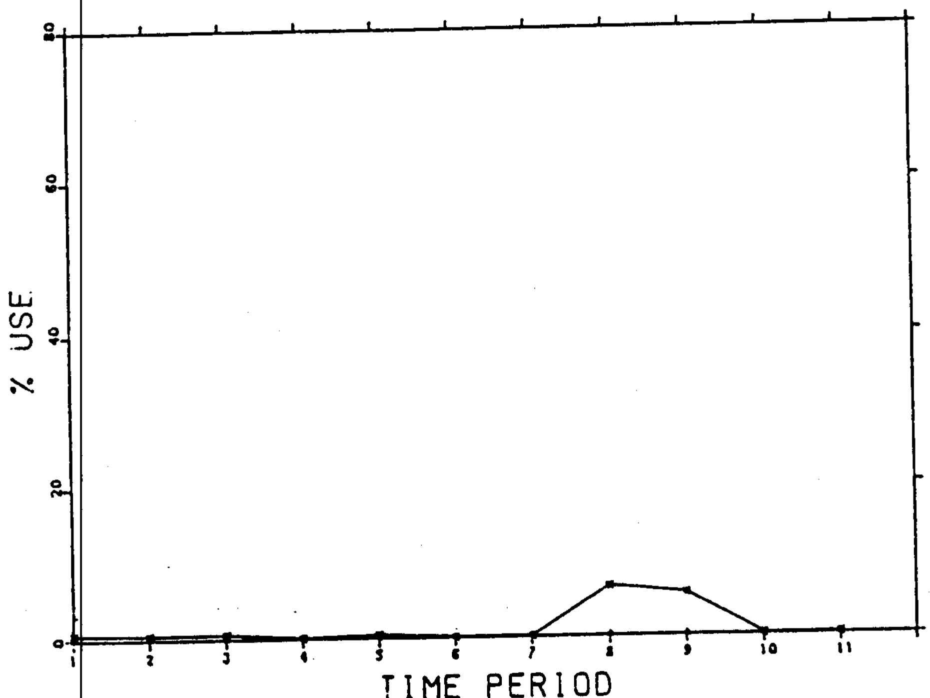
d. Breaks



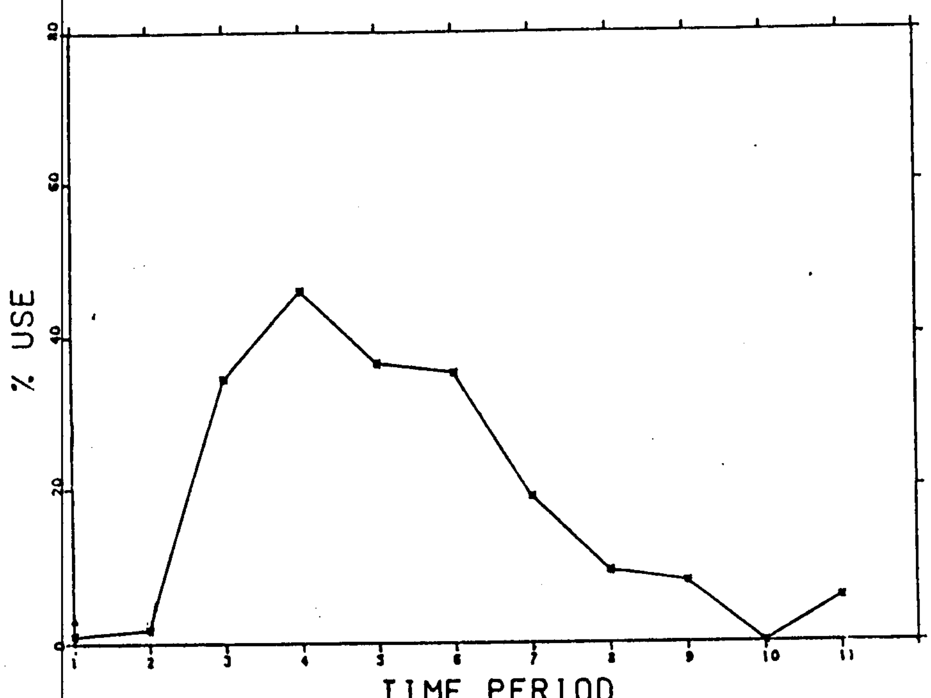
e. Old River Terrace



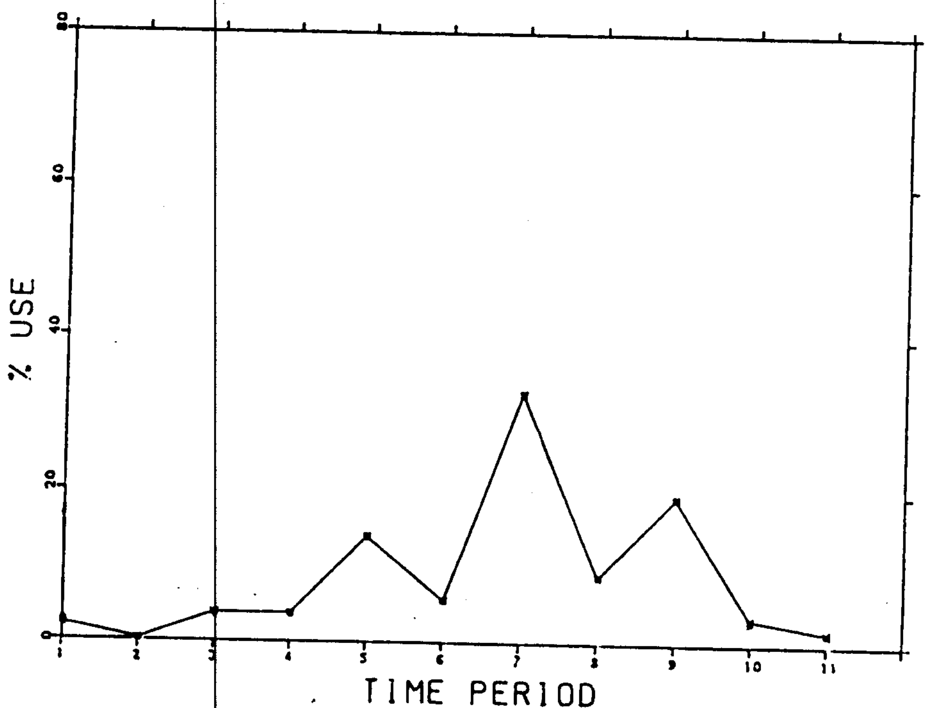
f. Upland Grassland



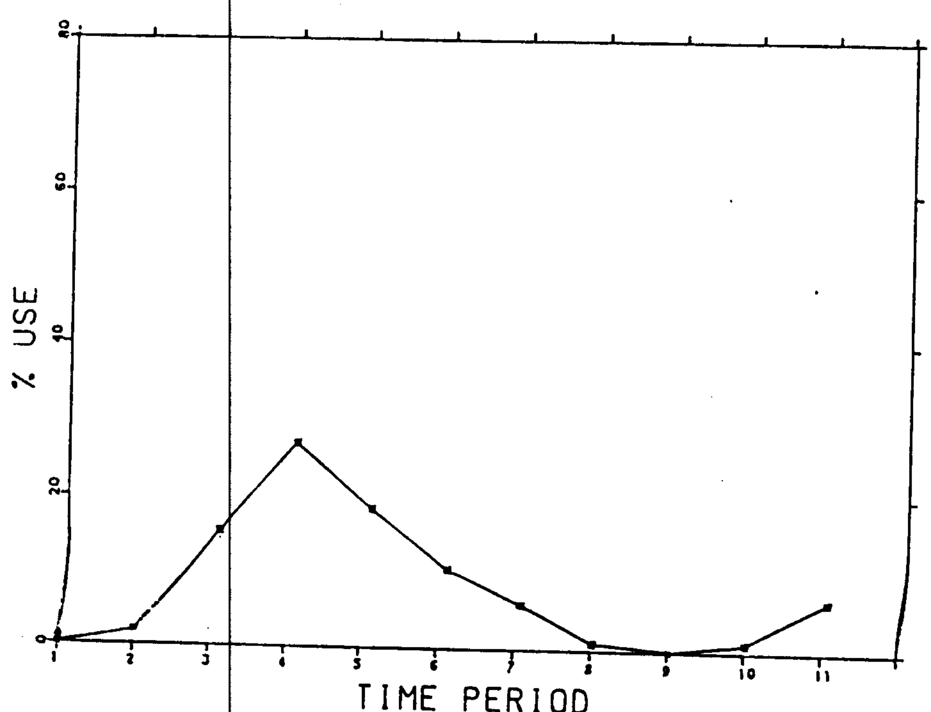
g. **Wooded Draw**



h. **Prairie Dog Towns**



i. Sage Bottoms



j. Grassed Flats

Table 6. Composition of Primary, Secondary, and Marginal Ranges in the Theodore Roosevelt National Park.

Range	NORTH Physiographic/Vegetation Class	SOUTH Physiographic/Vegetation Class
Primary	Prairie Dog Towns Upland Grassland Achenbach Hills Toe Slopes Grassland Bottoms	Upland Grassland Old River Terraces Prairie Dog Towns
Secondary	Cottonwood Bottoms Rolling Grasslands	Grassland Bottoms Sagebrush Bottoms
Marginal	Breaks Sagebrush Bottoms Wooded Draws	Breaks Cottonwood Forests Wooded Draws Ridge-Ravine Scoria Hills

2.2b Spatial Distribution:

The locations of bison herds in the SU (Figure 4) indicated that most of the SU was used by bison during 1982-83. Fecal transect results suggested that virtually all areas of primary and secondary range were utilized at some time.

Because no direct observations were made in the NU, our knowledge of bison distribution was based on fecal transects and conversation with park personnel. These sources indicated that bison were restricted to the area west of UTM latitude line 6290 (a line running roughly south to north from a point just east of the bison corrals to a point 1/4 mile east of Stevens Spring).

Home ranges were determined for two of the four individually identifiable cows. The other two died before home ranges could be adequately delineated. Both of the home ranges (Figures 5 and 6) were similar to the overall distribution of bison herds (Figure 4) indicating that individual bison home ranges were essentially as large as the park fence would allow. Norland[3] found that associations among bison were temporary and that interchanges of individuals between herds and changing associations within herds were daily occurrences.

Herds in TRNP rarely stayed in the same locality for more than 48 hours. Comparison of locations of herds at one-week intervals indicated an apparently random movement pattern within the park during most of the year. This movement pattern would markedly reduce the chances of overutilization due to herds "camping" at specific sites.

Norland[3] did find evidence that bison would restrict their movements to specific regions of the park in some seasons. These restrictions in movement were most frequently linked to weather (snow) or physical barriers (high spring runoff) and could result in localized overutilization even at low stocking rates. Such overutilization would probably be a short-term problem at current stocking rates since restricted use areas apparently vary from year to year.

2.2c Distribution Relative to Water:

Although bison used the entire SU and their movement from area to area was apparently random, Norland[3] found that herd relocations were clumped around permanent water sources. Behavioral observations, however, indicated that bison were not as dependent on permanent water sources as the distribution pattern suggested:

---

[3] Norland, J.E. 1984. Habitat use and distribution of bison in Theodore Roosevelt National Park. MS Thesis. Animal & Range Sciences Dept. Montana State University. Bozeman, MT.

