AN ABSTRACT OF THE THESIS OF

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Title: The diet of pronghorn (Antilocapra americana) in the tallgrass prairie

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Pronghorn (Antilocapra americana) is a native fixture to the tallgrass prairie ecosystem. Pronghorn is a species known to consume significant quantities of forbs and shrubs when found in short and mixed-grass prairies. Understanding the diet of pronghorn in the tallgrass prairie is essential for knowing the role of pronghorn in the tallgrass prairie.

The diet of pronghorn in the tallgrass prairie was assessed by using fecal analysis. Fecal pellets were collected in the Flint Hills of Kansas throughout the year beginning June 1995 and ending in August of 1996. The nutritional quality of pronghorn diet was also determined by investigating the amount of crude protein, net energy, calcium, and phosphorus in forage samples.

During the winter months, pronghorn consumed graminoids and forbs, while shrubs were a dominant forage component in the summer and fall. The most commonly consumed grass was in the genus Poa. Sumac (Rhus spp.) was the most frequently consumed shrub, and was by far the most commonly consumed plant. Helianthus spp. was the most frequently found forb in the fecal pellets.

An evaluation of the nutritional quality of available forage material indicated that samples of summer Rhus spp. contained adequate amounts of all daily nutritional requirements for pronghorn. Randomly collected summer and winter forage samples

contained less than the estimated protein requirements for pronghorn. Therefore, pronghorn must be selective foragers to obtain all their nutritional requirements and survive in the tallgrass prairie.

Fecal pH was determined to aid in identifying fecal pellets as pronghorn feces. I found that fecal pH did not change in regard to diet or season. The fecal pH observed in my study was slightly lower than that reported by other researchers. However, fecal pH could be used to distinguish pronghorn fecal pellets from mule deer (Odocoileus hemionus) fecal pellets because of differences in reported fecal pH. The fecal pH of pronghorn was too similar to the reported values of white-tailed deer (Odocoileus virginianus) fecal pH to be used as an identification technique.

THE DIET OF PRONGHORN (ANTILOCAPRA AMERICANA) IN THE TALLGRASS PRAIRIE

A Thesis

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PREFACE

My thesis is composed of two chapters. Chapter one details my investigation of pronghorn diet and the nutritional quality of available forage in the tallgrass prairie. Chapter two pertains to research investigating the use of fecal pH as a means of identifying pronghorn fecal pellets. Both chapters are written in the style appropriate for publication in the Journal of Mammalogy.

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INTRODUCTION TO THESIS

Pronghorn (Antilocapra americana) is in the order Artiodactyla, suborder Ruminantia, infraorder Pecora, superfamily Bovoidea, and is the only extant genus of the family Antilocapridae. There is one species composed of five subspecies: A. americana americana, A. a. mexicana, A. a. oregona, A. a. peninsularis, and A. a. sonoriensis. The five subspecies were once more isolated, but due to recent translocations it is difficult to accurately indicate which subspecies is in a particular region. Antilocapra americana americana is the most abundant of the subspecies, and historically ranged across the northern Great Plains region of North America. Populations were once found in western Iowa, Kansas, western Missouri, western Minnesota, Nebraska, North Dakota, and South Dakota. Populations of A. a. americana also frequented other areas such as western Wyoming, western Montana, Utah, and California (Simpson, 1992). Individuals from populations of A. a. americana have been introduced to populations of the other four subspecies, which has made subspecies identification difficult (Moore, 1987).

The subspecies of A. a. mexicana and A. a. sonoriensis were historically found in the southwestern region of the species distribution. The subspecies A. a. mexicana occurred in southeastern Arizona, northern Mexico, southwestern New Mexico, and Texas. The historical distribution of A. a. sonoriensis was in the desert plains of central and western Sonora and into southern Arizona. Populations of A. a. peninsularis were located in Baja California (O'Gara, 1978). According to Grub (1993), A. a. sonoriensis and A. a. peninsularis are the only two subspecies listed as threatened or endangered. Antilocapra a. oregona was found along the northwest edge of the species range in

northeastern Oregon, but today the population of A. a. oregona lacks discrete population boundaries.

Pronghorn once roamed freely throughout the Great Plains, including the western edge of the tallgrass prairie (O'Gara, 1978; Sexson and Choate, 1981). Today pronghorn can be found as far east as Kansas. The western edge of their distribution is California and they can be found as far south as Mexico and north into Canada (Dirschl, 1963; Moore, 1987; Yoakum, 1978).

O'Gara (1978) estimated the pronghorn population of North America to be approximately 35 million prior to European settlement. During his 1828 expedition to what is today Kansas, Isaac McCoy noted the presence of pronghorn east of the Neosho River in eastern Kansas (Barnes, 1936). During his trip through Kansas, Zebulon Pike noted the prominent number of pronghorn located in what is today Chase County, Kansas (Sexson and Choate, 1981).

Excessive hunting and westward settlement of the North American prairie led to the decline of native herbivores. The large herds of pronghorn disappeared. By 1923 all but a few pronghorn were extirpated from the state of Kansas. Pronghorn currently occupy approximately 75% of their historic range (Moore, 1987).

In an attempt to re-establish pronghorn to their historical range, and to establish gene flow with western populations, the Kansas Department of Wildlife and Parks (KDWP) initiated a reintroduction program to the tallgrass prairie (Eccles, 1995). The project began in 1978 with the release of 37 individuals into the tallgrass prairie of the Flint Hills of Chase County, Kansas. Subsequently, 98, 127, and 24 individuals were

translocated in 1979, 1982, and 1983 respectively (Rothchild, 1993). The two most recent translocations took place in 1991 and 1992 when 50 and 49 pronghorn were released, respectively (Rothchild, 1993).

Outside of aerial surveys, the condition of the early population was unknown. The two most recent reintroductions have been followed with research investigating the behavior of translocated pronghorn. Simpson (1992) investigated behavior, home range, movement, and habitat use of adult pronghorn. Rothchild (1993) studied the home range, habitat use, and mortality of pronghorn fawns. Eccles (1995) also investigated habitat use, but concentrated on microhabitat conditions and found pronghorn frequented areas heavily disturbed by cattle.

Two aspects of the natural history of pronghorn in the tallgrass prairie neglected by previous researchers are the components of pronghorn diet and the nutritional requirements of pronghorn. The herd located in the Flint Hills provides a unique research opportunity to investigate the diet of pronghorn found in the tallgrass prairie. Previous studies investigating the components of pronghorn diet are numerous (e.g. Ellis and Travis 1975; Kessler et al., 1981; Krueger, 1986; Medcraft and Clark, 1986; Stephenson et al., 1985a, 1985b; Torbit et al., 1993), however, no previous researchers have investigated the diet of pronghorn found in the tallgrass prairie.

The primary objective of my study was to document the annual diet of pronghorn found in the tallgrass prairie. The second objective of my investigation was to determine how pronghorn forage selectivity changes in regard to season. The third objective of my research was to investigate the nutritional quality of available forage. The final objective

was to investigate the relationship between fecal pH, season, and diet.

Chapter 1 details my investigation of the diet of pronghorn in the tallgrass prairie. It also addresses the aspects of my study that deal with the nutritional quality of the available forage, and the estimated nutritional requirements of pronghorn as a small ruminant. Chapter 2 deals with aspects of pronghorn fecal pH as a means of identifying fecal pellets and the association of fecal pH with diet.

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CHAPTER 1

DIET AND NUTRITIONAL REQUIREMENTS OF PRONGHORN (ANTILOCAPRA AMERICANA) IN THE TALLGRASS PRAIRIE

ABSTRACT

The diet of pronghorn (Antilocapra americana) living in the tallgrass prairie of the Flint Hills was determined by using microhistological analysis. Fecal samples were collected from July 1995 through August 1996 in Chase and Lyon counties, Kansas. The herd located on the study area consisted of individuals translocated by the Kansas Department of Wildlife and Parks.

Results of the fecal analysis suggested graminoids and forbs were necessary resources for pronghorn in the spring and winter. Shrubs were the dominant forage type consumed in the fall and summer. Pronghorn winter diet consisted of 33% graminoids and 52% forb. The most frequently consumed forb was Helianthus spp. Pronghorn spring diet consisted of 62.1% graminoids dominated by Poa spp. Summer diet contained 74.4% shrubs, of which, 71% were Rhus spp.

To further investigate forage use by pronghorn, an evaluation of the daily nutritional requirements of pronghorn was determined. Nutritional requirement values were then compared to the nutritional quality of the available forage. The nutritional quality of the available forage was quite variable. Samples of Rhus spp. collected during the summer were found to exceed crude protein requirements for pronghorn. Rhus spp. were also found to be easily digested. Randomly collected summer forage did not meet the estimated protein requirement for pronghorn and was found to be less digestible than Rhus spp. Similarly, randomly collected winter forage failed to meet the nutritional requirements of pronghorn.

Pronghorn in the tallgrass prairie used high protein food sources. Managing for a

sustainable tallgrass prairie, which includes pronghorn, requires a management plan directed at allowing some shrub and forb growth without compromising tallgrass prairie quality with excessive woody growth.

Key words: pronghorn, Antilocapra americana, tallgrass prairie, diet, nutrition, nutritional requirements, Flint Hills, Kansas

Running heading: Diet of pronghorn in tallgrass prairie

Pronghorn (Antilocapra americana) eats a variety of grasses, shrubs and forbs in the western part of its range (Beale and Smith, 1970; Ellis and Travis, 1975; Kessler et al., 1981; Krueger, 1986; Medcraft and Clark, 1986; Sexson et al., 1981; Smith and Shandruk, 1979; Stephenson et al., 1985a, 1985b; Torbit et al., 1993; Yoakum, 1990). In a 1980-81 study in northcentral New Mexico, Stephenson et al. (1985a) found pronghorn diet consisted of 2% and 5% total grass in the winter of 1980 and 1981 respectively, 13% and 8% total grass in the spring of the same years, and 6% and 4% total grass for the summer. The percent forbs was 44% and 36% in the winter, 49% and 48% in the spring, and 56% and 68% in the summer. The percent of shrubs found in pronghorn diet for winter 1980 was 54%, and for 1981 was 59%. In the spring it was 38% and 44%, while in the summers of the same years it was 38% and 27%. Torbit et al. (1993) reported that pronghorn supplemented winter diet by foraging on winter wheat in eastern Colorado. In a study of pronghorn, prairie dog (Cynomys ludovicianus), and bison (Bos bison) interactions, Krueger (1986) documented that 24.6 % of the pronghorn's diet consisted of graminoids, 62.3% forbs, and 13.1% shrubs. The diet of pronghorn located in western Kansas consisted of 40% cacti, 36% forbs, 22 % grass, and 2% browse (Havlacheck, 1968).

In previous studies of pronghorn diet, researchers documented that pronghorn consumed large proportions of forbs, shrubs, and browse. Conversely, relatively little amounts of graminoids were consumed. Previous studies were done on populations of pronghorn found in shortgrass prairie, desert scrub, and mixed-grass prairie ecosystems. The herd I studied was located in the tallgrass prairie.

The tallgrass prairie is an ecosystem with a unique plant community. The tallgrass prairie receives approximately 60-100 cm of rainfall per year (Steinauer and Collins, 1996). Contrary to the shortgrass and desert scrub ecosystems, the tallgrass prairie receives more precipitation per year, and as a result, a mixture of C_4 and C_3 grasses dominate the plant community (Simpson, 1992). The proportion of shrubs, forbs, and woody browse found in the system is low. Shrubs, forbs, and browse are often restricted to disturbed patches of tallgrass prairie. Today the disturbed patches are a result of grazing by domestic cattle. Historically, bison and fire played a significant role in disturbing the plant community (Steinauer and Collins, 1996). A commensal relationship existed between bison and pronghorn (Krueger, 1986). Bison grazed on substantial amounts of graminoids, and as the large herds used an area the prairie plant community was disturbed. The disturbance allowed increased shrub and forb growth, which pronghorn consumed. With the extirpation of bison from most of its natural habitat, the commensal relationship between bison and pronghorn was displaced. However, with current grazing techniques, domestic cattle may fill the role of bison as far as disturbing plant communities and promoting growth of forbs and shrubs (Eccles, 1995).

