SEASONAL FOOD HABITS OF MULE DEER AT THE CORONA RANGE AND LIVESTOCK RESEARCH RANCH, CENTRAL NEW MEXICO

BY

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in partial fulfillment of the requirements
for the Degree
Master of Science

Subject: Wildlife Science

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Las Cruces, New Mexico
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ABSTRACT

SEASONAL FOOD HABITS OF MULE DEER AT THE CORONA RANGE AND LIVESTOCK RESEARCH RANCH, CENTRAL NEW MEXICO

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Dr. Volney W. Howard, Jr. Chair

In September 1993 vegetation was sampled using the line point method, from 36 pairs of transects randomly located in the 2 major vegetation types of the ranch, pinyon-juniper woodlands and grasslands, to determine vegetational cover and composition and for habitat evaluation. Twelve species predominated by Juniperus monosperma, Bouteloua gracilis and Lycurus phleoides constituted 87.8% of the vegetational composition. ANOVA showed significant differences ($P<0.05$) in cover between the woodlands and grasslands for browse and grass covers. Three species differed between the vegetation types.

Microhistological analysis of fecal samples seasonally collected (summer 1993 through spring 1994) from 36 randomly distributed permanent pellet group

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transects was done to determine botanical composition of mule deer diets. The overall diets were predominantly browse (77%). Forbs (21%) and grasses (2%) comprised the remainder. Significant variations ($P<0.05$) were observed among seasons and between vegetation types for some species.

Most important (≥5%) browse species constituting the overall diets were Juniperus monosperma, Yucca glaucca, Pinus edulis, and Artemisia bigelovii. Higher ingestions of browse were found in fall and winter. These declined in spring and summer as the utilization of forbs increased.

Most forbs were ingested in small quantities. Gaura coccinea was the only forb regarded as one of the most important (≥5%) forage plants. The highest utilization of forbs was observed in spring and summer when they were most abundant. Grasses received consistently low utilization during all the seasons.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Mule deer (Odocoileus hemionus) population in New Mexico declined by 32% in eight years from 1967 to 1975. Most of this decline took place on private lands (Snyder 1976). The viability of mule deer populations on private commercial ranches, where resource allocation to an enterprise is dependent on the profits such enterprises generate, depends on their economic value to the ranchers. Ramsey (1965) and Simonds (1988) have reported commendable profits from fee hunting mule deer in Texas and Utah, respectively.

Although derivation of financial returns from fee hunting is relatively new in New Mexico (Knight 1985), it is becoming increasingly common (Morgan 1988). In view of this it is important that mule deer populations on private land be considered in grazing management plans.

At Corona Range and Livestock Research Ranch (CRLRR), fee hunting of mule deer has been an important and stable source of revenue for 6 years (Moore 1994). To sustain or enhance such income to CRLRR, impacts on mule deer numbers have to be considered when manipulating range habitats or allocating resources such as forage. Therefore, forage allocation and sound habitat manipulation dictates the need for knowledge of mule deer food habits.

In New Mexico food habits of mule deer have been studied in areas that differ in elevation, climate, vegetation and available forage (Anderson et al. 1965, Boeker et al. 1972, Hunt 1978, Mahgoub et al. 1984, Stephenson et al. 1985, Mahgoub 1989). Those studies showed that percent botanical composition of mule deer diets varied among localities. No data have been collected at New Mexico State University's CRLRR. Hence, this study was initiated in September 1993. The objectives of the study were:

1. To determine seasonal changes in botanical composition of mule deer diets at CRLRR.
2. To determine the relationship between seasonal changes in botanical composition of mule deer diets at CRLRR and availability of forage species they consume.

This study was funded by the McIntire-Stennis program and the New Mexico Agricultural Experiment Station. The principal investigator was Dr. V.W. Howard Jr., Professor, Department of Fishery and Wildlife Sciences, New Mexico State University.

STUDY AREA

Physiography and Drainage

New Mexico State University's 11,264 ha Corona Range and Livestock Research Ranch is located 22.5 km east of Corona in the Pecos River Basin along the boundary between Lincoln and Torrance Counties of central New Mexico (Fig. 1). The ranch is situated in the Great Plains Province whose main physical feature is the eastward-sloping eastern uplands (USDA 1970).