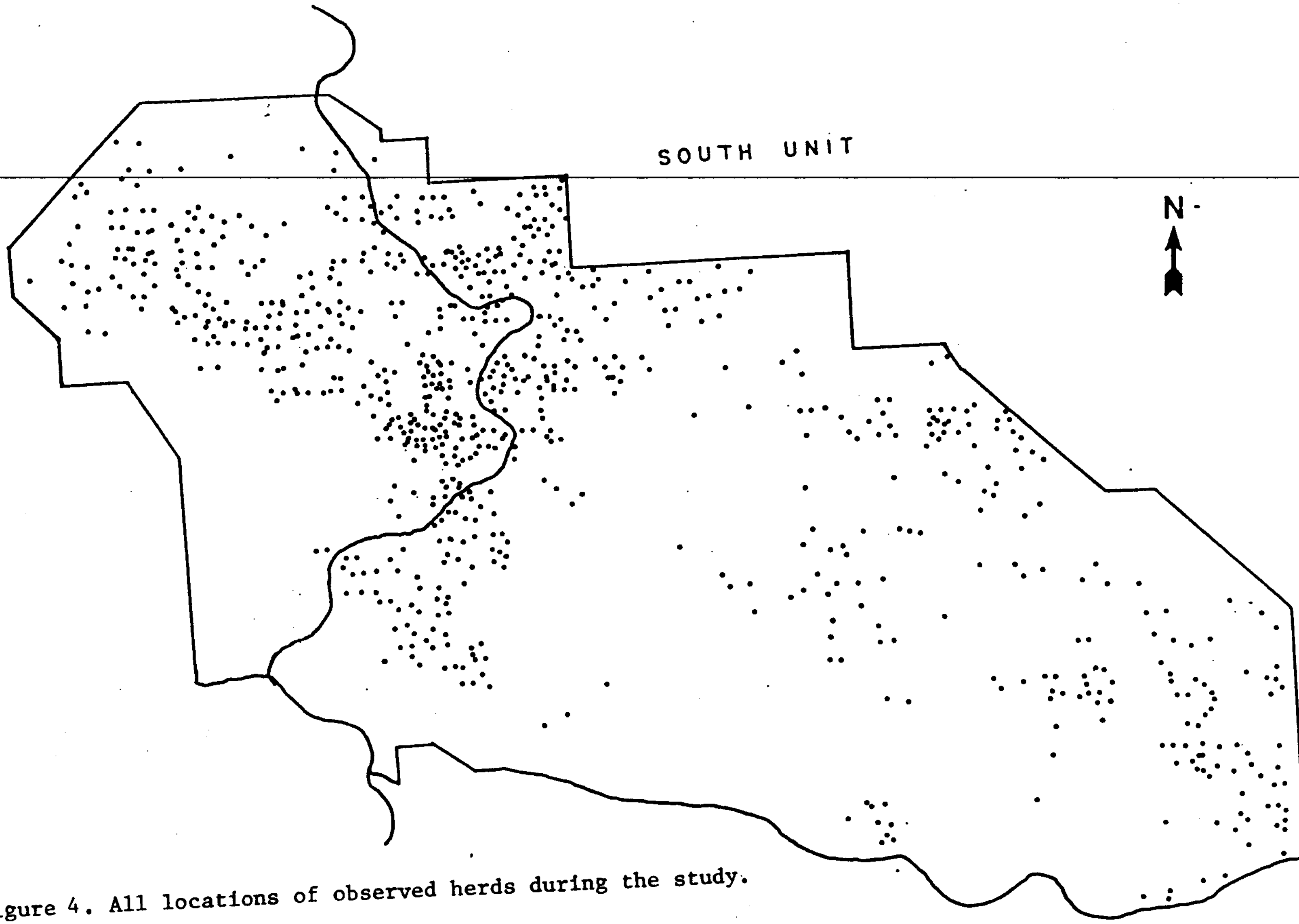


Figure 4. All locations of observed herds during the study.

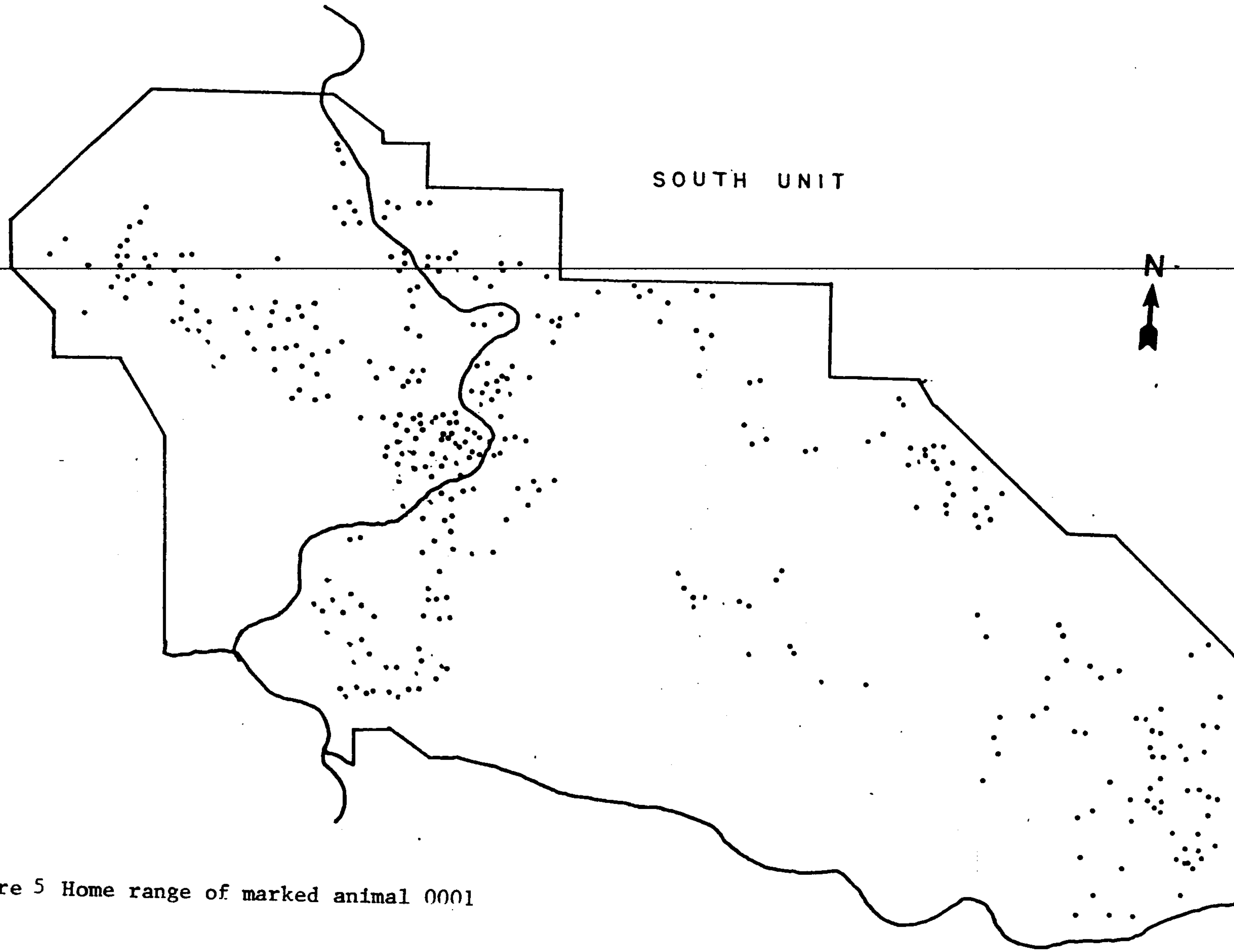


Figure 5 Home range of marked animal 0001

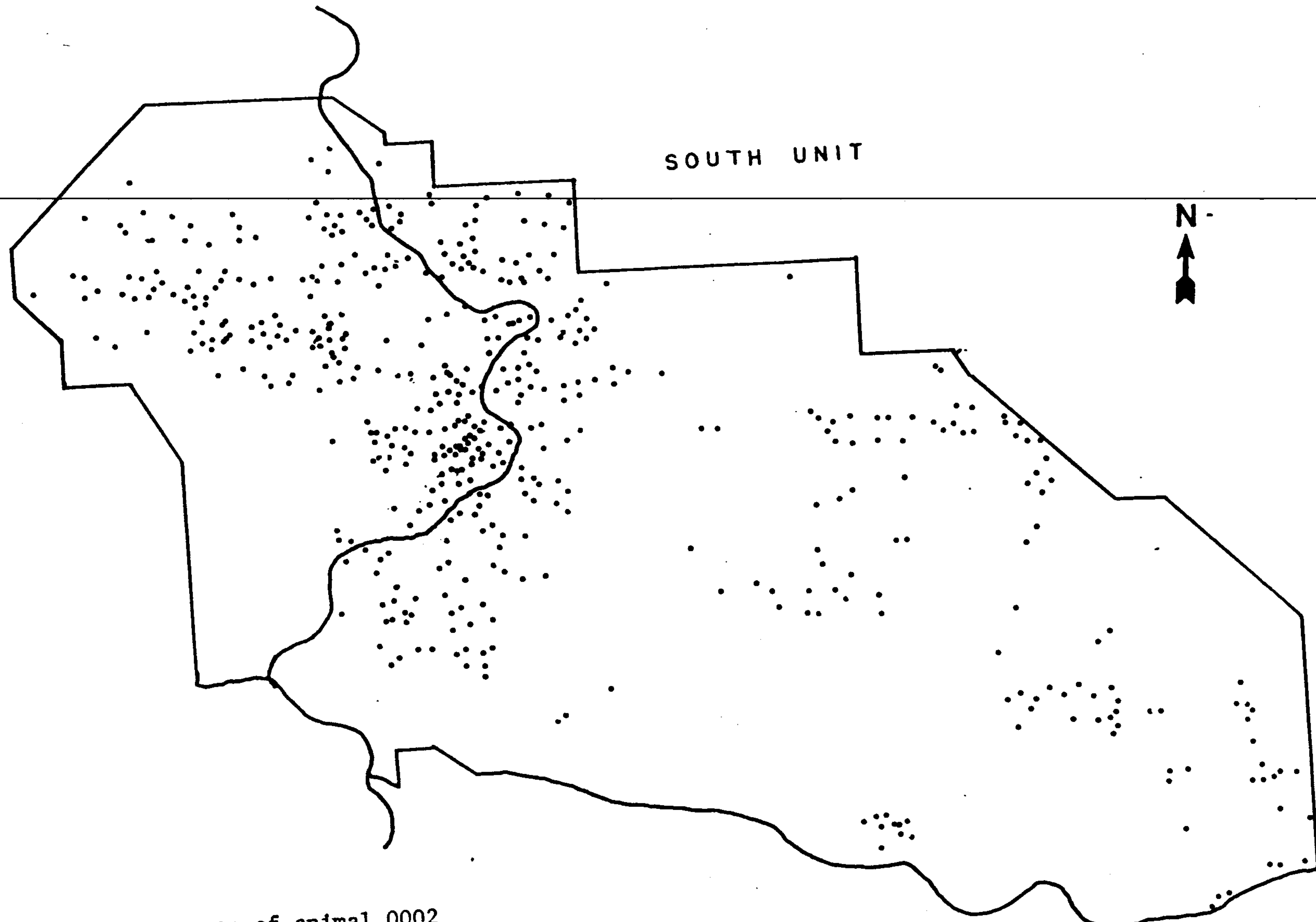


Figure 6. Home range of animal 0002

1. During winter, bison were never observed drinking but were often seen eating snow.

2. At times other than winter, bison were observed to drink only once a day. When herds were in areas far from surface water, they frequently did not drink at all during the day.

3. Bison, because of their high mobility, were not dependent on specific watering sites and tended to change watering locations daily. Bison remained at water only long enough to drink. Even large herds normally remained at water for less than an hour.

4. Bison were often observed using ephemeral water. Ephemeral watering sites included intermittently flowing creeks, pools in dry water courses, water in depressions, and even puddles on asphalt roads. As long as these sources were available, bison had no need to remain in close proximity to permanent water.

Even though bison were not completely dependent on permanent water sources, there are times when permanent water sites provide the only available water. Current distribution of sites is adequate, but development of new sites near large blocks of lightly used primary and secondary range could be considered in the future.

2.2d Population Characteristics:

Bison herds were composed of all age classes of females and males up to 4 years of age. Large numbers of mature bulls were found in herds only during the rut. At other periods of the year, older bulls were found alone or in small groups (4-6 individuals). Observed herds ranged from 10 individuals to 3/4 of the entire population.

Approximately 50% of the animals were males. The percentage of calves in the population ranged from 20-25% during the study.

Section 3.0 FORAGE INTAKE

3.1 Methods

Information on population structure was collected from observation of herds in the SU and TRNP records. Weights for age classes were taken from bison captured in TRNP in 1964-1970. Forage intake was derived from this information through use of daily intake rates from published sources.[4]

3.2 Results

Based on a population with an equal sex ratio and 20% calves, (Table 7) we calculated an average bison weight of 1000 lb. The literature on forage consumption indicated an average bison would consume approximately 1.8% of its body weight in forage (dry weight) per day or 540 lb/mo (6480 lb/yr).

Table 7. Average weights (lbs) of different classes of bison from 1964 to 1970. Data collected during the fall roundup.

Class	Males	Females
Young of year	350	350
1 1/2 year old	700	650
2 1/2 year old	950	800
3+ years old	1400	1000

Largest male 2000 lb
Largest female 1500 lb

[4] Reynolds, H.W., R.D. Glaholt, and A.W.L. Hawley. 1982. Bison, Chapter 49. pp. 927-1007. In: Wild Mammals of North America: Biology, Management, and Economics. J.A. Chapman and G.A. Feldhamer (eds.). The John Hopkins University Press, Baltimore, MD.

Rice, R.W. Personal communication, Colorado State University.