Pronghorn was reported to be a selective forager when its preferred forage type was available (Berger et al., 1983). Not only did they select specific types of plants, they also selected specific parts of the plants (Krueger, 1986). However, when preferred forage types were not available, pronghorn changed their dietary intake to compensate for the lack of forbs and browse (Schwartz and Nagy, 1976). Because the tallgrass prairie lacks the predominance of forbs associated with the shortgrass and mountain steppe

ecosystems, one must ask not only what are pronghorn consuming and how selective must their foraging patterns be, but also are pronghorn located in the tallgrass prairie receiving adequate amounts of vitamins and nutrients? If pronghorn are able to adjust their diet as Berger et al. (1983) and others suggested, is the available forage of high enough nutritional quality to sustain a healthy population of pronghorn?

Little research has been done to investigate the nutritional needs of pronghorn (Dirschl, 1963; Schwartz et al., 1977; Smith and Malechek, 1974). The information gathered is patchy at best, and often used the nutritional requirements of domestic sheep, deer (Odocoileus spp.) or cattle as a baseline for the nutritional requirements of pronghorn. Comparison to sheep or goats may not pose problems in regard to accurate dietary information. All three species have similar gut morphologies and are considered small ruminants (Sisson and Grossman, 1975). Studies by Schwartz and Nagy (1976) indicated that pronghorn and sheep have similar diets. A separate study investigating food resource partitioning by sympatric ungulates on the Great Basin suggested that pronghorn diet was more similar to mule deer (Odocoileus hemionus) and sheep than cattle and horses (Equus caballus) (Hanley and Hanley, 1982). Volatile fatty acids (VFA) found in rumen samples of pronghorn were not significantly different from VFA samples of sheep on a wheaten hay diet (Nagy and Williams, 1969).

Though pronghorn is in its own family, Antilocapridae, it is in the same superfamily as cattle, sheep, goats, and antelope (Nowak, 1991). O'Gara (1978;1982) even argues that pronghorn should not be assigned to its own family and should be included in the family Bovidae. Thus, comparison of pronghorn to sheep should pose little

problem because of similarities in size and diet (Hanely, 1982; Schwartz and Ellis, 1981).

Current theories regarding foraging strategy suggest that an animal forages selectively when it is found in a high quality habitat (Heller, 1980; Murden and Risenhoover, 1993). When there are copious amounts of forage material of high nutritional quality available, an animal can select the most nutritious or digestible forage types because the probability of not acquiring minimum dietary needs is extremely low. Conversely, if an organism is in a habitat devoid of high quality forage or forage quality is patchy, the organism must forage indiscriminately, to increase the probability that all dietary requirements are ingested (Heller, 1980).

The initial investigation of pronghorn diet and selectivity will provide some insight into nutritional quality of the available forage and to the nutritional health of the pronghorn in the tallgrass prairie. If the available forage is of high nutritional value, that is, nutritional quality exceeds daily nutritional requirements, then the pronghorn should be selectively foraging. Based on the foraging theories of Hanely (1982), Heller (1980), and Schwartz and Ellis (1981), if pronghorn are foraging selectively, and the foods constituting their diet exceed the estimated nutritional requirements, then I can be confident that my estimated values for pronghorn nutritional requirements reflect the actual nutritional needs of pronghorn.

I determined the annual diet of pronghorn living in the tallgrass prairie by using microhistological analysis of fecal pellets. Seasonal shifts in diet were detected by using an analysis of variance (ANOVA) and Bonferroni multiple comparisons to determine changes in fecal pellet composition among four seasons (spring, summer, fall, and winter).

I tested for different amounts of graminoids, forb, and shrub in fecal pellets. I then determined if pronghorn were foraging selectively based on the nutritional value and digestibility of the available forage. Finally, I compared the diet of pronghorn in the tallgrass prairie to the diet of pronghorn in the short and mixed-grass prairies.

STUDY AREA

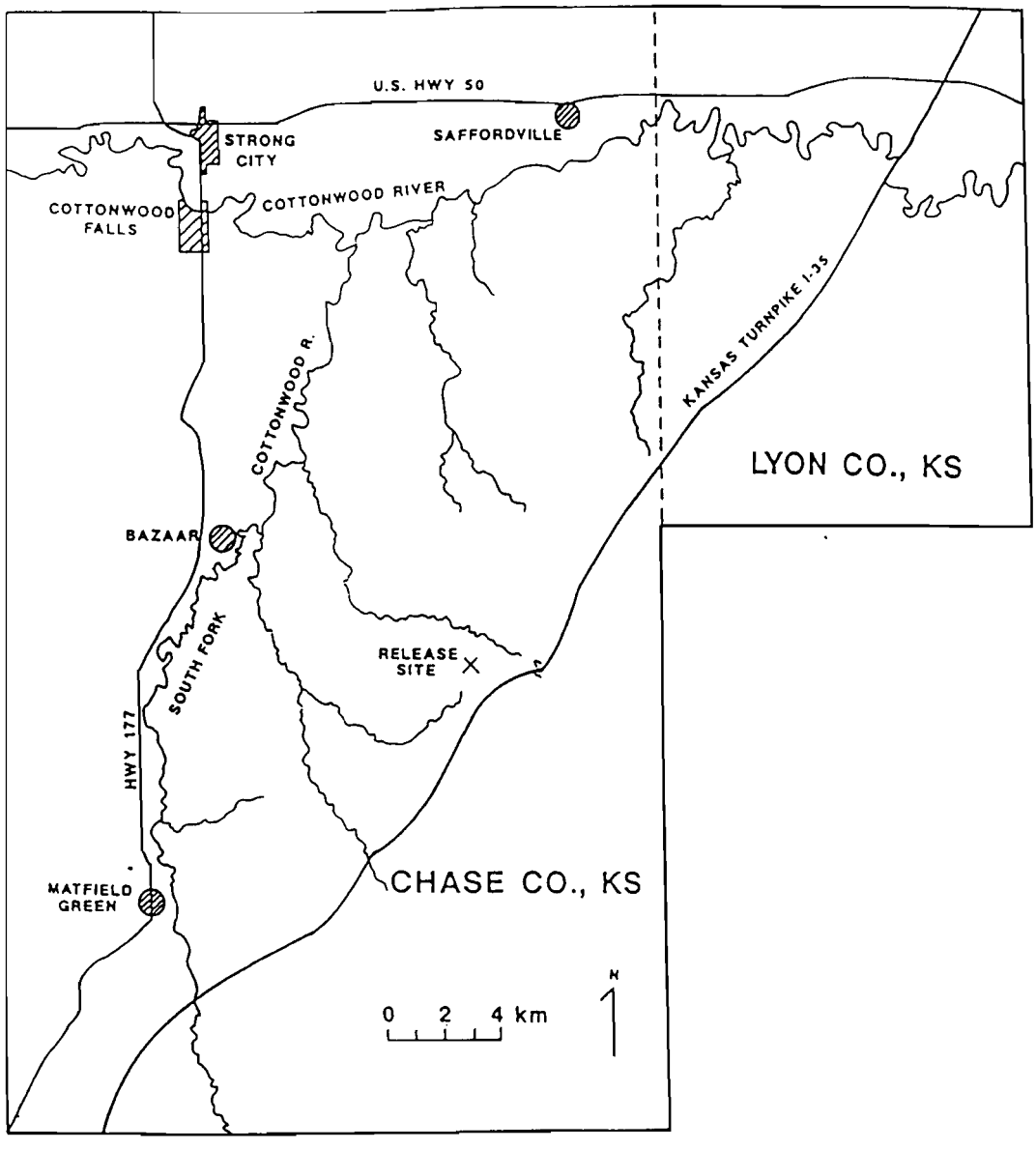
My study took place in the Flint Hills region of southeastern Chase County and southwestern Lyon County, Kansas. The Flint Hills region is 10,000 km^2 of continuous tallgrass prairie, and is the largest contiguous tract of tallgrass prairie in North America. The study site was 335 km^2 and was bounded by the Cottonwood River to the north, the South Fork of the Cottonwood River to the west, and the Kansas turnpike, Interstate 35, to the south and east (Fig. 1).

The area's topography was typical of the Flint Hills region with sloping hills (1 to 50 %), and moderately deep soils (Neill, 1974). The elevation ranged from 335 to 460 m above sea level. The entire area was privately owned, the majority of which was grazed by cattle. The area was usually annually burned in late March or early April.

The plant community was made up of grasses (71%), bare ground (13%), forbs (11%), litter (4%), and shrubs (1%) (Simpson, 1992). The dominant grasses were perennial C_4 grasses with Indian grass (Sorghastrum nutans), switchgrass (Panicum virgatum), big bluestem (Andropogon gerardii), and little bluestem (Andropogon scoparius) comprising the most abundant species (Horak, 1985).

Neill (1974) reported cold dry winters with an average snowfall of 42.5 cm per year. Accumulations of snow was infrequent, and the presence of snow on the ground seldomly lasted longer than one week. Thus, snowfall rarely rendered forage material inaccessible to pronghorn. Annual rainfall averaged about 80.4 cm a year (Neill, 1974). January was usually the coldest month with minimum temperatures reaching -7° C.

Fig. 1. General map of the study site. Boundaries to pronghorn movement off the area consisted of Kansas turnpike I-35, the South Fork of the Cottonwood River, and the Cottonwood River.


U.S. HWY 50
STRONG CITY
SAFFORDVILLE
COTTONWOOD FALLS
COTTONWOOD RIVER
COTTONWOOD R.
KANSAS TURNPIKE I-35
LYON CO., KS
BAZAAR
SOUTH FORK
RELEASE SITE
HWY 177
MATFIELD GREEN
CHASE CO., KS
0 2 4 km
N

MATERIALS AND METHODS

From June 1995 to July 1996 pronghorn fecal pellets were collected monthly. Only fresh fecal pellets, which were easily identified as pronghorn fecal pellets, were collected. Due to the inability to reach the study site because of flooding, I was unable to obtain any fecal pellets for the month of April. Additionally, the only fecal pellets found in June were in poor condition and could not be used. Therefore, I lacked data for two months. A total of 271 fecal samples were collected and prepared for microhistological analysis (Table 1). Fecal pellets were identified in the field as pronghorn fecal pellets and placed in plastic ziploc bags. Fecal pellets were stored in a freezer at -9° C until all samples had been collected and were ready to be analyzed.

Fecal pellets were dried in an oven at approximately 30° C until completely free of moisture. Fecal pellets were then ground with a Wiley Mill until they passed through a 20 mesh screen. Five grams of each fecal pellet were used to determine fecal pH.

The Composition Analysis Laboratory in Fort Collins, Colorado used microhistological analysis to determine fecal composition of the remainder of the fecal pellets. In addition to using cellular configurations, size, and morphological characteristics to identify plant fragments, plants were also identified by using various cellular characteristics unique to different genera and species of plants. Cell structures such as cuticles, stomates, cell walls, asperites, glands, trichomes, silica cells, druses, crystals, starch grains, and silica-suberose couples were also used to identify plant fragments. Plant components of fecal pellets were determined and reported as a percent of the total sample. Based on plant descriptions by Stephens (1969), I classified fecal

Table 1. Number of fecal samples collected each month from June 1995 through July 1996.

Month	Number of samples collected
January	40
February	33
March	55
April	0
May	7
June	0
July	34
August	48
September	10
October	32
November	2
December	10

components as either graminoid, forb, or shrub.