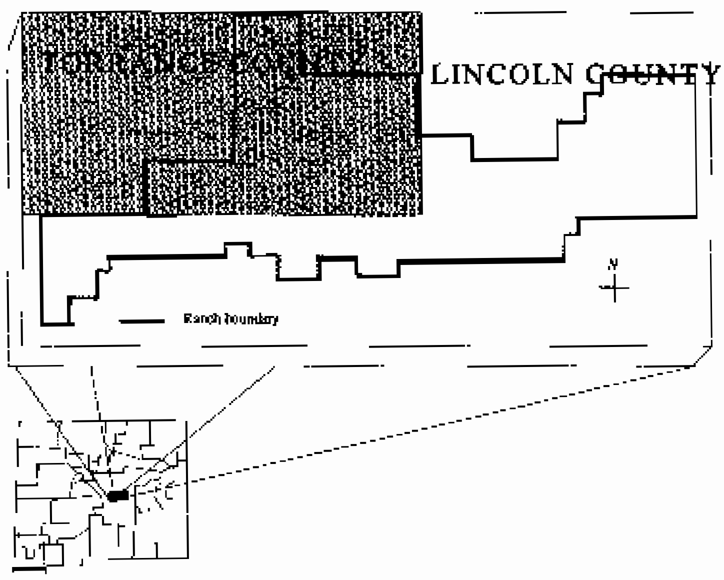

Fig.1. Location of New Mexico State University's Corona Range and Livestock Research Ranch, central New Mexico.

The topography is gently rolling hills and flat plains with a mean elevation of 1860 m. Steep rocky outcrops, sand dunes, mesas and limestone sink holes of various sizes occur in the ranch.

Most of the rain water resulting from the occasional thunderstorms quickly sink into the generally porous soil. Surface run-off from the slopes may drain along small 'arroyos' or galleys into the sink holes and depressions where it briefly provides surface water before evaporating or being absorbed into the soil. Hence, there are no permanent natural sources of surface water on the ranch. Livestock and wildlife drink from metal stock tanks located throughout the ranch.

Climate

The climate in this semiarid region is highly variable from one location to another and from year to year (Fig. 2). Precipitation originates from the Pacific Ocean and the Gulf of Mexico. While most winter precipitation is snow, summer precipitation, mainly between June and September, occurs as brief convectional thunderstorms. The mean annual precipitation on the ranch, based on rainfall data collected from the Headquarters and Johnson locations (1990-1993), was 314 mm and 219 mm, respectively. The mean monthly precipitation varied from 4 mm in January to 82 mm in August at the Headquarters and from 0 mm in January to 49 mm in August at Johnson. Based on monthly averages over a 30-year period the mean annual precipitation at Corona is 380 mm. Based on both the 4-year and 30-year data, more than 50% of the precipitation occurs from June to September.

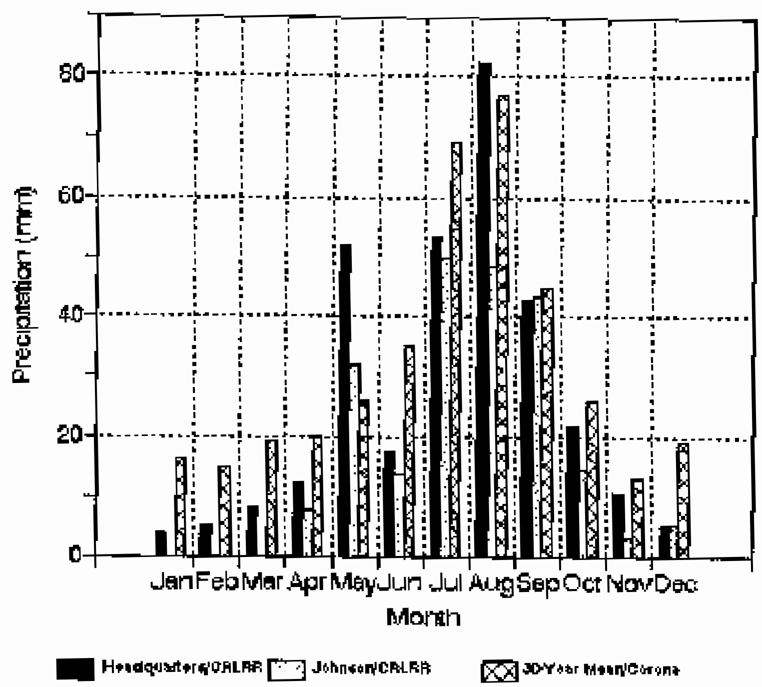

Fig. 2. Mean monthly precipitation at Headquarters and Johnson locations-CRLRR (1990-1993) and a 30-year average at Corona, New Mexico.