Section 4.0 BISON DIETS

4.1 Methods

During October 1982 - September 1983, fecal material was collected on the SU of TRNP for dietary analysis. Samples were collected twice monthly. Each sample consisted of pooled 5 cc samples from 10 different fresh fecal piles. Samples were frozen, shipped to Montana State University, thawed, oven dried, and ground in a Wiley Mill. Five gram subsamples were randomly selected from each sample and sent to a private lab for identification.

Qualitative and quantitative assessment of plants in fecal samples was undertaken using techniques described by Sparks and Malechek.[5] Twenty fields on 5 slides were surveyed for each sample. Reference specimens used in plant identification were collected in TRNP. Although attempts were made to classify all plant fragments at the species level, epidermal characters were unreliable at this level in many taxa. In these cases, items were classified at the most precise level possible.

Seasonal means were calculated from individual samples. Standard deviations were calculated to display the level of variability among samples taken in a single season. A five-season system (autumn, early winter, late winter/early spring, spring, and summer) was selected based on observation of bison and a preliminary analysis of food habits data.

Changes in occurrence of important ($\geq$ 3% of a seasonal diet) identifiable items were tested using analyses of variance and Tukey's means tests. This approach was selected despite the potential for deviation from normality

[5] Sparks, H.R. and J.C. Malechek. 1968. Estimating percentage dry weight in diets using a microscope technique. J. Range Manage. 21:264-265.

inherent in the data set because of its simplicity and robustness. No data transformations were applied due to the relative uniformity of variance between seasons for individual plant categories.

4.2 Results

Grasses make up 78% to 90% of seasonal bison diets (Table 8). Browse consumption reached its highest level (15.7%) in late winter/early spring. It is important to note that winterfat (*Ceratoides lanata*), a relatively uncommon shrub, supplied 62% of the total browse intake during this period. Individual species contribution to the diet on a bi-monthly basis can be found in Appendix C.

Table 8. Identifiable plant categories that contributed 3% or more to seasonal diets calculated from fecal analysis. Number of samples per season are given in parentheses (n=) below the associated seasons. Standard deviations for mean seasonal contributions to diet are given in parentheses adjacent to means.

Plant	Fall (n=4)	Early Winter (n=5)	Late Winter/ Early Spring (n=4)	Spring (n=5)	Summer (n=6)
GRAMINOIDS					
Agropyron	15.9(3.1)	16.2(2.0)	14.6(2.2)	13.0(1.0)	14.2(1.2)
Andropogon	11.4(2.2)	11.2(1.6)	6.0(1.4)	10.3(2.6)	11.5(2.6)
Bouteloua	21.1(3.8)	18.6(2.5)	16.2(1.9)	17.1(3.0)	21.2(3.6)
Bromus	0.9(1.0)	1.1(1.3)	3.2(1.0)	3.2(1.2)	1.4(0.7)
Cyperaceae	11.9(0.8)	11.8(2.0)	7.4(4.1)	7.0(1.8)	9.3(4.8)
Koeleria	4.1(1.q)	2.9(0.7)	4.8(1.8)	5.3(1.0)	3.9(1.3)
Muhlenbergia	1.8(0.5)	3.1(0.7)	0.6(0.5)	1.2(1.1)	0.9(1.1)
Panicum	0.7(0.5)	1.0(0.9)	2.0(1.5)	3.7(1.8)	1.0(0.7)
Poa	1.5(0.6)	3.4(1.5)	3.4(1.4)	3.9(0.8)	2.1(1.0)
Sporobolus	2.4(1.6)	3.2(0.7)	1.4(1.3)	1.5(0.7)	1.7(1.2)
Stipa	8.1(5.5)	9.0(0.9)	8.1(1.1)	9.0(1.0)	10.2(1.2)
Total Grass	89.4(5.1)	91.1(4.0)	78.3(3.2)	88.3(3.4)	87.6(2.9)
FORBS					
Total Forbs	5.7(5.3)	2.1(1.9)	6.1(3.2)	9.1(3.4)	10.2(3.6)
BROWSE					
Ceratoides	1.5(3.1)	3.1(1.6)	9.7(5.8)	1.0(1.0)	0.1(0.3)
Total Browse	5.1(6.2)	6.9(2.8)	15.7(6.2)	2.7(1.6)	2.2(1.0)

Section 5.0 CALCULATION OF CARRYING CAPACITY

5.1 Methods

To establish a carrying capacity for bison, the following information is necessary.

A. The total annual forage production (TAP) for each species or plant type (perennial graminoids, perennial forbs, shrubs, trees, etc.) must be calculated for the ranges available to bison. All production figures should be adjusted to an average year.

B. The amount of a species or plant type which can be grazed without detriment to the survival of the plant; this is the allowable use factor (AUF). This is commonly represented by a percentage (0% for no grazing to 100% for total consumption). The AUF can also account for competition from other species, damage to the plants by trampling and defecating on them, and other complicating factors which make plants unavailable to grazing animals. An AUF of 0.5 is the accepted level of use for a plant for the entire growing season. If the plant will be grazed 1-2 times during its growth period then total removal should be 0.5 to 0.6 of that year's production. Consequently, if other grazers are using that same plant or it is frequently regrazed, a conservative AUF would be 0.40.

C. Annual production depends on previous and current climatic conditions. A production factor (PF) was developed to take this into account. We have selected 1.0 as being a normal year, 0.4 a drought year, and 1.5 a very favorable year for growth.

D. The proportion that the target species or plant type contributes to the diet of the bison (PD) is needed. This value can be obtained from the adjusted diet composition table (Table 9).

Table 9. Adjusted percent contribution of species and genera to the diet after clumping.

Species	Spring & Summer	Fall & Winter	Total Year
Agropyron spp.	14.4	16.6	15.5
Andropogon spp.	11.6	10.7	11.15
Bouteloua spp.	20.4	20.4	20.4
Carex spp.	8.6	11.5	10.05
Koeleria pyramidata	4.9	3.6	4.25
Muhlenbergia spp.	1.1	2.0	1.5
Poa spp.	3.2	2.6	2.9
Stipa spp.	10.2	8.8	9.5
Perennial Grass	13.3	10.8	12.05
Perennial Forbs	9.6	4.8	7.2
Trees - Shrubs	2.45	7.95	5.2

E. Finally, the amount of forage which is consumed by an average bison over a whole year (Intake) is needed. Bison are generally considered to consume 540 lbs. of dry matter per month or 6480 lbs. per year.

F. This information is then utilized in the carrying capacity formula:

$$\frac{TAP_j \times AUF_j \times PF}{PD_j \times \text{Yearly Intake}} = \text{No. of Bison/Year}$$

where j denotes the value for the species or plant type being considered.

The number of bison/year will indicate the number of bison that can be carried by the species or plant type under consideration. Those species with large amounts of production and low proportions in the diet will have higher carrying capacities than those with lower production and high dietary composition. That plant species with the lowest carrying capacity can be the limiting species because higher animal numbers would result in that species being overutilized and eventually eliminated by grazing.

For animal species with high mobility or low territorial affinity, carrying capacities should be calculated for the primary and secondary ranges in combination and marginal or little used ranges separately. Total production for each forage species in an HT or MU in the primary and secondary ranges is calculated by multipling the production per acre from each HT or MU by its respective area in acres. The production of each species of interest is then summed over each HT or MU to arrive at one value for the range. The same process is performed for marginal range.

For example, if western wheatgrass occurred in four HT on the primary range and two on the secondary range, total production would be calculated in the following manner:

[HT#1 in lbs/ac) (ac of HT#1)] +

[HT#2 in lbs/ac) (ac of HT#2)] +

... [HT#6 in lbs/ac) (ac of HT#6)] =

total production of western wheatgrass on primary and secondary ranges

Species production from the <u>Andropogon gerardii</u> HT and the Marsh MU were not included in the carrying capacity estimates derived for this report. The <u>Andropogon</u> HT occurs in such small, scattered patches that accurate mapping of all patches proved impossible. The Marsh MU was not used because its production estimate involved species completely different from any other MU or HT and it contained species that were not identified in the bison diet.

5.2 Results

Several basic assumptions have been established for the computation of a carrying capacity. These are:

1. In the SU, the carrying capacity will be based on the whole unit. In the NU the carrying capacity will be based on that area determined to be used by bison.

2. Since there are no separate ranges for individual herds or age/sex classes, the area available to bison can be used by the whole population.

3. Forage production in classes designated as primary and secondary range will be combined and used as the forage base for establishing a unit's carrying capacity. For those classes in the marginal ranges with use higher than 2%, production will also be combined, but the carrying capacity derived for these will be used only as a buffer for the primary and secondary ranges.

Because the marginal range in the NU includes only one class which has production available for it, and since this production is only for a few species, the carrying capacity for marginal ranges in the NU was not calculated.

The first approximation of carrying capacity only considered forage production in three major forage catagories: total graminoid production, total forb production, and total tree and shrub production. This results in a year-long carrying capacity on the primary and secondary ranges of approximately 1145 bison in the SU. The marginal range in the SU could support about 1370 additional bison. Using the same procedure, it was determined that the NU's primary and secondary ranges could carry 797 bison. These figures were calculated allowing fifty percent utilization (AUF) of the total forage base during a normal production year. Using these figures, a manager could maximize bison production, but certain plant species or even habitat types could be eliminated.

A second method could be used which would allow maintenance of existing plant species and communities. The Soil Conservation Service has established initial stocking rates for range sites in various levels of condition for the Badlands region of North Dakota. Assuming the range sites in both units are in good to excellent condition as calculated by the SCS, the stocking rate for both units is 0.3 AUM's (Animal Unit Months) per acre. Assuming that the average bison is equal to one AUM, the primary and secondary ranges in the SU could carry approximately 288 bison per year, while the marginal range could carry 296. The primary and secondary ranges in the NU could support 191 bison annually. The SCS stocking rates are conservative so these numbers should be close to those which could be supported under normal conditions without any deterioration of the range.

The two previous ways of calculating carrying capacities are presented as guidelines. A more refined method of forage allocation is needed if plant and bison populations are to be kept in balance. By considering all of the major dietary species and their productivity separately, those plant species with the highest risk of overuse under increased bison numbers could be determined.

Individual graminoids used in carrying capacity calculations were limited to species or genera that made up 3 or more percent of the diet during any season. Carrying capacity was calculated from spring and summer diets because the level of grazing during this period is critical to plant survival. At this time plants are growing and completing their life cycles and if grazed too closely or frequently, their chances for survival are reduced. If grazing can be held to moderate levels during the spring and summer, individual plant health and that of the plant community could be maintained. But once grasses have completed their annual growth cycles, they can tolerate up to 80% removal of aboveground production without damage to plant health. Limiting the amount of the plant removed during the growing season also produces a larger reserve of forage for the winter.

Graminoids which contributed less than 3% to all seasonal diets were combined into one category, perennial grasses. Those species were: _Aristida longiseta_, _Calamagrostis montanensis_, _Calamovilfa longifolia_, _Distichlis stricta_, _Echinochloa crusgallia_, _Schedonnardis paniculatus_, _Elymus_ spp. and _Oryzopsis_ spp.

Several species or genera were grouped for reasons other than low occurrence in the diet. Reasons for grouping these species and genera were:

1. _Bromus_ spp. includes both the perennial _Bromus inermis_ and the annual bromes (_Bromus tectorum_ and _Bromus japonicus_). Since the only production estimate available was for _Bromus inermis_, and much of the _Bromus_ spp. in the diet were annual bromes, it was felt that grouping was better than establishing a biased carrying capacity.

   Basing carrying capacities on any annuals generally results in inaccurate estimates. The error arises primarily from the fact that yearly production by annuals is very erratic so their contribution to the forage base is questionable.

2. Annual production for _Panicum_ spp. was not reported for any of the HT's. Three _Panicums_ are present in the park. _Panicum capillare_ (witchgrass) is a weed, _Panicum wilcoxionum_ (Wilcox panicum) is an uncommon small perennial which because of its small stature and scattered distribution is in little danger of overutilization, and _Panicum virgatum_ (switchgrass) occurs primarily in the _Andropogon gerardii_ HT which was not included in the calculations because of its small acreage. Because switchgrass is highly palatable from July to August and it occurs in the _Andropogon gerardii_ HT, there is a distinct possibility it could be overutilized. Establishment of range trend transects in the _Andropogon gerardii_ HT should allow regular monitoring of both _Andropogon_ and _Panicum_ survival under existing bison numbers. A decline in either or both species could indicate a need for reduction in bison numbers.

3. _Sporobolus cryptandrus_ had little herbage production. It is our feeling that the production was underestimated, but the danger of this species being overutilized is small since it constituted less than 4% of the bison diet during all seasons.

The rest of the plants clumped into the perennial grass category appear to be in no danger of being overutilized because of the low level of use by bison.