All statistical analyses were performed by using the Statistical Analysis Systems (SAS) licensed to Emporia State University. Percentage data are usually non-normally distributed (Zar, 1996). I used the SAS UNIVARIATE procedure to test for normality. Because the data failed the test of normality, I ranked the data and then tested for differences in fecal components among seasons. I used an analysis of variance (ANOVA) to test for differences in the amount of each forage type (graminoid, forb, and shrub) found in the fecal pellets among four seasons. See Conover and Inman (1981) for a perspective on using parametric statistical tests on ranked nonparametric data. The SAS ANOVA procedure was used to calculate all the analyses of variance. I then used Bonferroni multiple comparisons to indicate which seasons had statistically different percentages of forage material (Rice, 1989).

Each season consisted of three months. The winter season began on December 1 and lasted until the last day of February. Fecal pellets obtained during the spring were collected between 1 March and 31 May. Fecal pellets collected in the summer were gathered from 1 July through 31 August. Fall fecal pellets were collected from 1 September through 30 November.

To illustrate changes in forage use among months and seasons, I calculated the mean for the amount of graminoids, forbs, and shrubs in fecal pellets. Similarly, I calculated the mean for each genus of forage used by pronghorn. A complete list of plants found in pronghorn fecal pellets can be found in Appendix 1.

I determined the spatial pattern of the most common forage type found in

pronghorn fecal pellets. I wanted to determine if inclusion of the particular plant taxa into the diet was a function of its relative abundance in the study area or if its inclusion into the diet was a result of some other factor such as overall forage quality. Because Rhus spp. was the most commonly found plant taxa in fecal pellets, I determined its spatial pattern on the study site. There are a variety of ways one can test for spatial patterns (see Ludwig and Reynolds, 1988; Rosenzweig, 1995). I chose to use the T-square distance sampling method, also called the T-square index of spatial pattern (Equation 1) (Diggle, 1983; Diggle et al., 1976; Ludwig and Reynolds, 1988).

$$\text{Eq. 1} \qquad C = \frac{\Sigma^{N}_{I}[\, x^{2}_{i}(x^{2}_{i} + {}^{1}/_{2}\, y_{i}^{2})]}{N}$$

Equation 1 was then used to calculate a C-value, the index of spatial pattern. If C is approximately 0.5, then the spatial distribution pattern is random. If C is less than 0.5, then the spatial pattern is uniform. However, if C is greater than 0.5, then the spatial pattern is clumped (Ludwig and Reynolds, 1988). In order to test if the C-value departed from 0.5 significantly, a Z-score was calculated by using Equation 2.

$$\text{Eq. 2} \qquad Z = \frac{C - 0.5}{(1/(12N))^{-1/2}}$$

The calculated Z-score from Eq. 2 was compared to the critical Z-score from a standard Z value table for a given α, which I set at 0.05.

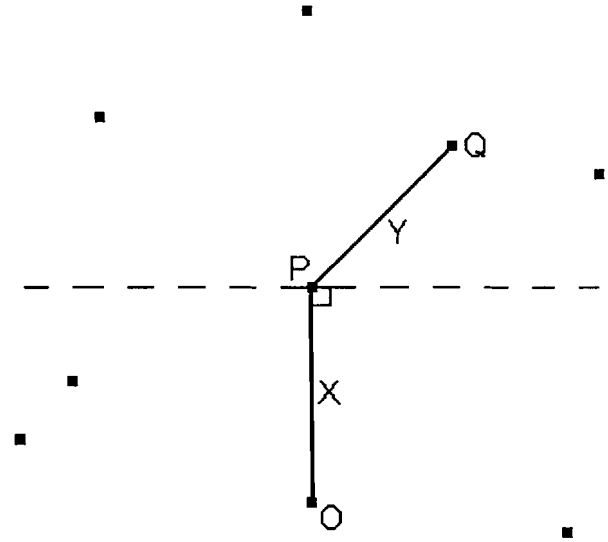
I constructed one 1-km transect and one 0.5-km transect, which ran in a north-south direction from randomly selected points on the study site. At 50-m intervals along each transect I searched 500 m to the west and 500 m to the east for Rhus spp.

When the nearest Rhus plant was encountered, I then initiated the T-square sampling method (Fig. 2).

To assess the nutritional quality of available forage, a variety of chemical analyses were done on plants collected during the summer and winter seasons. All randomly collected winter samples (n = 8) were collected in the month of January, and all but two randomly collected summer samples (n = 13) were collected in late July and August. The two randomly collected summer samples of forage, which were not collected in late summer (late July and August), were collected during the last week of June and the first week of July. Randomly collected forage was considered all the plant material in 0.5-m^2 quadrats near where pronghorn were observed grazing. The randomly collected forage was placed in a ziploc bag and frozen at -9° C until it was analyzed for nutritional quality. Fresh samples of Rhus spp. were collected during the month of August. Rhus spp. samples (n = 4) were collected and handled in a manner similar to the randomly collected forage samples. All nutritional analyses were done at Peterson Laboratory Inc., Hutchinson, Kansas. Randomly selected forage material was analyzed for the following: percent moisture content (MC), percent dry matter content (DC), percent crude protein (CP), percent acid detergent fiber (ADF), net energy lactation (NEL, KJ/kg), net energy gain (NEG, KJ/kg), net energy maintenance (NEM, KJ/kg), percent total digestible nutrients (TDN), percent calcium (Ca), and percent phosphorus (P).

The nutritional quality of Rhus spp. was determined by using the same analyses as that for randomly collected forage, with the addition of several minerals: aluminum (Al), cobalt (Co), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), percent

Fig. 2. T-square sampling distance. The distance from *P* to its nearest neighbor, *O*, in a 360° radius is *x*. The distance from *P* to its nearest neighbor, *Q*, in a 180° radius for individuals in the plane opposite of *O* is *y*.


Q
Y
P
X
O

potassium (K), percent sodium (Na), and zinc (Zn).

The major indicators of nutritional quality are CP, ADF, NEM, TDN, Ca, and P (Barrett,1979; Morison, 1951; Subcommittee on sheep nutrition 1985). Values for these analyses were compared seasonally among the two randomly selected forage types and Rhus spp. The data were not normal and failed a test of equal variances. Thus, I used a two sample Mann-Whitney test with $\alpha = 0.05$ to compare randomly collected summer forage values to randomly collected winter forage values. A separate Mann-Whitney test was used to compare each type of nutritional analysis.

I also compared the nutritional quality of randomly collected summer forage to that of summer Rhus spp. nutritional quality. Again, CP, ADF, NEM, TDN, Ca, and P were used to assess overall forage quality. I used a two sample Mann-Whitney test to examine differences between the two forage types. Mean values of nutritional quality are listed in Appendix 2.

RESULTS

Results of an ANOVA on the ranked data indicated significant differences among seasons for amount of grass in fecal pellets ($F = 94.89$, $P = 0.0001$, $df = 3, 267$, Table 2). The Bonferroni multiple comparison indicated that the amount of graminoid found in fecal pellets was different in all seasonal comparisons (Table 3).

Comparison between the different amounts of forbs found in fecal pellets suggested that there was a significant difference in the amount of forbs found in fecal pellets among different seasons ($F = 34.71$, $P = 0.0001$, $df = 3, 267$, Table 2). The results of the Bonferroni multiple comparison for different amounts of forbs in fecal pellets among seasons indicated differences in all seasonal comparisons except when spring was compared to fall and summer (Table 3).

Results from the ANOVA testing for differences in the amount of shrub in fecal pellets among seasons suggested fecal pellets contained different amounts of shrub material among seasons ($F = 196.85$, $P = 0.0001$, $df = 3, 267$, Table 2). A Bonferroni multiple comparison for shrub content of fecal pellets indicated significant differences across all seasonal comparisons (Table 3).

The number of taxa and amount of graminoids, forbs, and, shrubs in fecal pellets varied among seasons (Table 4). In regard to seasonal use, the number of taxa and amount of forb material found in fecal pellets were the most variable. Eleven taxa of forbs were found to have different abundances among seasons (Table 5). With the exception of Rhus spp., consumption of shrub taxa was relatively stable (Table 6). The amount of graminoids was also dependent on season. Pronghorn used the six taxa of graminoids

Table 2. Analysis of variance table of the amount of graminoid, forb, and shrub found in fecal pellets among the four seasons.

Forage type	df	F-value	Significance level
Graminoid	3, 267	94.89	0.0001
Forb	3, 267	34.71	0.0001
Shrub	3, 267	196.85	0.0001

Table 3. Results of Bonferroni multiple comparisons of graminoid, forb, and shrub taxa among seasons found in fecal pellets. Values are in percent composition of fecal sample.

Seasonal Comparisons	Difference between means		
	Graminoid	Forb	Shrub
spring-winter	28.11*	21.42*	5.23*
spring-fall	47.31*	1.26	42.62*
spring-summer	56.51*	10.74	66.55*
summer-fall	9.20*	12.00*	23.93*
summer-winter	28.40*	32.16*	61.32*
fall-winter	19.20*	20.16*	37.39*

(*) Denotes significant difference between seasons $\alpha = 0.05$, critical T = 2.658, d.f. = 267.

Table 4. Analysis of variance table of graminoid, forb, and shrub taxa with significantly different amounts of material found in fecal pellets among seasons.

Plant genera	F - value	Significance level
Amorpha spp.	4.37	0.005
Andropogon spp.	5.09	0.001
Antennaria spp.	9.05	0.0001
Asteraceae 1	7.11	0.0001
Asteraceae 2	3.76	0.011
Asteraceae seed	28.98	0.0001
Astragalus spp.	3.04	0.003
Bouteloua curtipendula	13.91	0.0001
Bouteloua gracilis	2.94	0.033
Carex spp.	12.11	0.0001
Ceanothus spp.	3.55	0.015
Chenopodiaceae seed	7.77	0.0001
Helianthus spp.	23.21	0.0001
Legume pod	11.36	0.0001
Medicago - Melilotus	7.16	0.0001
Panicum spp.	5.60	0.001

Table 4 (Continued). Analysis of variance table of grass, forb, and shrub taxa with significantly different amounts of material found in fecal pellets among seasons.

Plant genera	F - value	Significance level
Poa spp.	35.52	0.001
Rhus spp	222.01	0.0001
Sida spp.	4.62	0.003
Symphoricarpos spp.	3.33	0.02

Table 5. Results of Bonferroni multiple comparisons of individual forb taxa found in fecal pellets among seasons. Only comparisons which were significantly different at $\alpha = 0.05$ are reported.

Plant genera	Seasonal comparison	Difference between means
Amorpha	spring-winter	6.01 % composition
Antennaria	spring-fall	4.12 % composition
	summer-winter	5.54 % composition
Asteraceae 1	spring-summer	2.98 % composition
	spring-fall	4.53 % composition
	fall-winter	3.20 % composition
Asteraceae 2	spring-winter	0.77 % composition
Asteraceae seed	spring-winter	6.79 % composition
	summer-winter	7.71 % composition
	fall-winter	6.86 % composition
Chenopodiaceae seed	spring-fall	0.47 % composition
	summer-fall	0.47 % composition
	fall-winter	0.45 % composition

Table 5 (Continued). Results of Bonferroni multiple comparisons of individual forb taxa found in fecal pellets among seasons. Only comparisons which were significantly different at $\alpha = 0.05$ are reported.

Plant genera	Seasonal comparison	Difference between means
Helianthus	spring-fall	7.83 % composition
	spring-winter	10.59 % composition
	summer-winter	16.26 % composition
	fall-winter	18.42 % composition
Legume pod	spring-winter	1.72 % composition
	summer-fall	2.55 % composition
	summer-winter	2.90 % composition
Medicago - Melilotus	spring-winter	2.66 % composition
	summer-winter	2.90 % composition
	fall-winter	2.43 % composition
Sida	spring-fall	0.68 % composition
	summer-fall	0.65 % composition
	fall-winter	0.64 % composition

Table 6. Results of Bonferroni multiple comparisons of shrub taxa found in fecal pellets among seasons. Only comparisons which were significantly different at $\alpha = 0.05$ are reported.