Mean daily temperatures are lowest in January (near 1°C) and highest in July (21°C). For about 30 days each year summer daytime temperatures are above 32°C. The average annual relative humidity is near 50%. Late winter and spring are the driest periods in the area during which the relative humidity usually falls to about

30%, but is frequently below 20% during the warmer periods of the day (USDA 1970).

The windiest period is late winter and spring when the average velocity approaches 16 km/hr. Occasionally, velocities exceeding 50 km/hr may be reached and maintained for several hours. Most of the strong winds are from a westerly direction though local topography may influence both its strength and direction (USDA 1970).

The average dates of the first frost in the area are October 20-30. Last killing frosts occur between April 20-30. There are approximately 160 frost-free days in a year (New Mexico State Planning Office 1973).

Soils

Soils in the area may be broadly categorized into: Kim-Pastura-Tapia loams, Tapia-Dean loams, Pinyon-Channery loams, Pastura-Harvey, Deama-Pastura and Davey-Pastura (Harrington 1992). Kim-Pastura-Tapia associations occur on slopes of 1-2% on the central to western portion of the ranch. This soil type is capable of absorbing moisture efficiently and it has a high storage capability.

Tapia-Dean loam associations are found on nearly level to strongly sloping (0-9%) soils formed over caliche on uplands. Tapia soils occur on crests of piedmont fans and they are moderately deep and most have a thin surface layer of brown loam. Dean soils occur on crests and side slopes of piedmont fans. They are gently to strongly sloping shallow soils layered over partly cemented caliche and normally have thin surface layer of light brownish gray loam (USDA 1970).

Pinyon-Channery loam associations occupy slopes of 3-20% on the southern portion of the ranch where they are associated with the pinyon-juniper woodland. These soils which are classified as brown, friable limy channery loams (Harrington 1992) have moderate granular structure. They have a surface layer of about 15 cm and a subsoil layer of about 10 cm. They also have a low water storage capacity and absorb moisture moderately.

Pastura-Harvey, Deama-Pastura and Davey-Pastura associations occur in the central pastures of the ranch. They range in depth from shallow to very shallow, are well drained and light in color.

Vegetation

The vegetation of CRLRR may be broadly grouped into grasslands and pinyon-juniper woodlands. Grasslands dominate the northern pastures. Harrington (1992) classified the grasslands vegetation into five communities: blue grama (Bouteloua gracilis); blue grama/purple threeawn/broom snakeweed (Bouteloua gracilis/Aristida purpurea/Gutierrezia sarothrae);

wolftail (*Lycurus phleoides*); sideoats grama (*Bouteloua curtipendula*); and the New Mexico feathergrass (*Stipa neomexicana*) (Table 1).

The woodlands constitute the main vegetation community of southern areas though understory growth of grasses and forbs may be present. In the open areas

Table 1. Five main grassland vegetation communities of CRLRR (Harrington 1992).

Community	Dominant Vegetation Type
Bogr	Blue grama (72%)
BoArGu	Blue grama (32%) Purple threeawn (15%) Broom snakeweed (20%)
Lyph	Wolftail (54%) Blue grama (12%)
Bocu	Sideoats grama (43%) Wolftail (9%) New Mexico feathergrass (9%)
Stne	New Mexico feathergrass (54%) Sideoats grama (11%)

small shrubs including *Yucca glauca*, *Opuntia imbricata*, *Quercus undulata* and *Rhus trilobata* may be present.

Land Use

Cattle grazing is the dominant form of land use, but sheep also graze the ranch. The ranch is also used as a livestock, range and wildlife research facility. Long-term research goals of the facility include examining ecological changes in the pinyon-juniper woodlands and the blue grama (Bouteloua gracilis) rangeland habitats, analyzing livestock and wildlife responses to these changes and examining the interactions between livestock grazing and wildlife with emphasis on mule deer. Other goals include reviewing management practices such as brush control and specialized grazing systems. Various species of wildlife including, but not limited to pronghorn (Antilocapra americana), jack rabbit (Sylvilagus spp.), cottontail rabbit (Sylvilagus spp.), porcupine (Erethizon dersatum), coyote (Canis latrans), several small mammal, reptilian and avian species occur on the ranch but current research focuses on mule deer. Fee hunting of mule deer has diversified the ranch's source of income.