Perennial forbs and woody species were entered into carrying capacity calculations as forage classes. This clumping was necessary because available production studies gave values only for "total forbs" and "total shrubs/trees". In most instances, analyses were not affected since winterfat was the only dicot recorded at levels greater than 3% in a seasonal diet. Bison use of winterfat was mainly restricted to winter, a period when winterfat can withstand heavy use. Should elk be introduced, this forage species could be more vulnerable to damage and should be monitored closely.

Tables 10, 11, and 12 contain the calculated carrying capacities for each major forage. In these calculations, the allowable use factor (AUF) of 0.35 and production factor (PF) of 0.4 represent the level of use allowable in a prolonged drought situation. For the primary and secondary ranges in the SU, the two genera most limiting were _Andropogon_ and _Muhlenbergia_ (Tables 10 and 11). HT's and MU's in the primary and secondary ranges have very little of these two genera whereas the marginal range contains large amounts of these species. Since the bison population spends about 30% of its time in the marginal range, we feel a manager could assume that a proportion of the bison diet was taken from the marginal range. Because large amounts of _Andropogon_ and _Muhlenbergia_ were present in the marginal range, it was likely that the largest amount of foraging for these species was done there. Consequently, the carrying capacity in the SU was based on the next most constraining genera, _Bouteloua_ and _Carex_, in the primary and secondary ranges. An added safety measure in calculating a carrying capacity from these species was that the resulting value could not be larger than the carrying capacity for _Andropogon_ and _Muhlenbergia_ in the marginal range. The average year-long carrying capacity for _Bouteloua_ and _Carex_ was approximately 200 bison. This carrying capacity was below that for _Andropogon_ and _Muhlenbergia_ in the marginal ranges so the bison population should be in balance with its forage base during a drought.

Table 10. Carrying capacity estimates for each species or genera in the primary and secondary ranges of the South Unit using the spring and summer diet estimates (drought year).

Species or Genera	TAP	AUF	PF	PD	Intake	Bison/Year[1]
Agropyron cristatum*	334,500	.35	.4	.001	6480	7227
Agropyron spp.	5,645,343	.35	.4	.144	6480	847
Andropogon spp.	51,387	.35	.4	.116	6480	9
Bouteloua spp.	1,998,961	.35	.4	.204	6480	212
Koeleria pyramidata	605,006	.35	.4	.049	6480	267
Muhlenbergia spp.	18,299	.35	.4	.011	6480	36
Poa spp.	459,651	.35	.4	.033	6480	301
Stipa spp.	1,381,558	.35	.4	.102	6480	293
Perennial Grasses	1,819,144	.35	.4	.133	6480	295
Carex spp.	706,120	.35	.4	.086	6480	177
Forbs	1,134,625	.35	.4	.096	6480	255
Woody Plants	2,232,723	.35	.4	.0245	6480	1969

*The proportion in the diet was estimated from observations of bison use.

[1] Bison/Year from Agropyron cristatum $= \frac{(334{,}500)(.35)(.4)}{(.001)(6480)} = 7227$

Table 11. Carrying capacity estimates for each species or genera in the Marginal Range using the spring and summer diet estimates (drought year).

Species or Genera	TAP	AUF	PF	PD	Intake	Bison/Year
Agropyron cristatum*	Not Present	.35	.4	.001	6480	Not Present
Agropyron spp.	3,856,223	.35	.4	.144	6480	579
Andropogon spp.	1,392,354	.35	.4	.116	6480	259
Bouteloua spp.	2,854,167	.35	.4	.204	6480	302
Koeleria pyramidata	555,790	.35	.4	.049	6480	245
Muhlenbergia spp.	438,848	.35	.4	.011	6480	1362
Poa spp.	275,070	.35	.4	.033	6480	180
Stipa spp.	2,277,796	.35	.4	.102	6480	482
Perennial Grasses	2,485,929	.35	.4	.133	6480	404
Carex spp.	1,424,118	.35	.4	.086	6480	358
Forbs	1,165,678	.35	.4	.096	6480	262
Woody Species	1,296,201	.35	.4	.0245	6480	1143

*The proportion in the diet was estimated from observations of bison use.

Table 12. Carrying capacity estimates for each species or genera in the primary and secondary ranges of the North Unit using the spring and summer diet estimates (drought year).

Species or Genera	TAP	AUF	PF	PD	Intake	Bison/Year
Agropyron cristatum*	26,250	.35	.4	.001	6480	567
Agropyron spp.	3,493,735	.35	.4	.144	6480	524
Andropogon spp.	220,815	.35	.4	.116	6480	41
Bouteloua spp.	1,563,010	.35	.4	.204	6480	165
Koeleria pyramidata	423,555	.35	.4	.049	6480	187
Muhlenbergia spp.	100,425	.35	.4	.011	6480	197
Poa spp.	312,645	.35	.4	.033	6480	205
Stipa spp.	953,035	.35	.4	.102	6480	202
Perennial Grasses	1,362,593	.35	.4	.133	6480	221
Carex spp.	607,790	.35	.4	.086	6480	153
Forbs	685,470	.35	.4	.096	6480	154
Woody Species	625,445	.35	.4	.0245	6480	551

*The proportion in the diet was estimated from observations of bison use.

In the NU (Table 12) Andropogon spp. were again the limiting species for bison use on the primary and secondary ranges. The year-long carrying capacity of Andropogon spp. was approximately 41 animals. The marginal range in the North Unit provides very little production of Andropogon so we could not assume forage use of the Andropogon came from the marginal range as in the SU.

This low number of animals in the NU was not realistic given the amount of herbage produced by other forage species. The reasons for such a low calculated carrying capacity are:

1. Fecal samples contained both Andropogon scoparius and Andropogon gerardii. (The two species could not be reliably separated, but A. scoparius was evidently the most abundant.) Production data in mapped HT's includes only Andropogon scoparius. Although Andropogon gerardii is present in the NU, mapping of the Andropogon gerardii HT was impractical because of the limited size and scattered distribution of stands. Total Andropogon production is therefore underestimated.

2. The diet estimates were based on fecal samples from the SU. The SU diets may not be representative of the NU diets so the low carrying capacity may be an artifact of using the same diet for both populations. On the other hand, the diet estimate for the SU was developed under low population densities and high forage availability. These conditions should produce a situation where bison forage selection is unrestricted. If the SU diet is a reflection of forage preference irrespective of forage availability, the use of this diet should be a valid basis for calculating carrying capacity.

3. The estimated production of Andropogon scoparius may be low. There are large areas where a high density of Andropogon scoparius occurs in the rolling grassland class, but the areas are classified as Agropyron smithii - Stipa viridula HT, and published production figures for that HT did not have any production for Andropogon scoparius.

For these reasons, we calculated the NU carrying capacity by averaging the two genera that were used in the SU, Bouteloua and Carex with Andropogon (Table 12). Use of this average suggested approximately 100 bison could be supported in the NU during a severe drought.

Results from these calculations reflect what we consider the worst possible forage conditions (production factor of 0.4). Even if drought conditions continued for several years, an AUF of 0.35 would be conservative enough to limit overutilization of important forages. The only way a species could be overutilized is if its production dropped disproportionately to other species or if there is a shift in the diet.

The forage allocation model is linear. Thus, any changes in the inputs will result in a proportional change in bison numbers. Figures 7 and 8 show that bison numbers increase linearly with increases in the production factor. Thus, a twofold increase in herbage production will allow twice as many bison.

There were many forage species of annual or biennial nature which were not considered in the carrying capacity calculations. None of these species contributed more than 2% to a seasonal diet, but the potential for change does exist. Availability of any forage species can change drastically from one year to the next. Consequently, bison diets may also change. The erratic and unpredictable nature of forage production limits the value of basing long-range carrying capacity estimates on these species. It is important, therefore, to monitor plant community composition on a three to five year basis. Undesirable changes in community composition would indicate the necessity for revising carrying capacity estimates.

As pointed out in the diet section, many dietary "items" (usually genera) were composed of two or more species. We feel that none of the available species in a genus would respond to grazing in a significantly different manner than what would be expected of the whole genus. Individual species are in little danger of overutilization as long as the utilization level for the entire genus is not exceeded. The major possible exception is the genus Andropogon.

Andropogon sps., especially Andropogon gerardii and its HT are the most sensitive species and HT to grazing by bison in both units.

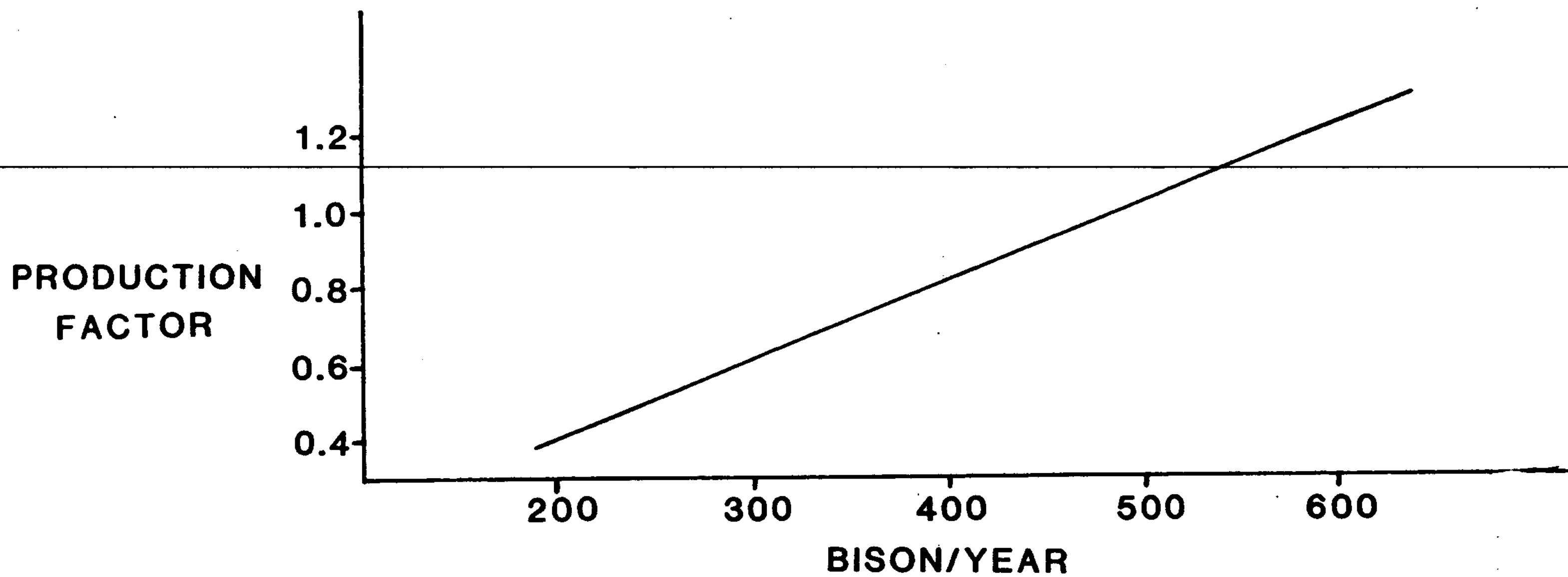


Figure 7. Average carrying capacities of Bouteloua sps. and Carex sps. with different levels of the production factor for the primary and secondary ranges in the South Unit. AUF of 0.35.

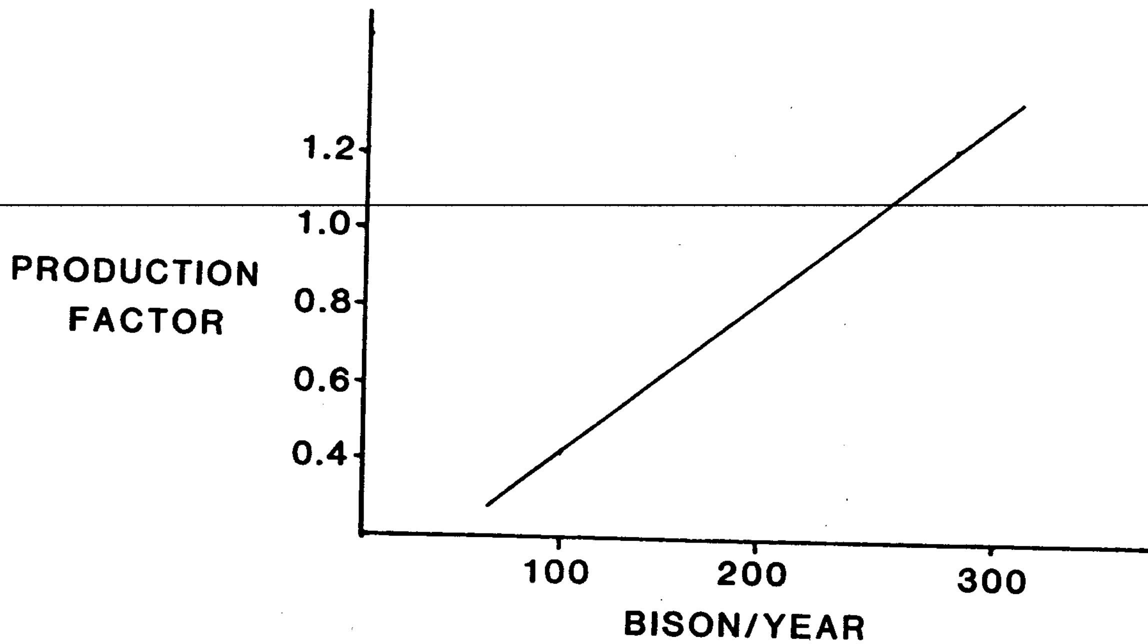


Figure 8. Average carrying capacity of Bouteloua sps., Carex sps., and Andropogon sps. with different levels of the production factor for the primary and secondary ranges in the North Unit. AUF of 0.35.