Plant genera	Seasonal comparison	Difference between means
Ceanothus	spring-winter	1.63 % composition
Rhus	spring-summer	64.91 % composition
	spring-fall	40.05 % composition
	summer-fall	24.86 % composition
	summer-winter	61.94 % composition
	fall-winter	37.08 % composition
Symphoricarpos	summer-fall	0.15 % composition
	fall-winter	0.15 % composition

differently across seasons (Tables 4 and 7). Of the six taxa, the proportions of Bouteloua gracilis, B. curtipendula, and Andropogon spp. found in fecal pellets had the lowest degree of seasonal use.

Shifts in seasonal use were apparent when mean values of major components of fecal pellets collected in spring (Fig. 3), summer (Fig. 4), fall (Fig. 5), and winter (Fig. 6) were graphed. Spring diet of pronghorn was dominated by the graminoids, Poa spp. (32.3%) and Bouteloua spp. (19.1%). Helianthus spp. (13.5%) was the most abundant forb in fecal pellets, and Rhus spp. was the most commonly found shrub (6.5%). During the summer, Rhus spp. (71%) was the most commonly consumed forage material. Small amounts of the forb Helianthus spp. (7.8%) and the grass Bouteloua spp. (2.3%) were found in fecal pellets collected in the summer. Rhus spp. (46.5%) remained the most abundant forage material in fecal pellets collected in the fall. Bouteloua spp. (4.4%) and Andropogon spp. (3.9%) were the most abundant grasses found in fecal pellets collected in the fall. Andropogon spp. were the most abundant grasses in the tallgrass prairie and the fall season is the only season when Andropogon spp. made up greater than 3% of the total diet. The most abundant forbs found in fecal pellets collected in the fall were Helianthus spp. (5.7%) and Antennaria spp. (7.6%). Use of Antennaria spp. was highest in the fall, but its occurrence in fecal pellets decreased in winter. Forbs dominated the composition of fecal pellets collected in the winter. Helianthus spp. (24.1%) and Asteraceae seeds (7.9%) were the most abundant forbs. Bouteloua spp. (12.3%) and Poa spp. (10.6%) were the most commonly occurring grasses in winter fecal pellets. Rhus spp. (9.4%) was the most commonly consumed shrub. Appendix 1 is a complete listing

Table 7. Results of Bonferroni multiple comparisons of graminoid taxa found in fecal pellets among seasons. Only comparisons which were significantly different at $\alpha = 0.05$ are reported.

Plant genera	Seasonal comparisons	Difference between means
Andropogon	summer-fall	2.75 % composition
Bouteloua curtipendula	spring-fall	14.55 % composition
	spring-summer	16.22 % composition
	summer-winter	9.13 % composition
B. gracilis	summer-winter	0.89 % composition
Carex	spring-summer	2.13 % composition
	summer-fall	2.13 % composition
	summer-winter	3.77 % composition
Panicum	spring-winter	1.00 % composition
	spring-fall	1.04 % composition
	spring-summer	1.32 % composition

Table 7 (Continued). Results of Bonferroni multiple comparisons of graminoid taxa found in fecal pellets among seasons. Only comparisons which were significantly different at $\alpha = 0.05$ are reported.

Plant genera	Seasonal comparisons	Difference between means
	spring-winter	21.71 % composition
Poa	spring-fall	31.62 % composition
	spring-summer	32.24 % composition
	summer-winter	10.53 % composition

Fig. 3. Mean percentages of major components of pronghorn fecal pellets collected in the spring.

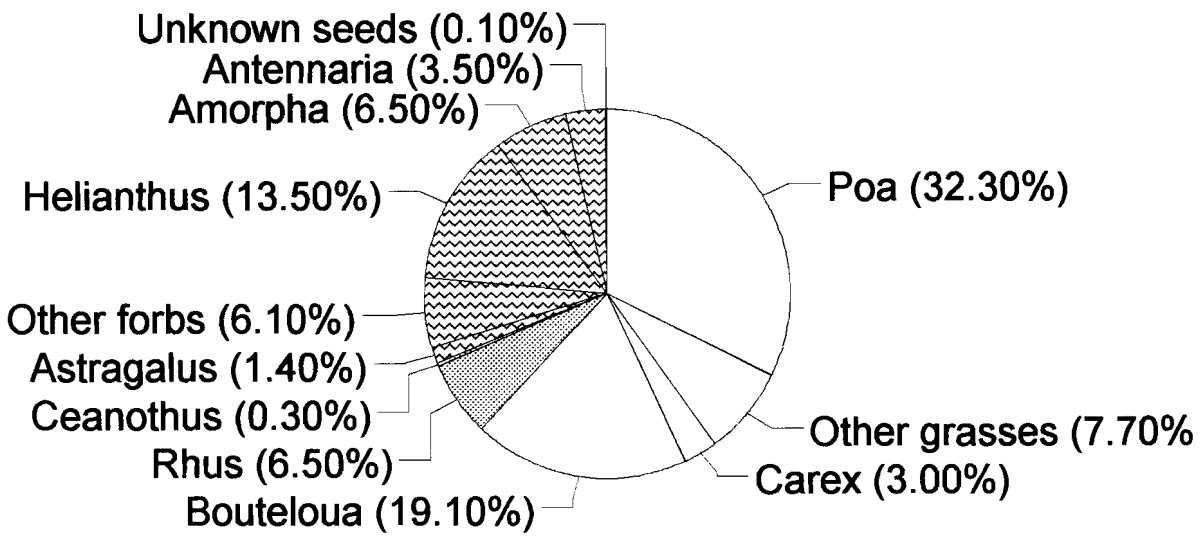

Unknown seeds (0.10%)
Antennaria (3.50%)
Amorpha (6.50%)
Helianthus (13.50%)
Other forbs (6.10%)
Astragalus (1.40%)
Ceanothus (0.30%)
Rhus (6.50%)
Bouteloua (19.10%)
Poa (32.30%)
Other grasses (7.70%
Carex (3.00%)

Fig. 4. Mean percentages of major components of pronghorn fecal pellets collected in the summer.

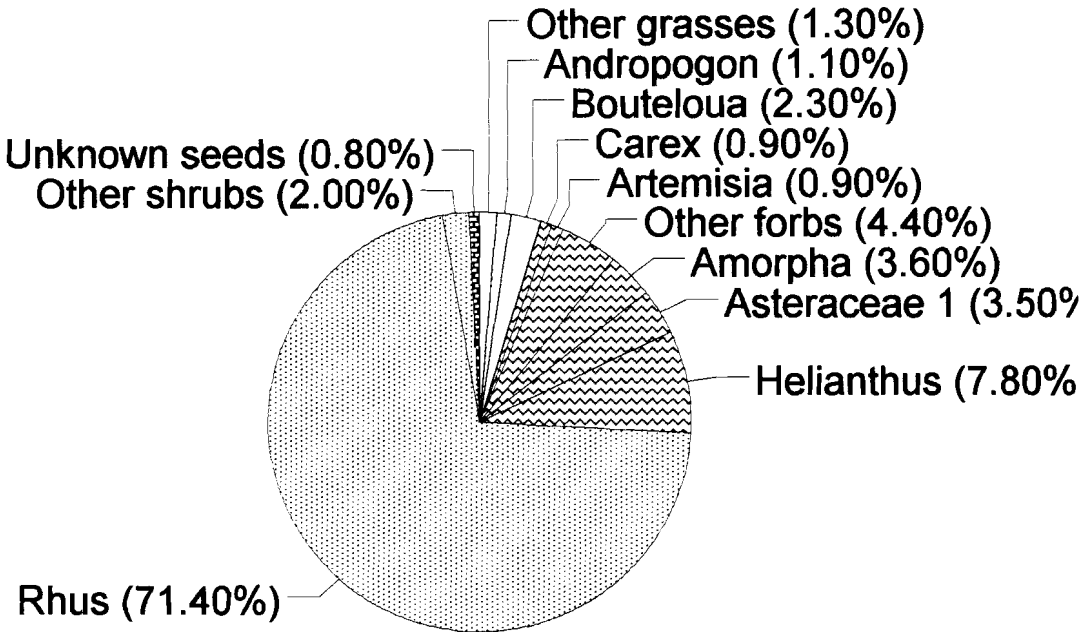

Other grasses (1.30%)
Andropogon (1.10%)
Bouteloua (2.30%)
Carex (0.90%)
Artemisia (0.90%)
Other forbs (4.40%)
Amorpha (3.60%)
Asteraceae 1 (3.50%
Helianthus (7.80%
Rhus (71.40%)
Other shrubs (2.00%)
Unknown seeds (0.80%)

Fig. 5. Mean percentages of major components of pronghorn fecal pellets collected in the fall.

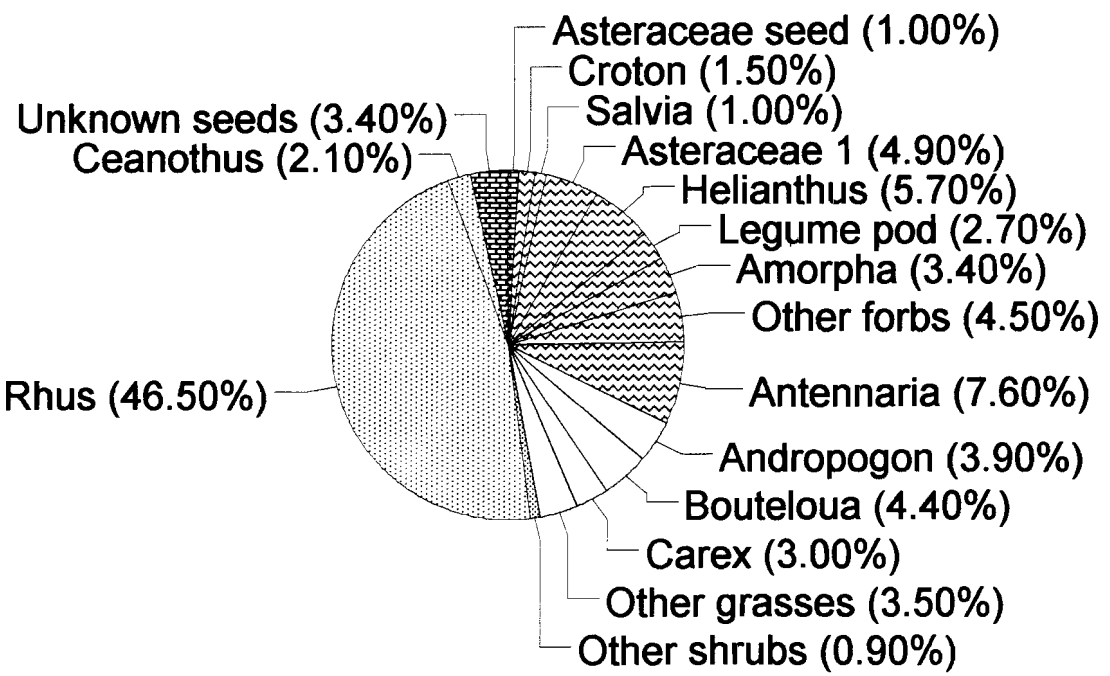
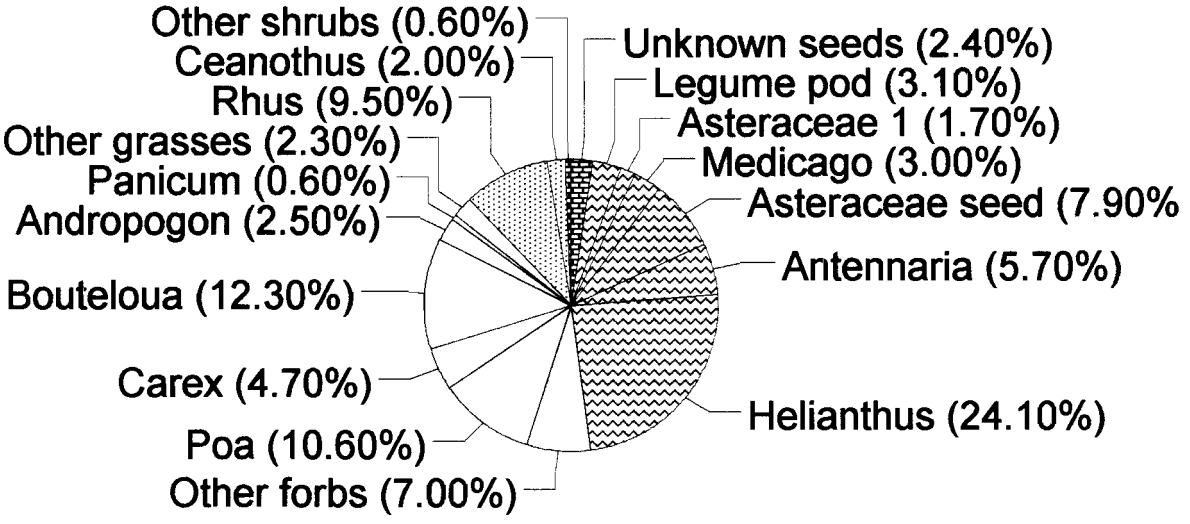