Andropogon scoparius may not be as highly preferred or in as much danger of overutilization as is *Andropogon gerardii*. *Andropogon scoparius* is found in classes and HT's with generally low use. There may be certain localities or HT's which contain *Andropogon scoparius* that may be overutilized under higher bison populations, but such overuse will not be widespread because of topography and inaccessibility. In underutilized stands, *Andropogon scoparius* occurs as "wolf plants". Such plants have so much dead and standing dead material in them that new growth is hindered and the green foliage that is present is so hard to get at that the plants are essentially unavailable for grazing. These plants have developed from the lack of fire and low grazing use. More frequent fires or more grazing will actually invigorate and make them more palatable. If the species is preferred by bison and the plants do not become wolfy again, these plants may suddenly be in danger of overutilization. So use of preferred species after burning should be monitored to protect the plant community and eventually the grazing herds.

6.0 FEEDING CRATERS (Low Density Grazing)

6.1 Methods

Because closely grazed areas surrounded by an ungrazed sward are common on primary and secondary ranges in both units of the park, it was decided to monitor these feeding craters in an attempt to further clarify our understanding of the bison - mixed prairie relationship. Frequency of use by bison and plant species composition inside and immediately outside the craters appeared to be the best parameters for initial study.

Species composition within feeding craters and adjacent microsites was determined with the Daubenmire technique.[6] Briefly, the procedure was performed as follows:

The proportion of the total plant cover made up by each identifiable species was determined from five 20 cm x 50 cm microplots randomly located within a feeding crater. This procedure was then repeated in the ungrazed microsite immediately outside the crater. It is important to note that the term "cover" refers to the basal area of the individual plant rather than its canopy cover. This was done to reduce variability in species composition due to current climatic conditions. Composition data was then used to calculate species diversity, for both the feeding crater and its adjacent ungrazed microsite. Diversity was estimated from the Shannon Diversity Index.[7]

---

[6] Daubenmire, R. 1968. Plant Communities: A Textbook of Plant Synecology. Harper and Row. New York. pp. 42-47.

[7] Odum, E.P. 1971. Fundamentals of Ecology. Third Edition. W.B. Saunders Company. Philidelphia, PA. p. 144.

$$\text{Diversity} = \sum \left(\frac{n_i}{N}\right) \log \left(\frac{n_i}{N}\right) \quad \text{where}$$

n_i = importance (cover) value for a species, and
N = total importance (cover) value for study site

Differences between craters and microsites were tested for significance with a paired "t" test at the 0.05 confidence level.[8]

Frequency of use (reuse) was determined by randomly selecting twenty feeding craters and then permanently marking each crater. Initially an area was chosen which had several craters (usually 3 or 4) in close (< 5 m distance) proximity. A fiberglass rod was driven into the ground to allow relocation of the site at a later date. The direction and distance from the post for each crater was recorded. Then a large nail was driven to ground level in the approximate center of the crater for future identification. An equal number of unused microsites was then marked with a nail and distance and direction from the rod recorded. Twelve months later the site was revisited and the craters and microsites were examined for grazing use. Entries were made as to whether marked craters were grazed or not grazed and whether new craters had been formed near the nails located in previously ungrazed microsites. Differences in frequency of use where tested with a nonparametric sign test.[9]

---

[8]Steel, R.G.D. and J.H. Torrie. 1960. <u>Principles and Procedures of Statistics</u>. McGraw-Hill Book Company. New York, NY. pp. 78-79.

[9]Daniel, W.W. 1978. Applied Nonparametric Statistics. Haughton Mifflin Co. Boston, MA. pp. 27-31.

6.2 Results

Plant species diversity within the feeding craters was significantly lower ($P<.05$) than that of the adjacent microsites. Average diversity for a feeding crater was 1.0296 while diversity in the ungrazed microsites averaged 1.3677. This data suggests that bison might be selecting microsites with low diversity to maximize consumption of a highly preferred genera or species. But, the validity of this argument is questionable when seasonal diets and frequency of use are taken into account.

The most frequently encountered genera in the feeding craters sampled was bluegrass (Poa spp.), second most common was the species yellow sweetclover (Melilotus officinalis) and third was western wheatgrass (Agropyron smithii). But, bluegrass and yellow sweetclover made up less than 5% of any seasonal diet while the wheatgrass genera (Agropyron spp.) constituted 11% - 18% of the seasonal diets. Genera or species most often encountered in the ungrazed microsites were bluegrass, western wheatgrass, yellow sweetclover, and needleandthread grass (Stipa comata). Because needleandthread grass made up 6% - 11% of the seasonal diets, it appears that if bison were selecting for needleandthread, new craters would be formed or old ones enlarged as this preferred species declined in abundance.

Bison were found to regraze the same crater rather than form new ones. Sixty-three percent of the feeding craters had been regrazed in a year's time while only 11% of the adjoining ungrazed microsites had been grazed. It is possible that continual grazing by bison enhances the availability of palatable plant parts. Cattle are known to repeatedly graze the same plant because previous grazing has removed standing litter.[10] Because the presence

[10] Norton, B.E., P.S. Johnson, and M.K. Owens. 1982. Increasing Grazing Efficiency. Utah Sci. Utah Exper. Sta. 43(4):110-113.

of litter apparently impedes animal use of available green forage, grazed plants are overutilized while ungrazed individuals of the same species continue to go unused. This will probably continue until some factor, e.g. increased animal density or fire, removes the litter on unused microsites. Low bison population levels during normal or above normal forage production years are largely responsible for the formation of feeding craters. Maintenance of suboptimal bison numbers will perpetuate these features and because of the apparent decline in community stability (low species diversity) within craters weed infestations or erosion problems are likely to begin here.

7.0 RANGE CONDITION AND TREND

7.1 Methods

Seventeen permanent range trend transects were established in August 1983 for monitoring of bison grazing impacts on native plant communities. Transect sites were based on frequency of bison use. Thus areas most often used by bison were surveyed and described for future reference. It should be noted that these transects are for determination of range trend and not necessarily for the description of plant community types.

Each transect consists of a thirty meter line with a 2.5 cm x 5 cm microplot sampled at 1 m intervals. Basal cover of vegetation was used in determining percent composition to avoid year to year variation due to climatic conditions. The percentage of the 2.5 cm x 5 cm covered by litter, bareground or clubmoss was also recorded.

The area within the 2.5 cm x 5 cm microplot is considered to have a value of 10. Thus, the total of plant basal cover, litter, bare ground or clubmoss must equal 10. The value for each category (species basal cover, litter, bare ground, and clubmoss) is then totaled for the entire line and divided by the number of microplots read along the line (30 in this case). The resulting average (a percent) indicates what proportion of the land surface is made up of each category. Comparison of this information collected over consecutive years will enable the manager to detect changes in plant cover which might be due to bison management. The most sensitive indicators will be bare ground and litter. Changes in either (or both of these categories) will proceed a change in plant species composition. A departure from current conditions would indicate an upward or downward trend in range condition.

Range condition is based on the potential natural vegetation (excellent condition) for a site. Anything less than what would be found under this condition is considered a lower condition class. Because current range condition guides are based on plant species composition by weight, a different method had to be used to evaluate the condition of ranges within both units of the park. Consequently, results of an intensive survey of grassland habitat types in western North Dakota were used as a baseline for determining range condition. Two criteria were used in assessing condition:

A) Total composition of decreaser species, and
B) clubmoss cover.

On the sites sampled, the following grass species can be considered decreasers under grazing pressure:

A. *Agropyron dasystachyum*
B. *Agropyron smithii*
C. *Andropogon gerardii*
D. *Bouteloua curtipendula*
E. *Calamagrostis montanensis*
F. *Calamovilfa longifolia*
G. *Muhlenbergia cuspidata*
H. *Puccinellia nuttalliana*
I. *Stipa spartea*
J. *Stipa viridula*

These species usually comprise a large proportion of the potential natural vegetation in the Northern Plains. An increase in or maintenance of existing cover for these species would indicate a balance between grazing and plant health. Conversely, a decline could indicate overuse or climatic changes. Because clubmoss can produce a solid mat with which few plant species can compete, a high clubmoss cover would indicate limited opportunity for the plant community to reach its natural potential. A lower condition rating would then be applied.

7.2 Results

Seven of the seventeen transects were considered to be in poor condition because the basal cover of decreaser species was less than half of that reported in the baseline study (Table 13). An eighth site was placed in poor condition because of a clubmoss cover of 23.67%. Two more sites were given a fair condition rating because there was only one decreaser species present or the site was dominated by a non-native species (Kentucky bluegrass). Seventy-one percent of the sites sampled in the NU were in poor or fair condition while 55% of the sites in the SU were in the same condition. Since there has been no range condition survey of the park to date, it is not possible to attribute the low condition of some transect sites to bison use.

A detailed description of plant community composition, bare ground, litter and clubmoss cover for each transect can be found in Appendix D. Future range condition surveys should be compared with this data for determination of range trend. We recommend resampling the transects every 3 to 5 years. If personnel and field time are limited, those sites determined to be in poor condition (Table 13) should be given priority.

Table 13. Condition classification of range sites in North and South Units of Theodore Roosevelt National Park.

		Percent Composition Contributed by Decreaser Species			
Unit	Transect	Whitman*	TRNP	Condition	Comments
North	8	18.0	18.6	poor	clubmoss cover greater than 8.0%
	9	17.1	27.9	very good	
	10	39.3	10.3	poor	
	11	17.1	56.5	fair	western wheatgrass monoculture
	12	32.5	8.9	poor	
	13	17.1	35.3	very good	
	14	17.1	2.4	poor	
South	1&2	39.3	42	good	
	3	21.5	8	poor	
	4	18.3	27.1	very good	
	5	15	18.4	good	
	6	13.8	3.7	poor	
	7	33.8	7.4	poor	
	15	17.1	17.5	good	
	16	36.2	14.6	poor	
	17	17.1	25.4	fair	Kentucky bluegrass western wheatgrass biculture

*Whitman, W.C. 1978. Analysis of grassland vegetation on selected key areas in southwestern North Dakota. N. Dak. Reg. Envir. Prog.

SUMMARY AND RECOMMENDATIONS

Bison Numbers

Under average rainfall and with no other large grazing herbivores, forage production on the South Unit of TRNP could support 1,100 bison and the North Unit 800 bison. This stocking rate could not be maintained during drought years, does not allow for forage needs of feral horses or potential needs of elk, and would eventually lead to deterioration of several plant communities.

Our data on current bison food habits, habitat use, and distribution patterns indicate herds of 200 in the South Unit and 100 in the North Unit could be maintained through several years of severe drought with minimal damage to plant communities in the park. Herds of 500 and 250 in the South and North Units, respectively, would be unlikely to damage plant communities during average years. Therefore, we recommend that bison be maintained at levels of 200-500 on the South Unit and 100-250 on the North Unit. These estimates are based on conservative plant utilization factors (35% of annual growth) and should allow a large margin of safety at the upper stocking rates for most communities. Changes in bison distribution and food habits at higher stocking rates than we observed, increases in feral horses, and the introduction of elk will influence vegetation use and could necessitate a reevaluation of bison stocking rates.

Vegetation

At suggested base stocking levels (200 in the South Unit and 100 in the North Unit), big bluestem (*Andropogon gerardii*) and possibly little bluestem (*Andropogon scoparius*) in primary and secondary ranges could be overutilized. At the upper recommended levels (500 in the North Unit and 250 in the South Unit), upland sedges and gramas in primary range might be overutilized in dry years. Most other communities and most common grass species are more likely to be underutilized than overutilized at the upper recommended levels. However, should feral horse and elk populations increase, additional species would be in danger of overutilization.