Asteraceae seed (1.00%)
Croton (1.50%)
Salvia (1.00%)
Asteraceae 1 (4.90%)
Helianthus (5.70%)
Legume pod (2.70%)
Amorpha (3.40%)
Other forbs (4.50%)
Antennaria (7.60%)
Andropogon (3.90%)
Bouteloua (4.40%)
Carex (3.00%)
Other grasses (3.50%)
Other shrubs (0.90%)
Rhus (46.50%)
Ceanothus (2.10%)
Unknown seeds (3.40%)

Fig. 6. Mean percentages of major components of pronghorn fecal pellets collected in the winter.


Other shrubs (0.60%)
Ceanothus (2.00%)
Rhus (9.50%)
Other grasses (2.30%)
Panicum (0.60%)
Andropogon (2.50%)
Bouteloua (12.30%)
Carex (4.70%)
Poa (10.60%)
Other forbs (7.00%)
Unknown seeds (2.40%)
Legume pod (3.10%)
Asteraceae 1 (1.70%)
Medicago (3.00%)
Asteraceae seed (7.90%
Antennaria (5.70%)
Helianthus (24.10%)

of the mean values of all forage material found in fecal pellets.

Forage selectivity did not appear to be dependent solely on availability. If it did, Andropogon spp. would have constituted a greater proportion of the diet throughout the year. Rather, forage selection seemed to track nutritional quality.

Using the Mann-Whitney test, I showed randomly collected summer forage was more nutritious than randomly collected winter forage. Though the analysis suggested that no difference occurred between crude protein levels in randomly collected winter forage and randomly collected summer forage ($Z = 0.07$, $P = 0.94$, $df = 1$), significant differences occurred in all other nutritional parameters excluding mineral analysis. The mean of winter CP was 5.85 % while the mean of summer CP was 7.22%. Results from the Mann-Whitney test indicated randomly collected winter forage contained significantly more fiber ($Z = 3.29$, $P = 0.001$, $df = 1$). The acid detergent fiber test indicated randomly collected winter forage had a mean fiber content of 47.47 %, while mean summer fiber content was 41.40%. A comparison of net energy maintenance showed randomly collected winter forage (mean NEM = 498.42 KJ/kg) contained significantly less energy for maintenance than randomly collected summer forage (mean NEM = 553.80 KJ/kg, $Z = -3.25$, $P = 0.001$, $df = 1$). Randomly collected summer forage contained significantly more total digestible nutrients (mean TDN= 56.18 %) than randomly collected winter forage (mean TDN = 51.39 %, $Z = -3.29$, $P = 0.001$, $df = 1$). Mineral analysis for Ca content indicated significantly greater amounts of Ca in the randomly collected summer forage than in the randomly collected winter forage. Calcium values were 0.96 % and 0.64 %, respectively ($Z = -3.04$, $P = 0.002$, $df = 1$). No significant difference existed between

summer P values (mean = 0.09 %) and winter P values (mean = 0.09%, Z = -0.18, P = 0.852, df = 1).

Comparison of nutritional quality of randomly collected summer forage to Rhus spp. collected in the summer showed a trend similar to the comparisons of randomly collected summer forage to randomly collected winter forage. Using the Mann-Whitney test, I showed that there was no significant difference in crude protein levels of randomly collected summer forage (mean CP = 7.22%) and summer Rhus spp. samples (mean CP = 9.6 %, Z = 1.64, P = 0.100, df = 1). Summer Rhus spp. samples contained significantly lower amounts of fiber, mean ADF = 18.44 %, than randomly collected summer forage samples, mean ADF = 41.40 % (Z = -2.88, P = 0.003, df = 1). Summer Rhus spp. samples contained higher NEM values than randomly collected summer forage (Z = 2.91, P = 0.003, df =1). The mean of summer Rhus spp. NEM was 821.48 KJ/kg and randomly collected summer forage mean score was 553.80 KJ/kg. Mean values for TDN of summer Rhus spp. and randomly collected summer forage were 77.64 % and 56.18 %, respectively. Rhus spp. samples contained significantly greater amounts of total digestible nutrients than randomly collected summer forage samples (Z = 2.88, P = 0.003, df = 1). Comparisons of Ca and P levels also indicated that Rhus spp. samples were of higher quality. Mean values of Ca in Rhus spp. equaled 1.33 %, while values for randomly collected summer forage were 0.96% (Z = 2.32, P = 0.02, df = 1). Mean phosphorous values for Rhus spp. were 0.16 % and 0.09 % for randomly collected forage (Z = 2.67, P = 0.007, df = 1). Appendix 2 is a complete list of forage quality.

To determine if the available forage contained adequate amounts of CP, NEM,

TDN, Ca, and P to meet daily requirements for maintenance, I converted NEM values to a measure of KJ/day. After the conversion process, I was able to compare nutritional value of the forage to the estimated nutritional requirements of pronghorn derived from the nutritional requirements of sheep (Subcommittee on sheep nutrition, 1985). I used the mean values of CP, NEM, TDN, Ca, and P to make comparisons between daily nutritional requirements and the nutritional quality of available forage material. Pronghorn could obtain sufficient amounts of NEM, Ca, and P in all seasons (Table 8). Daily requirements of TDN could nearly be met in winter. During the winter, pronghorn seemed to have no access to a forage type with adequate amounts of CP. Thus, pronghorn selected forage with high protein levels or the estimated requirement of CP was greater than the actual amount of CP required for pronghorn.

Analysis of the spatial distribution pattern of Rhus spp. was determined by using the T-square index of spatial pattern. During the summer the calculated C value for Rhus spp. on the study site was 0.641. The Z-score was significantly larger than 0.5 (Z_{cal} = 1.3717, Z_{tab} = 0.085). Thus, Rhus spp. had a clumped spatial distribution.

Table 8. Estimated nutritional requirements for pronghorn and the mean nutritional quality of randomly collected winter and summer forage, and summer Rhus spp.

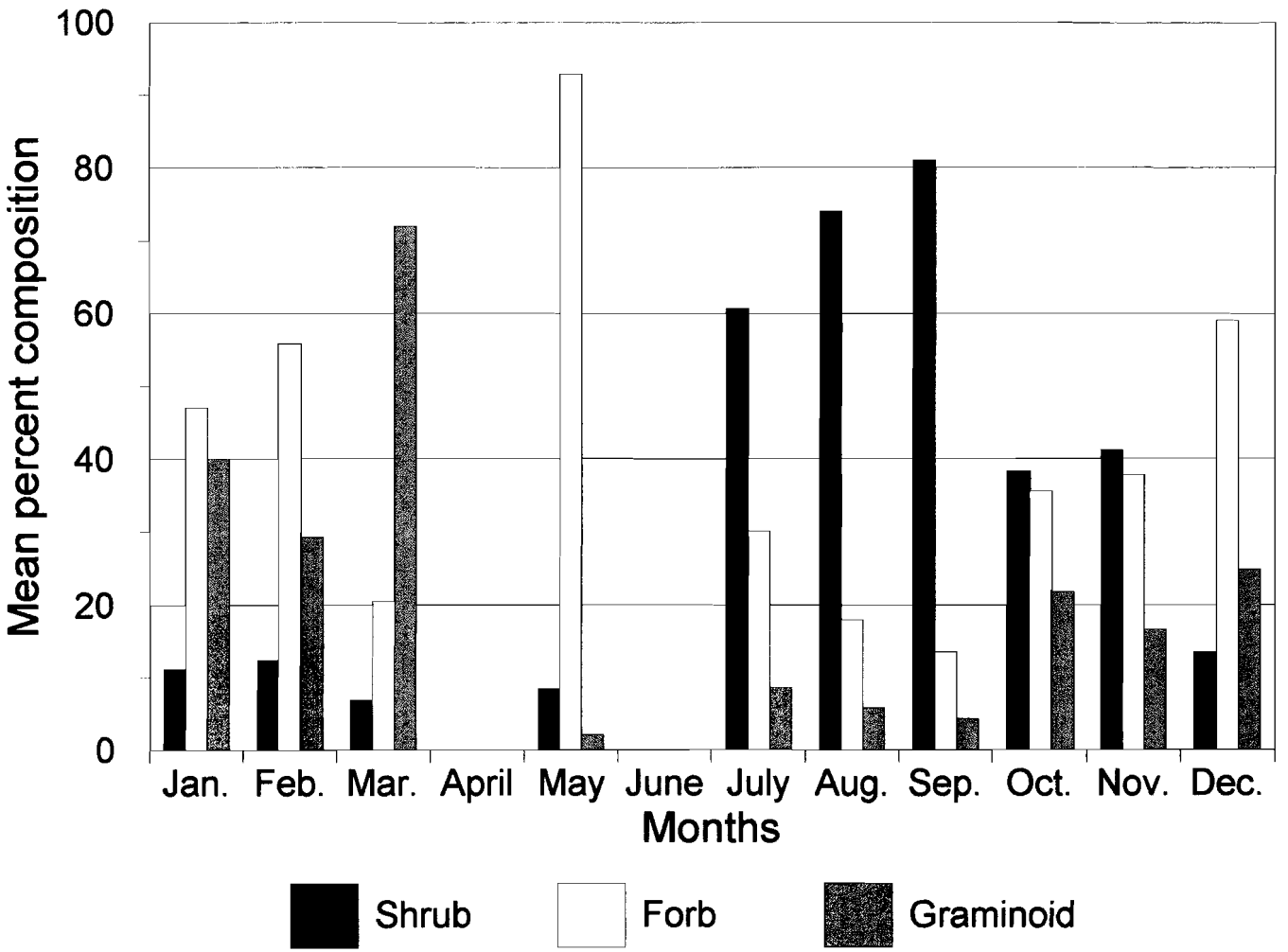
Nutrient	Daily requirement	Winter range	Summer range	Summer Rhus spp.
CP	9%	5.8%	7.2%	9.6%
NEM	4538.49 KJ/day	4521.74 KJ/day	5024.16 KJ/day	7452.50 KJ/day
TDN	55%	51%	56%	77%
Ca	0.2 ppm	0.64 ppm	0.96 ppm	1.33 ppm
P	0.2 ppm	0.09 ppm	0.09 ppm	1.65 ppm

DISCUSSION

The diet of pronghorn, which appeared to be determined by the nutritional value of available forage, varied seasonally. During the spring, graminoids were the most abundant forage type found in fecal pellets (Fig. 7). Forbs were the second most abundant forage type found in fecal pellets followed by shrubs. During the spring, graminoids were mostly fresh shoots and leaf growth. They contained relatively large amounts of protein, relatively low amounts of silica, and tannin. Conversely, forbs and shrubs may contain increased levels of tannin and additional woody material, which decreases the overall digestibility of the plants. As the summer progressed, the nutritional value of grass decreased. The digestibility of grasses decreased, which is indicated by the inflated ADF value with a mean of 47.4%. The amount of crude protein dropped to a mean of 5.8% (Table 8). As the amount of graminoid found in fecal pellets decreased to about 6%, the amount of shrub increased (73%). This increase can be explained by the high crude protein values of Rhus spp., the most commonly consumed shrub, and its relatively high digestibility score (mean values CP = 9.6 %, ADF = 18.44 %). When comparing the overall nutritional quality of randomly collected forage, which included forbs as well as grasses, to the nutritional quality of Rhus spp., Rhus spp. contained higher quantities of nutrients, minerals, and was easily digested, as indicated by the lower amount of fiber.