Under the present bison, longhorn, and feral horse population levels, a majority of the park's annual forage production is not being utilized. Underutilization has led to a litter buildup which could be limiting plant succession. Continuation of this situation will result in lower species diversity and eventual deterioration of the existing vegetation complex. Addition of another grazing species (elk) and an increase in bison numbers may limit future litter accumulations but would do little to reduce the existing litter buildup. Consequently, the regular planned use of fire will be necessary to redirect and enhance plant succession.

Management Recommendations

1. Bison - Bison should be censused (aerial or ground) every 2-3 years and production monitored annually. Should numbers exceed recommended upper limits (or if range trend transects indicate downward trends), trapping should be initiated to reduce herds to base levels, of about 200 in the South Unit and 100 in the North Unit. The upper bounds are sufficiently conservative to allow numbers to remain above the upper limits for 1 or 2 years without long-term damage to plant communities. Fecal transects, as described in this report, can be employed at 3-5 year intervals to detect broad changes in bison habitat use and distribution that may necessitate addition or deletion of range trend monitoring sites or re-evaluation of upper population bounds.

Although this study used 100 fecal transects in the South Unit and 52 fecal transects in the North Unit, periodic monitoring will not require as many. Since transects 1 m x 500 m will give a reliable indicator of bison use on approximately 150 ha (300 ac) of contiguous habitat surrounding the line, twenty transects located in the primary range, ten in the secondary range, and five in the marginal range should produce a reliable estimate of bison use.

2. Feral horses - Food habits of feral horses should be determined. Numbers, distribution, and productivity should be monitored, and an upper population limit compatible with bison and elk numbers should be determined.

3. Elk, deer, pronghorn - When elk are introduced, a study of food habits and habitat use should be initiated to assess potential additional impacts on vegetation and to provide preliminary information on the relationship of elk to resident ungulates. Numbers, productivity, and distribution of elk, mule deer, white-tailed deer, and pronghorns should be monitored on a regular basis.

4. Vegetation measurement - Permanent range transects established during this project should be run every 3 years to determine range trend. With increases in bison and/or horse numbers and introduction of elk, additional transects may be necessary at different sites or in additional communities such as big bluestem and deciduous tree communities. Production data at the species level for minor communities (and possibly for specific uncommon or rare plant species) should be collected if signs of overutilization are detected in routine observations of range condition.

Because of the high mobility of bison, grazing exclosures will be of minimal value to long-term range trend monitoring. This does not mean that exclosures would not be useful in evaluating the effects of more sedentary species, e.g. longhorns, elk, deer, and feral horses.

5. Fire - Controlled burns will not only stimulate plant succession but provide a means of attracting bison to underutilized areas and away from potential problem sites, e.g. campgrounds and boundary fences. Individual burns should not exceed 350 ha (700 ac).

6. Water - Water developments for bison should be constructed in large contiguous areas of primary and secondary range with little present use, and where present water developments are more than 2 miles apart. Care should be given to the placement of watering facilities so that bison are not required to traverse large areas of marginal range when moving from primary and secondary range to the watering area.

7. Mapping - Further mapping of the big bluestem habitat types should be done. At the same time, patches which receive little present use should be identified. These could be used as a visual check for condition and could indicate if grazing pressure is increasing.

APPENDICES

APPENDIX A

Table a. Acreage of habitat types, mapping units, and complexes as they occur in each physiographic/vegetational class in the North Unit.

Breaks		
1.	Stipa comata - Bouteloua gracilis	5.9
2.	Hardwood Draws	8.6
3.	Populus tremuloides - Betula occidentalis	24.9
4.	Andropogon scoparius - Juniperus horizontalis	18.8
5.	Juniperus scopulorum - Oryzopsis mircantha	599.2
6.	Artemisia tridentata - Atriplex confertifolia	305.4
7.	Andropogon scoparius	20.5
8.	Unvegetated	6226.2
Sagebrush Bottom		
1.	Hardwood Draws	15.6
2.	Artemisia cana	1850.0
3.	River Bottom	41.7
4.	Willows	76.1
5.	Marsh	46.4
6.	Man-Managed	17.3
7.	Brush	3.2
8.	Grassed Sand Floodplains	179.9
9.	Unvegetated	37.4
Wooded Draws		
	Included in the other classes as Hardwood Draw and Populus tremuloides - Betula occidentalis	
Upland Grasslands		
1.	Agropyron smithii - Stipa comata	425.2
2.	Agropyron smithii - Stipa viridula	284.4
3.	Stipa comata - Bouteloua gracilis	241.1
4.	Hardwood Draw	1.5
5.	Andropogon scoparius - Juniperus horizontalis	19.3
6.	Artemisia tridentata - Atriplex confertifolia	4.7
7.	Andropogon scoparius	38.8
8.	Brush	0.5
9.	Unvegetated	22.5

Table a. Continued

Prairie Dog Town		
1.	Prairie Dog Town	119.0
Toe Slopes		
1.	Agropyron smithii - Stipa comata	303.2
2.	Agropyron smithii - Stipa viridula	1506.3
3.	Stipa comata - Bouteloua gracilis	33.8
4.	Hardwood Draw	769.0
5.	Populus tremuloides - Betula occidentalis	33.8
6.	Artemisia cana	15.6
7.	Andropogon scoparius - Juniperus horizontalis	333.6
8.	Juniperus scopulorum - Oryzopsis mircantha	286.6
9.	Artemisia tridentata - Atriplex confertifolia	770.9
10.	Andropogon scoparius	657.5
11.	Brush	9.1
12.	Unvegetated	939.9
Rolling Grassland		
1.	Agropyron smithii - Stipa comata	56.1
2.	Agropyron smithii - Stipa viridula	1823.3
3.	Stipa comata - Bouteloua gracilis	18.5
4.	Hardwood Draw	128.2
5.	Populus tremuloides - Betula occidentalis	2.0
6.	Andropogon scoparius - Juniperus horizontalis	65.7
7.	Artemisia tridentata - Atriplex confertifolia	13.1
8.	Andropogon scoparius	120.1
9.	Introduced Grasses	34.8
10.	Brush	22.2
11.	Unvegetated	189.9
Achenbach Hills		
1.	Achenbach Hills Complex	191.7
2.	Populus tremuloides - Betula occidentalis	3.4
Bottom Grasslands		
1.	Agropyron smithii - Stipa viridula	526.3
2.	Hardwood Draw	0.2
3.	Juniperus scopulorum - Oryzopsis mircantha	0.5
4.	Brush	3.7
5.	Grassed Sand Floodplains	150.0
6.	Unvegetated	12.5
Cottonwood Forests		
1.	Populus deltoides - Juniperus scopulorum	219.0

Table b. Acreage of habitat types, mapping units, and complexes as they occur in each physiographic/vegetational class in the South Unit.

	Acres
Breaks	
1. Agropyron smithii - Stipa comata	20.7
2. Agropyron smithii - Stipa viridula	75.1
3. Stipa comata - Bouteloua gracilis	30.4
4. Hardwood Draw	230.8
5. Populus tremuloides - Betula occidentalis	3.9
6. Andropogon scoparius - Juniperus horizontalis	179.9
7. Juniperus scopulorum - Oryzopsis mircantha	579.6
8. Artemisia tridentata - Atriplex confertifolia	748.0
9. Andropogon scoparius	331.6
10. Man-Managed	16.8
11. Artemisia tridentata - Bouteloua gracilis	156.9
12. Steep Scoria	75.1
13. Rolling Scoria	8.6
14. Brush	4.7
15. Unvegetated	6674.6
Sagebrush Bottoms	
1. Agropyron smithii - Stipa viridula	115.8
2. Hardwood Draws	35.8
3. Artemisia cana	2418.9
4. Andropogon scoparius	3.9
5. River Bottom	230.3
6. Man-Managed	46.0
7. Unvegetated	88.1
Wooded Draws	
Included in the other classes as Hardwood Draws.	
Upland Grassland	
1. Agropyron smithii - Stipa comata	190.8
2. Agropyron smithii- Stipa viridula	1268.8
3. Stipa comata - Bouteloua gracilis	475.2
4. Hardwood Draw	0.7
5. Artemisia tridentata - Atriplex confertifolia	1.7
6. Andropogon scoparius	63.5
7. Introduced Grasses	384.7
8. Brush	6.4
9. Unvegetated	105.2
Prairie Dog Towns	
1. Prairie Dog Town	416.0

Table b. Continued

Old River Terrace	
1. Agropyron smithii - Stipa comata	1503.8
2. Agropyron smithii - Stipa viridula	454.7
3. Stipa comata - Bouteloua gracilis	393.9
4. Hardwood Draw	7.2
5. Andropogon scoparius	19.0
6. Introduced Grasses	64.0
7. Man-Managed	12.8
8. Petrified Forest Complex	54.4
9. Unvegetated	--
Grassland Flats	
1. Agropyron smithii - Stipa comata	5.7
2. Agropyron smithii - Stipa viridula	3329.2
3. Hardwood Draw	34.1
4. Artemisia cana	33.6
5. Andropogon scoparius - Juniperus horizontalis	17.5
6. Juniperus scopulorum - Oryzopsis mircantha	13.3
7. Artemisia tridentata - Atriplex confertifolia	22.7
8. Andropogon scoparius	117.1
9. Introduced Grasses	7.2
10. Man-Managed	6.4
11. Artemisia tridentata - Bouteloua gracilis	80.8
12. Rolling Scoria Complex	31.6
13. Brush	7.2
14. Unvegetated	1143.2
Ridge & Ravine	
1. Agropyron smithii - Stipa comata	256.0
2. Agropyron smithii - Stipa viridula	919.9
3. Stipa comata - Bouteloua gracilis	35.8
4. Hardwood Draw	682.0
5. Populus tremuloides - Betula occidentalis	5.9
6. Artemisia cana	51.9
7. Andropogon scoparius - Juniperus horizontalis	1457.4
8. Juniperus scopulorum - Oryzopsis mircantha	191.5
9. Artemisia tridentata - Atriplex confertifolia	233.0
10. Andropogon scoparius	4084.0
11. Man-Managed	3.2
12. Steep Scoria Complex	30.6
13. Rolling Scoria Complex	45.0
14. Brush	10.9
15. Unvegetated	3679.8

Table b. Continued

Scoria Hills		
1.	Agropyron smithii - Stipa viridula	201.9
2.	Hardwood Draws	57.1
3.	Artemisia cana	20.7
4.	Andropogon scoparius - Juniperus horizontalis	11.4
5.	Juniperus scopulorum - Oryzopsis mircantha	155.7
6.	Artemisia tridentata - Atriplex confertifolia	88.2
7.	Andropogon scoparius	26.2
8.	Artemisia tridentata - Bouteloua gracilis	35.1
9.	Steep Scoria Complex	5833.8
10.	Rolling Scoria Complex	3474.2
11.	Unvegetated	1295.8
Cottonwood Forests		
1.	Populus deltoides - Juniperus scopulorum	219.0

APPENDIX B

Annual Production of all HT and MU for Which Production was Available

Values represent average production years

Species in parentheses contribute the major production for genera listed

Table a. Annual production of Agropyron smithii - Stipa comata HT

Species	lb/acre
Stipa spp.	247
Agropyron smithii	495
Koeleria pyramidata	83
Bouteloua spp. (B. gracilis)	330
PGRASS[1]	165
Carex spp.	82
PFORBS[2]	165
Woody spp.	83
Total	1650

[1]PGRASS = Production of perennial graminoids which were not given separately as species.
[2]PFORBS = Production of all perennial forbs.