The amount of forbs found in fecal pellets was relatively stable (Table 3). The percent of forbs found in pronghorn fecal pellets in the tallgrass prairie never dropped below 20%. The nutritional quality of forbs may be relatively stable, but secondary plant

Fig. 7. Monthly mean percent composition of pronghorn fecal pellets categorized as graminoids, forbs, or shrubs.


100
80
60
40
20
0
Mean percent composition
Jan.
Feb.
Mar.
April
May
June
July
Aug.
Sep.
Oct.
Nov.
Dec.
Months
Shrub
Forb
Graminoid

compounds such as alkaloids and tannins may make forbs a less desirable forage when more succulent and digestible shrubs or graminoids are available (Morrison, 1951), which might explain seasonal forb use. Pronghorn may consistently use forbs because they are selective foragers and can choose the most digestible part of the plant to browse. Thus, forbs are included in their diet. Shrubs continued to be the dominant forage type in the fall, however, forb use increased from 20% in the summer to 32.3% in the fall (Table 3). The increase in the amount of graminoids found in the fecal pellets during the fall and winter can be attributed to the visibility of some remaining green graminoids such as Bouteloua spp. and Poa spp. The dominant graminoids such as Andropogon spp. have cured and are of little nutritional value. As winter approaches, the only available nutritious forage are the forbs and grasses. The amount of grasses and shrubs found in fecal pellets decreased, while the amount of forbs in fecal pellets increased to 52.5%. The change from intense shrub use to forb use may be a result of depletion of usable shrub resources, especially after leaves and stems are gone, and only hard to digest seeds remain (mean seed TDN = 44.34 %, mean seed ADF = 43.24 %).

The limited data that I have on nutritional value of available forage supports the concept that pronghorn diet is a function of the overall nutritional value of the available forage. When each season is looked at on a finer scale by using months as its units, pronghorn consumed the most digestible and nutritious types of forage. Though there was not a significant difference between the amount of CP found between randomly collected winter and randomly collected summer forage samples, a trend was apparent. The lack of statistical significance may be due to the time of the summer I collected the randomly

collected summer forage and the small sample size. Grass summer forage values for CP are usually around 10.00 % . However, in late summer CP values drop, and by late July CP content of grass can decrease to nearly 4.00 % CP (Morrison, 1951). Randomly collected summer samples may have had larger amounts of grass than randomly collected winter samples. Conversely, randomly collected winter forage may have been over represented by forbs because of grass death during the winter. Samples of randomly collected summer forage contained lower amounts of fiber than randomly collected winter forage. The forbs in the randomly collected winter samples were mostly woody stems, which would increase fiber content of the forage. As the amount of fiber increases in a sample, its digestibility decreases. Because of its high fiber content, randomly collected winter forage was less digestible than randomly collected summer forage. Net energy maintenance, which was measured in KJ/kg, represented the amount of energy supplied by a sample. The higher the NEM value, the more nutritious a food source. Randomly collected samples of winter forage had significantly lower NEM values than randomly collected summer forage, also suggesting that randomly collected summer forage (mostly graminoids and not usable by pronghorn) was more nutritious than its winter counterpart. The TDN value is another measure of digestibility. It represents the amount of total digestible protein, fiber, carbohydrates, and fat the forage contains. The larger the TDN value, the more total digestible nutrients a forage type contained. Again, the randomly collected summer forage contained significantly larger amounts of digestible nutrients than the randomly collected winter forage. When the forage types are listed in order of nutritional quality, summer Rhus spp., are the highest quality available forage followed by

randomly collected summer forage, and then randomly collected winter forage. Pronghorn selected Rhus spp. because it was the highest quality forage. During the winter, pronghorn did not use large quantities of Rhus spp., because highly digestible leaves and stems were absent. During the winter no other nutritious forage was available leaving pronghorn to forage on forbs and graminoids.

Unfortunately, I do not have data on the nutritional value of Rhus spp. during the winter, but comparisons of summer Rhus spp. samples to randomly collected summer forage samples imply digestibility and nutritional value are factors in food choice. Again, there was no significant difference in CP levels of summer Rhus spp. and randomly collected summer forage, but a trend toward higher CP values in Rhus spp. was evident. During the winter months the higher ADF value of grasses made Rhus spp. and possibly Helianthus spp. a more digestible choice for pronghorn. Rhus spp. samples also contained higher amounts of NEM and TDN than randomly collected summer forage. Mineral analyses also indicate that Rhus spp. contains more P and Ca than randomly collected summer forage. Rhus spp. samples contained moderate amounts of K, Mg, Mn, Na, Co, Cu, and Mg. Less than 0.3 parts per million of Mo was contained in the forage samples. The quantities of Fe and Al are high, but did not exceed the maximum amounts necessary to cause harm (Subcommittee on sheep nutrition, 1985).

The population of pronghorn that I studied in the Flint Hills was the only population of pronghorn reported to consume significant quantities of Rhus spp. Stephenson et al. (1985a) reported pronghorn used large quantities of forbs and shrubs. The most abundant shrub in the diet of pronghorn they studied was fringed sagewort

(Artemisia frigida). Pronghorn in my study consumed only minor amounts of sagebrush (Artemisia spp.), which was most likely Artemisia ludoviciana. In the Flint Hills, A. ludoviciana is a small forb, which is quite different from the large shrub like growth of A. frigida in western prairies, which resembles Rhus spp. in shape. After comparing the nutritional quality of Rhus spp. to other available forages, I discovered that it was the most nutritious and digestible food type present during half of the year. A decision to consume Rhus was not unfounded. My results supported research conducted by Barrett (1979), which indicated pronghorn may be selecting for high values of CP. Similarly, Smith and Malechek (1974) found that pronghorn selected forage with high amounts of P and protein.

The unique discovery of pronghorn use of Rhus spp. led to the investigation of the occurrence and spatial distribution of Rhus spp. on my study site. There were only two species of Rhus in the Flint Hills, Rhus aromatica and Rhus glabra. Freeman and Hulbert (1985) listed the occurrence of R. aromatica as scarcely distributed on rocky slopes of the Konza Prairie Research Natural Area, which is located in the Flint Hills. The occurrence of R. glabra varied from scarce to frequent on rocky slopes and uplands (Freeman and Hulbert, 1985). The clumped distribution of Rhus spp. on Konza Prairie was similar to the clumped distribution of Rhus spp. on my study site. During my investigation of Rhus spp. spatial pattern, I discovered that there was more Rhus aromatica than I had expected, as well as dense patches of Rhus glabra. I did not quantify the amount of Rhus spp. on the study site other than determine it had a clumped distribution. Rhus spp. patches were limited to rocky outcrops with exposed rocks and little surface soil, or near stream banks.

During the summer and fall, pronghorn foraged selectively for Rhus spp., but during the winter and spring, pronghorn selected for graminoids and forbs. Though I did not analyze any observational data, anecdotal evidence also suggests pronghorn selectively used Rhus spp. During my study, I observed pronghorn frequenting upland areas where patches of Rhus spp. were located. Additionally, Simpson (1992) and Rothchild (1993) reported pronghorn to use upland prairies.

The most commonly used forb, Helianthus spp. also seemed to have a clumped distribution. Helianthus annuus was considered scarce on disturbed lowland habitats of Konza Prairie, however, Helianthus tuberosus was considered common along a stream of the original Konza Prairie (Freeman and Hulbert, 1985). Even though the occurrence of Helianthus spp. varied, heavy use of Helianthus spp. and the avoidance of a common forb such as Artemisia ludoviciana, which was common throughout upland prairie, also suggested that pronghorn foraged selectively. Furthermore, my data may under represent the use of Helianthus spp. by pronghorn. It is possible that some plant material identified as Asteraceae 1 may be a Helianthus spp. I chose not to lump Asteraceae 1 and Helianthus spp. together because of the possibility that other genera of Asteraceae were included in the Asteraceae 1 category. Because both Helianthus spp. and Asteraceae 1 are forbs, the results of the ANOVA were not affected. The seasonal use of forbs, especially Helianthus spp., and the reported variability of Helianthus spp. occurrence in the tallgrass prairie, further suggests that pronghorn are foraging selectively in the tallgrass prairie and may choose to use a forage type based on its nutritional quality and digestibility.

Andropogon spp. were by far the most abundant species of grass in the tallgrass

prairie (Freeman and Hulbert, 1985; Horak, 1985). Pronghorn use of Andropogon spp. was limited. However, pronghorn used large amounts of Poa spp., which is generally listed as an uncommon plant in the tallgrass prairie. Freeman and Hulbert (1985) listed Poa pratensis as rare on upland prairies and disturbed habitats throughout the prairie. Pronghorn were foraging selectively because the major components of their diet were listed as uncommon in the tallgrass prairie. Inclusion of a plant in the diet of pronghorn was not solely dependent on its overall abundance. I suggest nutritional quality of a specific plant is an important factor for inclusion into pronghorn diet.

The diet of pronghorn in the tallgrass prairie was slightly different than the diet of pronghorn in the short and mixed-grass prairies (Table 9). Stephenson et al. (1985a) reported pronghorn in New Mexico consumed 5% grass, 36% forbs, and 59% shrubs in the winter. Spring diets during 1981 consisted of 8% grass, 48% forbs, and 44% shrubs (Table 9). Differences in diet were apparent when the winter diet of pronghorn in the tallgrass prairie was compared to the winter diet reported in the New Mexico study because pronghorn in the tallgrass prairie consumed more graminoids and forbs, 33% and 52%, respectively. Similarly, the population of pronghorn that I studied consumed considerably more graminoid during the spring (62.1%) than pronghorn in New Mexico. Summer diet of pronghorn in the New Mexico study consisted of 68% forbs, 27% shrubs, and 4% grass (Stephenson et al., 1985a). I found that the summer diet of pronghorn in the tallgrass prairie consisted mostly of shrubs (73%), with little forb (16%), and graminoid (5%) use.

In the New Mexico study, fringed sagewort was the most frequently consumed

Table 9. Comparison of pronghorn diets from four different locations: the tallgrass prairie, New Mexico (NM), Wyoming (WY), and western Kansas (wKS). Data are given as percent of grass, forb, and shrub found in the diet. Late Spring = Lt. Spr., Early Summer = Er. Sum., and Late Summer = Lt. Sum. (WY, Medcraft and Clark, 1986; wKS, Sexson et al., 1981; NM, Stephenson et al., 1985a).

	Location of Study							
	Tallgrass Prairie				New Mexico			
Forage Type	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
Grass (%)	62	5	14	33	8	4	NA	5
Forb (%)	31	20	32	52	48	68	NA	36
Shrub (%)	6	73	49	12	44	27	NA	59

	Wyoming					Western Kansas		
Forage Type	Lt. Spr.	Er. Sum.	Lt. Sum.	Fall	Wint.	Spr.	Sum.	Wint.
Grass (%)	3.5	5.6	6.0	16.3	10.9	79	0	70.5*
Forb (%)	85.5	87.4	83	48.7	7.7	58.4	90.5*	25.5*
Shrub (%)	11	7	11	35	81.4	0	0	0

* denotes median of authors' value.

shrub in winter and spring. Wright's eriogonum (Eriogonum wrightii) was the most frequently used forb by pronghorn in the winter and spring. My study suggested little use of sagebrush, however, shrub use was still high because of the presence of Rhus spp. Similar to the New Mexico study, Helianthus spp. were a commonly eaten forb.