Table b. Annual production for Andropogon scoporius HT

Species	lb/acre
Stipa spp. (S. comata)	173
Andropogon scoparius	231
Calamovilfa longifolia	115
Muhlenbergia cuspidata	173
Agropyron smithii	57
PGRASS	57
Carex spp.	115
PFORBS	57
Woody spp.	115
Total	1093

Table c. Annual production for Artemisia tridentata - Atriplex contortifolia HT

Species	lb/acre
Agropyron smithii	500
Stipa spp. (S. viridula)	50
Bouteloua spp. (B. gracilis)	50
Muhlenbergia cuspidata	50
PGRASS	100
Carex spp.	20
PFORBS	100
Woody spp.	100
Total	970

Table d. Annual production for Andropogon scoparius - Juniperus horizontalis HT

Species	lbs/acre
Agropyron smithii & Agropyron spicatum	120
Stipa spp. (S. comata)	60
Andropogon scoparius	60
Bouteloua spp. (B. gracilis & B. curtipendula)	120
Koeleria pyramidata	30
Aristida longiseta	30
Muhlenbergia cuspidata	30
PGRASS	30
Carex spp.	60
PFORBS	30
Woody spp.	30
Total	600

Table e. Annual production for Agropyron smithii - Stipa viridula HT

Species	lbs/acre
Agropyron smithii	675
Stipa spp. (S. viridula)	75
Koeleria pyramidata	75
Bouteloua spp. (B. gracilis)	225
Calamagrostis montanensis	75
Buchloe dactyloides	75
Poa spp. (P. sandbergii)	75
PGRASS	37
Carex spp.	75
PFORBS	75
Woody spp.	75
Total	1467

Table f. Annual production for Agropyron smithii - Bouteloua gracilis - Distichlis stricta HT

Species	lbs/acre
Agropyron smithii	138
Bouteloua spp. (B. gracilis)	195
Poa spp. (P. sandbergii)	27
Buchloe dactyloides	27
PGRASS	27
Carex spp. (C. filifolia)	27
PFORBS	27
Woody spp.	55
Total	4941

Table g. Annual production of Artemisia cana HT

Species	lbs/acre
Agropyron smithii	456
Stipa spp. (S. viridula)	61
Poa spp. (P. sandbergii)	30
PGRASS	61
PFORBS	100
Woody spp.	649
Total	4418

Table h. Annual production of Andropogon gerardii HT

Species	lbs/acre
Andropogon gerardii	631
Poa spp. (P. pratensis)	248
Panicum virgatum	248
Stipa spp. (S. spartea)	228
Koeleria pyramidata	53
Elymus canadensis	79
Agropyron smithii	39
PGRASS	285
Carex spp.	148
PFORBS	738
Total	3061

Table i. Annual production for grassed sand floodplains HT

Species	lbs/acre
Stipa spp. (S. comata)	450
Calamovilfa longifolia	360
Agropyron smithii	90
Bouteloua spp. (B. gracilis)	180
Koeleria pyramidata	90
Andropogon hallii	90
Sporobolus cryptandrus	90
PGRASS	45
Carex spp.	180
PFORBS	180
Woody spp.	90
Total	1845

Table j. Annual production for Stipa comata - Bouteloua gracilis HT

Species	lbs/acre
Stipa spp. (S. comata)	425
Agropyron smithii	170
Calamovilfa longifolia	255
Bouteloua spp. (B. gracilis)	255
Koeleria pyramidata	85
PGRASS	85
Carex spp.	170
PFORBS	170
Woody spp.	85
Total	1700

Table k. Annual production for introduced grass MU

Species	lbs/acre
Agropyron cristatum	750
Bromus inermis	250
PFORBS	100
Total	1100

Table l. Annual production of marsh MU

Species	lbs/acre
Spartina pectinata	1040
PGRASS	1520
Carex spp.	1300
Cyperaceace spp.	1040
PFORBS	260
Total	5160

Appendix C. Food items identified in bi-monthly fecal samples. (Percent of Diet)

(AUTUMN)	17OC	28OC	09NO	22NO
GRAMINOIDS				
Agropyron	18.1	12.1	14.7	18.8
Andropogon	13.6	11.0	12.5	8.6
Aristida	0	0.4	0	0
Bouteloua	21.6	24.3	22.9	15.7
Bromus	1.9	0	1.6	0
Buchloe	0	0	0	0
Calamagrostis	0	0	0	0
Calamovilfa	0.5	2.4	2.5	3.4
Cyperaceae	13.0	11.0	11.9	11.7
Distichlis	0	0.4	0.4	0
Echinochloa	0	0	0	0
Elymus	0.5	0.4	0	0
Koeleria	4.7	4.9	4.2	2.5
Muhlenbergia	1.9	1.2	1.6	2.5
Oryzopsis	0.9	2.0	1.6	1.7
Panicum	0.9	0.8	1.2	0
Poa	1.9	1.2	2.0	0.8
Schedonnardus	0	0	0	0
Sporobolus	0	2.8	3.3	3.4
Stipa	0	12.1	9.8	10.6
Unknown Grass	5.8	4.9	5.1	5.2
Total	85.3	91.9	95.3	84.9
FORBS				
Astragalus	0.5	0	0	0
Compositae	0	0.4	0	0
Convolvulus	0	0	0	0
Liliaceae	0.9	0.4	0.8	0
Lupinus	0	0	0	0
Melilotus	0	0.4	0	0
Phlox	0	0	0.4	0
Selaginella	0	0	0	0
Sphaeralcea	9.0	1.6	0	0
Taraxacum	0	0	0	0
Unknown Forb	2.3	3.6	2.0	0.4
Total	12.7	6.4	3.2	0.4
SHRUBS				
Amelanchier	0	0	0	0.8
Artemisia cana	0	0	0	0
A. frigida	1.9	0.8	0.4	0
A. longifolia	0	0	0	0
A. tridentata	0	0	0	0
Atriplex	0	0	0	0
Ceratoides	0	0	0	6.1
Juniperus	0	0	0	1.2
Potentilla fruticosa	0	0	0.4	0.4
Rosa	0	0	0	0
Salix	0	0.8	0	0.4
Sarcobatus	0	0	0	0
Symphoricarpos	0	0	0	0
Unknown Browse	1.4	0.4	0.8	2.5
Total	2.3	2.0	1.6	14.4

Appendix C. (continued)

(EARLY WINTER)	08DE	30DE	19JA	21JA	02FE
GRAMINOIDS					
Agropyron	15.8	17.6	14.6	14.2	18.8
Andropogon	10.7	10.8	13.5	11.9	9.3
Aristida	0	0	0	0	0
Bouteloua	18.3	21.5	19.6	14.7	18.8
Bromus	0.4	0	0	2.9	2.0
Buchloe	0	0	0	0	0
Calamagrostis	0	0	1.2	0	0
Calamovilfa	3.0	1.2	0.4	3.7	1.6
Cyperaceae	11.2	11.9	13.5	13.6	8.8
Distichlis	0	0	0.8	0.4	0.8
Echinochloa	0	0	0	0.4	0
Elymus	0	0	0	0	0
Koeleria	3.4	2.0	3.9	2.5	2.9
Muhlenbergia	4.3	2.9	3.0	2.9	2.4
Oryzopsis	1.7	2.0	1.7	0.8	0
Panicum	0	2.4	0.8	1.2	0.4
Poa	3.9	4.6	4.8	1.6	2.0
Schedonnardus	0	0	0	0	0
Sporobolus	3.4	3.3	3.4	2.0	3.7
Stipa	9.2	8.8	8.1	8.4	10.3
Unknown Grass	5.3	5.9	6.2	5.5	5.9
Total	90.6	94.9	95.5	86.7	87.7
FORBS					
Astragalus	0	0	0	0	0
Compositae	0	0	0	0	0
Convolvulus	0	0	0	0	0
Liliaceae	0.4	0.4	0.4	0.8	2.9
Lupinus	0	0	0	0	0
Melilotus	0	0	0	0	0
Phlox	0	0	0	1.2	0
Selaginella	0	0	0	1.2	0.4
Sphaeralcea	0	0	0	0	0
Taraxacum	0	0	0	0	0
Unknown Forb	0	0	1.2	1.2	0.4
Total	0.4	0.4	1.6	4.4	3.7
SHRUBS					
Amelanchier	0	0	0	0	0
Artemisia cana	0	0	0	0	0
A. frigida	0	0	0	0	0
A. longifolia	0.4	0	0	0	0
A. tridentata	1.7	0.8	0	0.8	0
Atriplex	0	0	0	0.4	0.8
Ceratoides	5.3	1.6	1.7	4.2	2.9
Juniperus	0.8	0.4	0	1.6	2.9
Potentilla fruticosa	0	0	0	0	0
Rosa	0	0	0	0	0
Salix	0	0	0	0	0
Sarcobatus	0	0	0	0	0
Symphoricarpos	0	0	0.4	0	0
Unknown Browse	0.8	2.0	0.8	2.0	2.0
Total	9.0	4.8	2.9	9.0	8.6

Appendix C. (Continued)

(LATE WINTER)	27FE	12MR	29MR	13AP
GRAMINOIDS				
Agropyron	13.7	17.6	14.7	12.5
Andropogon	7.8	4.6	5.5	6.2
Aristida	0	0	0	0
Bouteloua	17.7	15.8	17.6	13.6
Bromus	1.9	4.2	3.1	3.6
Buchloe	0	0	0	0.4
Calamagrostis	0	0.4	0	0
Calamovilfa	3.5	1.2	0	0.8
Cyperaceae	13.2	3.7	6.0	6.6
Distichlis	0	0	0	0
Echinochloa	0	0	0	0
Elymus	0	3.3	6.0	1.6
Koeleria	3.5	3.3	5.5	7.1
Muhlenbergia	0.4	1.2	0.7	0
Oryzopsis	0.4	1.2	1.5	1.9
Panicum	1.1	0.4	3.5	3.2
Poa	1.5	4.6	4.3	3.2
Schedonnardus	0	0	0	0.4
Sporobolus	3.1	1.6	1.1	0.8
Stipa	6.4	8.8	8.7	8.5
Unknown Grass	5.6	4.6	3.9	4.5
Total	79.8	76.5	82.1	74.9
FORBS				
Astragalus	0	0	0.7	0
Compositae	0	0	0.4	0
Convolvulus	0	0	0	0
Liliaceae	1.9	1.6	1.9	1.6
Lupinus	0	0	0	0
Melilotus	0	0	0	0
Phlox	2.7	0	2.3	1.6
Selaginella	3.9	0	2.3	0.8
Sphaeralcea	0	0	0	0
Taraxacum	0	0	0	0
Unknown Forb	0.7	0.8	0.7	0.4
Total	9.2	2.4	8.3	4.4
SHRUBS				
Amelanchier	0	0	0	0
Artemisia cana	0	0.4	0.4	0
A. frigida	0	1.2	1.1	2.8
A. longifolia	0	0.4	0	0
A. tridentata	0	0	0	0
Atriplex	0	2.5	0.4	0.4
Ceratoides	3.5	14.1	6.0	15.2
Juniperus	5.2	0	0	0
Potentilla fruticosa	0	0	0	0
Rosa	0	0	0	0.8
Salix	0	0	1.5	0
Sarcobatus	0	0.4	0	0
Symphoricarpos	0	0	0	0
Unknown Browse	2.3	2.0	0.4	1.9
Total	11.0	21.0	9.8	21.1

Appendix C. (continued)

(SPRING)	25AP	09MY	22MY	06JN	23JN
GRAMINOIDS					
Agropyron	13.6	11.8	14.1	11.9	13.4
Andropogon	10.8	14.2	9.7	10.2	6.8
Aristida	0.8	0.4	0.4	0.9	0
Bouteloua	15.3	13.0	17.2	19.3	20.6
Bromus	3.4	2.2	2.1	3.2	5.0
Buchloe	0.4	0	0.8	2.2	0.4
Calamagrostis	0.4	0	0	0	0
Calamovilfa	3.0	0	0	0	0
Cyperaceae	8.2	8.5	5.7	4.5	8.3
Distichlis	0	0	0	0.4	0.4
Echinochloa	1.7	2.7	2.6	0.9	0
Elymus	3.0	3.1	2.6	0.9	3.2
Koeleria	5.3	4.5	4.8	7.1	5.0
Muhlenbergia	1.2	0.4	1.7	2.7	0
Oryzopsis	2.1	0.9	0	2.7	0.8
Panicum	4.8	6.0	3.4	3.2	1.2
Poa	2.6	4.1	4.8	4.1	4.1
Schedonnardus	0	0	0	0.4	0
Sporobolus	2.6	1.3	1.2	1.8	0.8
Stipa	7.7	9.6	8.7	8.6	10.2
Unknown Grass	5.3	5.5	5.3	6.0	4.6
Total	92.2	88.2	85.1	91.0	84.8
FORBS					
Astragalus	0	1.3	2.1	0.4	1.2
Compositae	0.4	0	0.8	0.4	0
Convolvulus	0.4	0	0.8	0	2.4
Liliaceae	1.7	2.2	0	0	0
Lupinus	0	0.4	0	0	0
Melilotus	0.4	0	1.2	2.2	3.7
Phlox	0	0	0	0	1.2
Selaginella	0.4	0.4	0	0	0
Sphaeralcea	0	0.4	0.4	0.4	0
Taraxacum	0	0	2.1	0.9	0
Unknown Forb	1.2	2.2	3.0	2.2	3.2
Total	4.5	7.8	10.4	9.2	13.7
SHRUBS					
Amelanchier	0	0	0	0.4	0
Artemisia cana	0.8	0	0	0	0
A. frigida	0.4	0	0.8	0	0.4
A. longifolia	0	0.9	0	0	0
A. tridentata	0	0	0	0	0
Atriplex	0	0	0	0	0
Ceratoides	1.2	2.2	1.7	0	0
Juniperus	0	0	0	0	0
Potentilla fruticosa	0	0	0	0	0
Rosa	0	0	0	0	0
Salix	0	0	0.4	0	0.4
Sarcobatus	0	0	0	0	0
Symphoricarpos	0	0	0	0	0
Unknown Browse	0.8	0.9	1.2	0	0.8
Total	3.2	4.0	4.1	0.4	1.6