Pronghorn in the Awapa Plateau and at the Desert Experimental Range in Utah consumed mostly forbs and browse (shrubs), with little or no grass use (Smith and Malechek, 1974). During the summer (1 May - 20 September) on the Awapa Plateau pronghorn diet consisted mostly of browse and forb. I recalculated the mean composition of grass, browse, and shrub for the eight collection periods during the years of 1969 and 1970. Diet of pronghorn in the area consisted of 60% browse, 39.5% forb, and 0.5 % grass. Pronghorn on the Desert Experimental Range had a similar diet, which consisted of 75% browse, 24.5% forb, and 0.5% grass. Artemisia frigida and A. nova were the most common browse consumed (Smith and Malechek, 1974). The diet of desert pronghorn was different from the tallgrass prairie herd in the amount of grass consumed and the specific types of shrubs and forbs commonly found in the diet of pronghorn (Table 8).

Schwartz and Nagy (1976) investigated the diet of captive pronghorn in northeastern Colorado by counting the number of bites of a specific forage type pronghorn took during specific times. In a heavily grazed pasture, forbs made up of 51-87 % of the bites during April, June, and August (Schwartz and Nagy 1976). Similar to my study, pronghorn consumed more grasses during the spring and late winter (64-79% during March, October, and January). Shrubs were consumed throughout the year, but never exceeded 15% of the diet (Schwartz and Nagy, 1976). In the same study, the diet of three

wild herds of pronghorn were investigated by using fecal analysis. Though slightly different from the diet of the captive pronghorn, the wild herds consumed mostly forbs, limited amounts of shrubs, and only trace amounts of grass (Schwartz and Nagy, 1976). Both the captive and the wild herds consumed less grass, and exhibited a greater dependence on forbs than the pronghorn in the tallgrass prairie (Table 9).

Forbs constituted the major dietary item of pronghorn on surface mines in northeastern Wyoming (Medcraft and Clark, 1986). Late spring diets consisted of 11% browse, 85.5% forb, and 3.5% grass. During the spring, graminoids dominated the diet of pronghorn in the tallgrass prairie. Similar to the previously reported studies, Medcraft and Clark (1986) reported summer diet consisted mostly of forbs (early summer = 87.4%, late summer = 83%). Similar to pronghorn in the tallgrass prairie, shrub use increased during the fall, forb use decreased, and grass use increased (Medcraft and Clark, 1986, Table 9).

Sexson et al. (1981) investigated the foraging habits of pronghorn in western Kansas, and found that shrubs were a favored forage in the spring, summer, and fall. Winter wheat was selected in the late fall, winter, and early spring. Though the herd in the Flint Hills used substantially more shrubs when the western Kansas herd consumed forbs, both herds used grasses in the spring. Pronghorn in the tallgrass prairie consumed more "native" grass, e.g., Bouteloua spp., while the western herd consumed mostly winter wheat (Table 9).

Throughout the year, pronghorn appeared to be searching out and consuming the most digestible and nutritious forage available to them. Foraging in the selective manner that they did, suggested that pronghorn were meeting their nutritional requirements and

could therefore "afford" to forage for the "best" food types available. If pronghorn were not meeting there minimal nutritional requirements, I would have expected to find a wider variety of different forage types, with larger variation in forage quality within a season, and much lower values from the nutritional analysis of dietary components than occurred in my study. The estimated values of pronghorn nutritional requirements may be elevated, but if higher values are being met, then I can be confident that actual nutritional requirements are being met.

My conclusion that pronghorn were selective foragers in the tallgrass prairie agreed with studies conducted in other parts of their range. Barrett (1979) and Smith and Malechek (1974) suggested pronghorn selectively foraged for high quality forage. My conclusion is further supported by research done by Berger et al. (1983) and Schwartz and Nagy (1976) who reported pronghorn to be selective foragers when a preferred forage type was available, but had the ability to change their dietary intake to compensate for the lack of forbs and browse.

Based on my estimations of pronghorn nutritional requirements (Table 8), pronghorn appeared to be obtaining enough crude protein for maintenance while consuming summer Rhus spp. The available diet of randomly collected forage lacked adequate amounts of CP to meet estimated nutritional requirements. The available forage contained adequate amounts of energy (NEM), Ca, and P.

Though a tremendous body of work already exists detailing the diet of pronghorn, there is still a need for specific research investigating foraging behavior of pronghorn. Research should determine actual, rather than estimated nutritional requirements of

pronghorn. Few studies have investigated the habits of pronghorn in the tallgrass prairie (Eccles, 1995; Rothchild, 1993; Simpson, 1992). As reintroductions and range expansion occur, a concerted effort should be made to understand the role pronghorn play in the tallgrass prairie. Future research efforts should also generate hypotheses concerning the role of pronghorn in the tallgrass prairie prior to European settlement and investigate possible differences between current and historic populations. Future investigations should include: investigations of pronghorn interactions with bison or cattle, pronghorn use of sites disturbed by cattle, effects of pronghorn grazing on plant community structure, pronghorn as seed dispersers because of their ability to travel long distances, and investigations into which plant species germinate in pronghorn fecal pellets.

Future research should investigate the effects of pronghorn grazing on Rhus spp. population and invasion of the tallgrass prairie. Petranka and McPherson (1979) reported that woody invasion of the tallgrass prairie by bottomland forest trees only occurred when Rhus copallina was present. Furthermore, the number of trees in a 16-year-old field increased sharply after R. typhina became a dominant plant species (Werner and Harbeck, 1982). The increase in R. typhina was followed by a decrease in Agropyron repens and an increase in the abundance of Poa spp. Summer grazing of pronghorn on Rhus spp., in conjunction with a change in dominant grass species in Rhus patches, and early summer fires may have played a role in slowing woody invasion of the tallgrass prairie. Future research should explore the possibility that pronghorn may have played an active role in maintaining tallgrass prairie integrity prior to European settlement.

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CHAPTER 2

IDENTIFYING PRONGHORN FECAL PELLETS BY FECAL pH

ABSTRACT

I investigated the pH of fecal pellets collected from pronghorn (Antilocapra americana) in the tallgrass prairie of east-central Kansas. My study took place in the Flint Hills region of Chase and Lyon counties, Kansas. Fecal pellets were collected from June 1995 to July 1996.

The fecal pH of pronghorn in the tallgrass prairie was 8.12, which is slightly lower than fecal pH (8.66) of pronghorn from western populations. I also investigated the relationship of fecal pH to diet. Fecal pH did not change in regard to diet or season of the year. Pronghorn fecal pH was lower than reported values for mule deer (Odocoileus hemionus) fecal pH (9.12 and 8.80), but similar to the reported values of white-tailed deer (Odocoileus virginianus) fecal pH (8.11).

Fecal pH may be a useful technique for identifying fecal pellets. Differences in mule deer fecal pH and pronghorn fecal pH may be sufficient enough to use fecal pH as a secondary method of identifying fecal pellets. However, pronghorn and white-tailed deer fecal pH is too similar to use pH as the sole method of identifying fecal pellets.

Key words: pronghorn, (Antilocapra americana), fecal pH, Flint Hills, Kansas, tallgrass prairie

Running heading: Pronghorn fecal pH

Several investigators (e.g. Beale and Smith, 1970; Kessler et al., 1981; Leite and Stuth, 1995; MacCracken and Van Ballenberghe, 1993; Palmer and Cowan, 1979; Smith and Shandruk, 1979; Wasser, 1996; Ziegler et al., 1996) have used fecal analysis to investigate many aspects of mammalian biology including: diet, energy and nitrogen intake during digestion, digestive capacities, and reproductive status. Others have used fecal pH and bile acids found in fecal pellets to identify feces. Major et al. (1980) used bile acids recovered from bobcat (Lynx rufus) fecal samples to identify fecal pellets. Rollins et al. (1984) reported that fecal pH could also be used to identify fecal pellets coming from either blackbuck antelope (Antilope cervicapra), fallow deer (Dama dama), and white-tailed deer (Odocoileus virginianus) from sheep, goats, and sika deer (Cervus nippon). Johnson and Belden (1984) used thin layer chromatography and gas chromatography to correctly identify mountain lion (Puma concolor) and bobcat scat. Still other researchers have used fecal pH to identify fecal pellets from a variety of ungulates. In one study fecal pH was used to identify fecal pellets from the following mammals: elk (Cervus elaphus), mule deer (Odocoileus hemionus), mountain sheep (Oreamnos americanus), and mountain goat (Ovis canadensis) (MacCracken, 1980).

Similarly, fecal pH has been used to identify and distinguish pronghorn (Antilocapra americana) fecal pellets from mule deer, sheep, and elk (e.g. Beasom, 1982; Howard 1967; Johnson and MacCracken, 1978). Though using fecal pH as a sole method of identification may have some inherent problems, researchers agree that fecal pH can help minimize misidentification of fecal pellets.

The association between fecal pH and diet of pronghorn is poorly understood.

Previous studies investigating fecal pH of pronghorn reported different values for fecal pH. For example, Howard (1967) reported mean pH = 7.61, and Johnson and MacCracken (1978) reported a mean pH of 8.60. A third study supported the research of Johnson and MacCracken, indicating pronghorn fecal pH = 8.66 (Beasom, 1982). The differences in values for fecal pH may be a result of the following factors: age of fecal pellets, location of study area, soil type, and the types of available forage. If fecal samples were left in the field for varying amounts of time between the studies, hydrogen ions may have leeched out. Depending on where each study was done, mineral content of the soil could lead to different pH values because of leeching. Because fecal pellets from herbivores are predominately waste, water, and undigested plant material, fecal pH may be affected by the type of plants that are found in the animal's diet. If fecal pH is affected by diet, then fecal pH may change as diet changes. Though Nagy and Williams (1969) suggested that the diet of the animal may affect the relative proportions of acids in the rumen, they reported no difference in rumen volatile fatty acids (VFA) across age and sex of pronghorn. Thus, I suggest that if VFA was constant, the bacterial flora of the rumen was also constant over time. A consistent bacterial flora will maintain a constant pH of the rumen and the fecal pellets. Thus, fecal pH should be a reliable technique to help identify the type of fecal pellet.

My objective was first to determine the mean pH of fecal pellets collected from pronghorn in the Flint Hills of Kansas. I then tested for differences in fecal pH among the seasons in which it was collected. Because pronghorn diet changes among season, I could test differences in pH associated with diet. My final objective was to investigate

differences in fecal pH of pronghorn from other studies and determine if fecal pH is a reliable secondary means of identifying pronghorn fecal pellets. The herd in the Flint Hills is one of two herds of pronghorn in the tallgrass prairie. This provides unique research opportunities for comparison of fecal pH of pronghorn in the tallgrass prairie to conspecifics in the short and mixed-grass prairies.

STUDY AREA

Fecal pellets were collected from a herd of pronghorn on a 335 km^2 study area in the Flint Hills of east-central Kansas. My study site was located in southeastern Chase County and southwestern Lyon County, Kansas. See chapter 1 for details.