Appendix C. (continued)

(SUMMER)	06JL	21JL	05AU	18AU	06SE	28SE
GRAMINOIDS						
Agropyron	13.8	13.5	13.5	16.7	13.7	14.0
Andropogon	8.0	8.6	12.4	13.9	12.2	14.0
Aristida	0	0.4	0	0	0	0
Bouteloua	26.6	16.4	22.1	23.2	20.2	18.8
Bromus	2.6	0.4	1.2	1.6	1.1	1.1
Buchloe	1.9	0	0.8	0	0	0
Calamagrostis	0.9	0	0.8	0.4	1.1	0
Calamovilfa	0	2.1	2.9	2.8	1.9	2.0
Cyperaceae	0	12.9	10.8	10.6	9.2	12.4
Distichlis	0	0	0	0	0	0
Echinochloa	0.9	1.2	0	0	0.4	0.4
Elymus	1.4	1.2	0.8	0	0	0
Koelaria	5.9	4.3	4.6	3.6	2.7	2.4
Muhlenbergia	0.5	3.0	0	0	1.1	0.8
Oryzopsis	1.4	0.4	0.4	0	1.1	0
Panicum	2.3	0.8	0.8	1.2	0.7	0.4
Poa	3.3	3.0	1.2	0.8	1.9	2.4
Schedonnardus	0	0	0	0	0	0
Sporobolus	0.9	1.2	0.4	1.6	2.3	3.7
Stipa	9.1	9.1	11.3	10.6	11.7	9.3
Unknown Grass	6.4	5.2	5.9	5.0	5.6	4.6
Total	86.1	83.7	89.9	92.0	86.9	86.8
FORBS						
Astragalus	0.9	3.8	0	0.8	0.7	1.2
Compositae	0	0.4	0	0	0	0
Convolvulus	1.4	0	0.4	0	0	0
Liliaceae	1.9	0.8	0	0	0.4	0.4
Lupinus	0	0	0	0	0	0
Melilotus	3.3	4.3	2.4	0	1.1	0
Phlox	0	0	0.4	0	0	0
Selaginella	0	0	0	0	0	0
Sphaeralcea	1.4	0.4	0	0	0	0
Taraxacum	0	0	0	0	0	0
Unknown Forb	3.8	3.8	4.1	3.6	2.7	2.4
Total	12.7	13.5	7.3	4.4	11.3	12.3
SHRUBS						
Amelanchier	0.5	0	0	0	0	0
Artemisia cana	0	0	0	0	0	0
A. frigida	0	0	0	0	0.4	0
A. longifolia	0	0	0.4	0.8	0	0
A. tridentata	0.5	0	0.4	0	0	0
Atriplex	0	0	0	0	0	0
Ceratoides	0	0	0.8	0	0	0
Juniperus	0	0.8	0	0.8	0.7	0
Potentilla fruticosa	0	0	0	0	0	0
Rosa	0	0	0	0	0	0
Salix	0	0	0.4	0.4	0	0
Sarcobatus	0	0	0	0	0	0
Symphoricarpos	0	0	0	0	0	0
Unknown Browse	0.5	1.7	0.8	1.6	0.7	0.8
Total	1.5	2.5	2.8	3.6	1.8	0.8

APPENDIX D
Range Condition Baseline Data

RANGE TREND BASELINE
(August 1983)

Mike Autney Exclosure:

INSIDE (Transect 1)

	Percent
Bare Ground	4.00
Litter	76.00
GRASSES:	
*Agropyron smithii	5.00
Poa pratensis	3.30
Stipa comata	4.00
*Stipa viridula	4.00
FORBS:	
Melilotus officinalis[1]	3.70

OUTSIDE (Transect 2)

	Percent
Bare Ground	3.70
Litter	68.70
GRASSES:	
*Agropyron smithii	4.70
Poa pratensis	6.30
Stipa comata	5.00
*Stipa viridula	6.30
FORBS:	
Melilotus officinalis[1]	5.30

[1] 1983 had above-average Melilotus production

*Denotes a decreaser species under bison, cattle and horse use.

BOUCOURT RIDGE (Transect 3)

Bare Ground	10.30
Litter	48.00
GRASSES & GRASSLIKE:	
*Agropyron smithii	3.33
Bouteloua gracilis	3.33
Bromus tectorum	0.33
Carex eleocharis	0.67
Carex filifolia	3.33
Carex heliophila	4.00
Koeleria pyrimadata	0.33
Stipa comata	8.00
FORBS:	
Gaura coccinea	0.67
Lygodesmia juncea	0.33
HALF-SHRUBS:	
Artemisia frigida	0.33
MOSSES & LICHENS:	
Selaginella densa	17.00

LIMBO FLATS: (Transect 4)

Bare Ground	33.00
Litter	45.00
GRASSES & GRASSLIKES:	
*Agropyron dasystachyum	3.00
*Agropyron smithii	1.00
Bouteloua gracilis	12.70
*Calamovilfa longifolia	0.70
*Calamagrostis montanensis	0.70
Koeleria pyrimadata	1.33
Poa canbyi	0.33
Poa pratensis	1.33
*Stipa viridula	0.70
FORBS:	
Melilotus officinalis	0.33
*Petalostemum purpureum	0.33

LOOP ROAD (Transect 5)

Bare Ground	7.67
Litter	43.00
GRASSES & GRASSLIKES:	
*Agropyron dasystachyum	2.00
*Agropyron smithii	5.67
Bouteloua gracilis	6.67
Carex filifolia	1.00
Carex heliophila	2.67
*Calamagrostis montanensis	0.33
Koeleria pyrimadata	2.00
Poa pratensis	0.33
Stipa comata	0.33
FORBS:	
Achillea millefolium	0.33
Orthocarpus luteus	0.33
Polygala alba	0.33
Viola spp.	0.33
SHRUBS & HALF-SHRUBS:	
Artemisia frigida	0.33
Symphoricarpos occidentalis	1.00
MOSSES & LICHENS:	
Lichen	4.67
Selaginella densa	20.00

PETRIFIED FOREST PLATEAU (Transect 6)

Bare Ground	16.70
Litter	37.00
GRASSES & GRASSLIKES:	
*Agropyron smithii	1.70
Bouteloua gracilis	10.30
Carex eleocharis	1.70
Carex filifolia	5.70
Koeleria pyramidata	0.70
Stipa comata	2.00
FORBS:	
Antennaria rosea	2.30
Heterotheca villosa	0.70
MOSSES & LICHENS:	
Selaginella densa	21.30

PETRIFIED FOREST PLATEAU DRAW (Transect 7)

Bare Ground	1.33
Litter	46.00
GRASSES & GRASSLIKES:	
*Andropogon gerardi	3.00
Bouteloua gracilis	1.00
*Calmovilfa longifolia	0.33
Carex filifolia	0.33
Carex heliophila	2.00
Poa pratensis	3.00
Stipa comata	4.00
*Stipa spartea	1.00
FORBS:	
Artemisia ludoviciana	0.33
HALF-SHRUBS:	
Artemisia frigida	1.00
SHRUBS:	
Rosa arkansana	0.33
MOSSES & LICHENS:	
Lichens	2.33
Selaginella densa	34.00

ACHENBACH HILLS (Transect 8)

Bare Ground	8.00
Litter	43.00
GRASSES & GRASSLIKES:	
*Agropyron smithii	7.67
Bouteloua gracilis	2.00
Carex filifolia	1.33
Koeleria pyramidata	3.67
*Muhlenbergia cuspidata	0.33
Poa canbyi	0.67
Stipa comata	0.33
*Stipa viridula	0.33
FORBS:	
Achillea millefolium	0.67
Artemisia dracunculus	0.67
Psoralea esculenta	1.00
HALF-SHRUBS:	
Artemisia frigida	2.33
MOSSES & LICHENS:	
Lichen	5.33
Selaginella densa	23.67

ACHENBACH HILLS TOE SLOPE (Transect 9)

Bare Ground	16.30
Litter	37.70
GRASSES & GRASSLIKES:	
*Agropyron smithii	5.30
Bouteloua gracilis	2.00
Carex heliophila	4.30
Koeleria pyramidata	3.70
Poa canbyi	1.70
Poa pratensis	0.30
*Stipa viridula	7.00
FORBS:	
Phlox hoodii	0.30
HALF-SHRUBS:	
Artemisia frigida	1.00
MOSSES & LICHENS:	
Lichen	2.00
Selaginella densa	18.70

NORTH UNIT RIVER BOTTOM (Transect 10)

Bare Ground	22.00
Litter	65.30
GRASSES & GRASSLIKES:	
*Agropyron smithii	0.30
Poa pratensis	2.00
Stipa comata	9.00
*Stipa viridula	1.00
FORBS:	
Psoralea lanceolata	0.30

NORTH UNIT ROLLING HILLS (Transect 11)

Bare Ground	4.70
Litter	74.70
GRASS & GRASSLIKES:	
*Agropyron smithii	11.00
Bouteloua gracilis	0.70
Carex eleocharis	1.00
Carex heliopha	0.30
Koeleria pyramidata	1.00
Poa pratensis	2.70
Stipa comata	3.00
*Stipa viridula	0.70
HALF-SHRUBS:	
Artemisia frigida	0.30

HAGEN SPRING DRAW (Transect 12)

Bare Ground	5.00
Litter	61.30
GRASS & GRASSLIKES:	
*Agropyron smithii	0.30
*Andropogon gerardi	2.70
Bouteloua gracilis	2.30
Carex filifolia	1.70
Carex heliophila	15.70
Koeleria pyramidata	0.70
Poa pratensis	1.00
Stipa comata	4.30
*Stipa spartea	0.30
FORBS:	
Artemisia drancunculus	0.30
Artemisia ludoviciana	1.00
SHRUBS:	
Symphoricarpos occidentalis	0.70
MOSSES & LICHENS:	
Selaginella densa	1.70
Lichens	1.00

BISON TRAP (Transect 15)

Bare Ground	10.30
Litter	57.30
GRASS & GRASSLIKES:	
*Agropyron smithii	5.00
Bouteloua gracilis	8.00
Carex eleocharis	1.70
Carex filifolia	3.70
Koeleria pyramidata	1.30
Stipa comata	6.00
FORBS:	
Crepis ssp.	0.30
Erysimum asperum	0.30
Erigeron ssp.	0.30
Hedeoma hispida	0.30
CACTI:	
Opuntia polyacantha	1.00
MOSSES & LICHENS:	
Lichen	3.70
Selaginella densa	0.70

SCORIA ROAD (Transect 16)

Bare Ground	13.33
Litter	50.33
GRASS & GRASSLIKES:	
*Agropyron smithii	3.67
Bouteloua gracilis	17.00
Carex filifolia	2.00
Distichlis stricta	1.67
Poa pratensis	1.67
*Puccinellia nuttalliana	0.67
Vulpia octoflora	1.67
FORBS:	
Plantago patagonica	1.00
MOSSES & LICHENS:	
Lichens	1.33
Moss	5.33
Selaginella densa	0.33

SQUAW CREEK PRAIRIE DOG TOWN (Transect 13)

Bare Ground	1.00
Litter	69.70
GRASS & GRASSLIKES:	
*Agropyron smithii	10.30
Bouteloua gracilis	6.70
Bromus tectorum	2.70
Carex eleocharis	4.30
Poa pratensis	0.30
Stipa comata	0.30
FORBS:	
Achillea millefolium	0.30
Annual Forbs	0.30
HALF-SHRUBS:	
Artemisia frigida	1.70
MOSSES & LICHENS:	
Selaginella densa	2.30

LONGHORN PASTURE (Transect 14)

Bare Ground	29.00
Litter	57.70
GRASS & GRASSLIKES:	
Agropyron smithii	0.30
Stipa comata	8.00
FORBS:	
Melilotus alba	1.00
Psoralea lanceolata	1.00
Salsola iberica	2.00

EAST SIDE (Transect 17)

Bare Ground	3.70
Litter	74.00
GRASS & GRASSLIKE:	
*Agropyron smithii	5.70
Carex eleocharis	0.30
Carex heliophila	0.70
Poa pratensis	14.70
FORBS:	
Achillea millefolium	1.00