MATERIALS AND METHODS

Entire fresh pronghorn fecal pellets were collected from June 1995 to July 1996 on a monthly basis. During the month of April, I could not gain access to the study site because of flooding and I was unable to obtain any fecal pellets. Additionally, fecal pellets collected in June were in too poor of condition to be used. Therefore, I lack data for two months. Fecal pellets were visually identified in the field as pronghorn fecal pellets and placed in plastic ziploc bags. I stored all fecal pellets in a freezer at -9° C until the year long collection period was over. Then I placed the fecal pellets in a drying oven at approximately 30° C until all moisture had evaporated. I then ground the fecal pellets with a Wiley Mill until they could pass through a 20 mesh screen. I determined fecal pH by following methods similar to those described by Howard (1967), MacCracken (1980), and Rollins et al. (1984). I collected 271 fecal samples for compositional analysis and fecal pH analysis. However, I only used 268 samples to calculate fecal pH because three samples were not large enough for both types of analyses. The three small samples were sent for microhistological analysis only. Five grams of fecal material were separated from each of the 268 usable fecal pellets. Each sample was dissolved in 25 ml of deionized distilled water. Samples were stirred for three minutes and then the pH was determined by using an Accumet pH meter 915 from Fisher Scientific.

To ensure that fecal pellets were in fact pronghorn feces, the fecal pH of each sample was then compared to values of pronghorn fecal pH that were reported in the literature (Beasom, 1982; Howard 1967; Johnson and MacCracken, 1978). I used the values reported by Beasom (1982) and Johnson and MacCracken (1978) as a baseline for

comparison because of similarities in methodology and results. I compared pronghorn fecal pH to reported values of mule deer pH to ensure that no deer fecal pellets were inadvertently collected and misidentified as pronghorn fecal pellets. I also compared pronghorn fecal pH to reported values of white-tailed deer.

To investigate if fecal pH changed with season and diet, I used analysis of variance and Bonferroni multiple comparisons to determine if fecal pH differed among seasons. If fecal pH changed with season a correlation analysis would be used to determine if a relationship existed between fecal pH and dietary composition.

RESULTS

Mean fecal pH of pronghorn feces was 8.12 with a standard deviation of 0.29. The value was slightly lower than reported values of mean fecal pH = 8.66 (Beasom, 1982) and 8.60 (Johnson and MacCracken, 1978) and higher than 7.61 reported by Howard (1967). Johnson and MacCracken (1978) reported mule deer fecal pH was 9.12. In a separate study MacCracken (1980) reported deer fecal pH to range from 8.5 to 9.1 depending on the age of the fecal pellets. Rollins et al. (1984) reported that fecal pH of white-tailed deer fed a diet of 16% crude protein commercial feed and alfalfa hay was 8.11 (Table 1).

The results of the analysis of variance suggested that fecal pH did not change with season ($F = 1.33$, $P > 0.2656$, $df = 3, 262$). Therefore, there was no association with fecal pH and diet.

Table 1. Mean pH of fecal pellets collected from deer (Odocoileus spp.) and pronghorn (Antilocapra americana).

Genus	Mean fecal pH	Studies
Antilocapra americana	8.12	My study
Odocoileus hemionus	9.12	Johnson & MacCracken (1978)
Odocoileus hemionus	8.8	MacCracken (1980)
Odocoileus virginianus	8.11	Rollins et al. (1984)

DISCUSSION

Variation in fecal pH within a species limits the usefulness of fecal pH as an identifying technique. The three previous studies each reported a different fecal pH for pronghorn (Beasom, 1982; Howard, 1967; Johnson and MacCracken, 1978). The fecal pH of pellets collected in the tallgrass prairie was only 0.48 less than the reported fecal pH of pronghorn in Johnson and MacCracken's (1978) study and 0.54 less than fecal pH reported by Beasom (1982). Though variation in fecal pH existed, the difference between previously reported values of pronghorn fecal pH and fecal pH of pronghorn in the tallgrass prairie was less than the difference between the fecal pH of pronghorn in the tallgrass prairie and previously reported values of mule deer pH. MacCracken (1980) reported mule deer fecal pH to be 8.80 with a standard deviation of 0.33. The difference between fecal pH of pronghorn from the Flint Hills and reported values of mule deer fecal pH was greater than three times the standard deviation of pronghorn fecal pH.

Differences in fecal pH were detectable when fecal pH results from my study were observationally compared to previously reported values of mule deer fecal pH. Differences between pronghorn fecal pH and mule deer fecal pH were also detected in the previous studies (Beasom, 1982; Howard, 1967; Johnson and MacCracken, 1978). I compared the fecal pH to reported fecal pH for mule deer as a second method of identifying fecal pellets (Table 1). My study is another example of slightly different values of fecal pH reported for pronghorn, but also indicates that the difference between mule deer and pronghorn fecal pH may be large enough to qualitatively separate the two fecal pellet types.

Though mule deer were considered rare in the Flint Hills, their associations with prairie systems and the availability of information in the literature allowed for qualitative comparisons between fecal pH. White-tailed deer are more common, but are often associated with edge habitat. Throughout the year long study, while observing pronghorn or searching for fecal pellets throughout the day, early morning, and at dusk, I observed only four white-tailed deer. Only one was observed in the open prairie frequented by pronghorn.

The limited usefulness of fecal pH as an identification technique was apparent when previously reported values of white-tailed deer fecal pH and pronghorn fecal pH were compared. The study done by Rollins et al. (1984) used 60 samples of white-tailed deer fecal pellets to determine fecal pH. They reported a standard error of 0.07 and a mean fecal pH of 8.11. Pronghorn in the tallgrass prairie had a fecal pH of 8.12. The difference in fecal pH of the two species is almost negligable. The degree of overlap between pronghorn fecal pH and white-tailed deer fecal pH is too great to accurately separate the two fecal types. However, in most areas where pronghorn occurred, white-tailed deer were not very common. Given that these two species are usually geographically separated and when in close proximity to each other, often use different habitats, misidentification of pronghorn and white-tailed deer fecal pellets should be minimal. Use of fecal pH as a means of identifying fecal pellets should be done so with caution, and is not applicable when attempting to separate white-tailed deer and pronghorn fecal pellets.

With the exception of pronghorn to white-tailed deer comparisons, comparison of

fecal pH appears to be a fairly reliable secondary methods of species identification. Fecal pH is a fast and inexpensive identification technique, which does not significantly compromise accuracy when done in conjunction with other methods of identification and when the data are interpreted with caution.

Why pronghorn fecal pH values are different from one study to the next is still undetermined. I suggest future research needs to investigate the role of microbial flora of the rumen in determining fecal pH. Differences in rumen bacteria from one population to the next may explain differences in fecal pH. Furthermore, the variability of fecal pH limits its usefulness as a sole identifying technique. Future research needs to be directed toward understanding variability in fecal pH and the relationship between fecal pH and diet.

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Appendix 1. Mean percent of graminoids, forbs, and shrubs found in pronghorn fecal pellets listed by season. Values are listed as percent of the seasonal diet. Taxa indicated with an (*) compose less than 1.0 % of the seasonal diet.

Forage type	Season			
Grasses	Spring	Summer	Fall	Winter
Agropyron	*	*	*	*
Andropogon	1.8	1.1	3.9	2.5
Aristida	*	*	*	*
Bouteloua curtipendula	18.5	2.3	3.9	1.4
B. gracilis	*	*	*	*
Bromus	3.4	*	1.1	12.1
Carex	3.0	*	3.0	4.7
Chloris	*	*	*	*
Eleocharis	*	*	*	*
Eragrostis	*	*	*	*
Muhlenbergia	*	*	*	*
Panicum	1.5	*	*	*
Poa	32.3	*	*	10.6
Schedonnarus paniculatus	*	*	*	*
Sporobolus	*	*	*	*

Appendix 1 (Continued). Mean percent of graminoids, forbs, and shrubs found in pronghorn fecal pellets listed by season. Values are listed as percent of the seasonal diet. Taxa indicated with an (*) compose less than 1.0 % of the seasonal diet.

Forage type	Season			
Grasses	Spring	Summer	Fall	Winter
Tridens	1.5	*	*	*
Forbs				
Achillea	*	*	*	*
Amorpha	6.5	3.6	3.4	*
Antennaria	3.5	*	7.6	5.7
Artemisia ludoviciana	*	*	*	*
Asteraceae 1	*	3.5	4.9	1.7
Asteraceae 2	*	*	*	*
Asteraceae flower	*	*	*	*
Asteraceae seed	1.0	*	1.0	7.9
Astragalus	1.4	*	*	*
Boraginaceae	*	*	*	*
Chenopodiaceae	*	*	*	*
Chenopodiaceae seed	*	*	*	*

Appendix 1 (Continued). Mean percent of graminoids, forbs, and shrubs found in pronghorn fecal pellets listed by season. Values are listed as percent of the seasonal diet. Taxa indicated with an (*) compose less than 1.0 % of the seasonal diet.

Forage type	Season			
Forbs	Spring	Summer	Fall	Winter
Comandra	*	*	*	*
Croton	*	1.4	1.5	1.0
Draba	*	*	*	*
Evolvulus	*	*	*	*
Gaura	*	*	*	*
Helianthus	13.5	7.8	5.7	24.1
Legume pod	1.3	*	2.7	3.1
Malvastrum	*	*	*	*
Medicago - Melilotus	*	*	*	3.0
Oenothera	1.9	*	*	*
Phlox	*	*	*	*
Plantago	*	*	*	*
Salvia	*	*	1.0	*
Sida	*	*	*	*
Unknown Forb	*	*	*	1.3

Appendix 1 (Continued). Mean percent of graminoids, forbs, and shrubs found in pronghorn fecal pellets listed by season. Values are listed as percent of the seasonal diet. Taxa indicated with an (*) compose less than 1.0 % of the seasonal diet.

Forage type	Season			
Shrubs	Spring	Summer	Fall	Winter
Ceanothus	*	*	2.1	2.0
Rhus	6.5	71.4	46.5	9.5
Salix	*	*	*	*
Symphoricarpos	*	*	*	*
Unknown seeds	*	*	3.4	2.4

Appendix 2. Nutritional quality of randomly collected forage during the summer and winter, and the nutritional quality of Rhus spp. during the summer .

Rhus

Summer	Nutritional value
Crude Protein	9.6 % of forage
Acid Detergent Fiber	18.44 % of forage
Net Energy Lactation	738.41 KJ/kg
Net Energy Gain	516.88 KJ/kg
Net Energy Maintenance	821.48 KJ/kg
Total Digestible Nutrients	77.64 % of forage
Calcium	1.33 % of forage
Phosphorus	0.16 % of forage
Potassium	1.22 % of forage
Magnesium	0.16 % of forage
Sodium	0.02 % of forage
Aluminum	53.5 ppm
Cobalt	Less than 0.2 ppm
Copper	3.85 ppm
Iron	57.32 ppm
Manganese	20.05 ppm

Appendix 2 (Continued). Nutritional quality of randomly collected forage during the summer and winter, and the nutritional quality of Rhus spp. during the summer.

Rhus

Molybdenum	0.41 ppm
Zinc	39.23 ppm

Randomly Selected Forage

Summer

Crude Protein	7.22 % of forage
Acid Detergent Fiber	41.40 % of forage
Net Energy Lactation	461.50 KJ/kg
Net Energy Gain	258.44 KJ/kg
Net Energy Maintenance	553.80 KJ/kg
Total Digestible Nutrients	56.18 % of forage
Calcium	0.96 % of forage
Phosphorus	0.09 % of forage

Winter

Crude Protein	5.85 % of forage
Acid Detergent Fiber	47.47 % of forage
Net Energy Lactation	387.66 KJ/kg
Net Energy Gain	193.83 KJ/kg
Net Energy Maintenance	498.42 KJ/kg

Appendix 2 (Continued). Nutritional quality of randomly collected forage during the summer and winter, and the nutritional quality of Rhus spp. during the summer.

Randomly Selected Forage	
Total Digestible Nutrients	51.39 % of forage
Calcium	0.64 % of forage
Phosphorus	0.09 % of forage

Signature of Graduate Student

Signature of Major Advisor

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Signature of Author

June 16, 1998

Date

The diet of pronghorn (Antilocapra americana) in the tallgrass prairie

Title of Thesis

Signature of Graduate Office Staff Member

August 25, 1998

Date Received