MATERIALS AND METHODS

Pellet Group Transect Establishment

Permanent pellet group transects (36) were established (1989-1990) for the initial mule deer herd study at CRLRR. The transect locations (Fig. 3) and their directions were randomly chosen (Berry 1992). Ten 43m^2 permanent circular plots at 30.5 m intervals were established along each 274.5 m transect. The center of each plot was demarcated with a stake marked with transect and plot numbers. A plot was delineated by affixing a 3.7 m chain to the center stake.

Vegetation Transect Establishment

On the second and seventh plots, 30.5 m permanent vegetation transects were established along each pellet group transect. The plots and direction of these transects were randomly determined. The starting point of a vegetation transect was marked by a rebar stake 3.9 m from the center of the chosen plot. A second stake located slightly beyond 30.5 m from the first marked its end. Thus, 36 pairs of vegetation transects were established in association with the 36 pellet group transects.

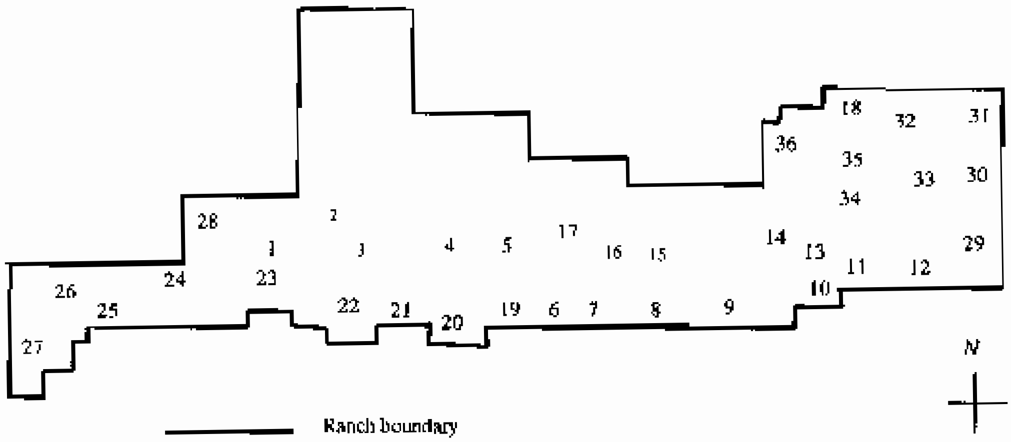

Fig. 3. Locations of pellet group and associated vegetation transects at CRLRR.

Pellet Group Sampling

Pellet samples were collected at the end of: summer (late September 1993), fall (early January 1994), winter (early April 1994), and spring (early July 1994) to represent mule deer diets during those seasons.

With the plot delineation chain stretched I walked in a clockwise direction and collected 5 pellets from every pellet group ($\geq$ 15 pellets) located within a plot. The remaining pellets were painted with Nel-spot tree marking paint to avoid resampling the following season. Pellets collected from all 10 plots of a transect were put in a marked polythene bag to compound a sample. In the food habits laboratory at New Mexico State University each sample was put in a marked paper bag, weighed and hot-air oven dried to a constant weight (Hinnant and Kothman 1988).

Habitat Inventories

To estimate forage availability and asses the ecological condition on the ranch, vegetation was sampled in September 1993. The line-point method (Pieper 1978) was used in conjunction with equipment described in (Howard 1966) for attaching the ends of the steel tape to the stakes and stretching it toughly. An observer walked along the stretched tape and recorded basal and aerial covers of all plant species, litter and bare ground directly hit by a line perpendicularly projected from each foot-mark (1-100) on the tape. Data collected were used to compute percentage cover and composition by species using the formulae:

$$\%\ \text{cover} = \frac{\text{No. of points scored on vegetation}}{\text{Total points}}$$

$$\%\ \text{composition} = \frac{\text{No. of points scored on a species}}{\text{Total points scored on vegetation}}$$

The soil conservation approach developed by Dyksterhuis (1949) was used to give an approximate evaluation of range condition in the grasslands.

Collection of Plant Material

In September 1993, leaves, twigs, flowers, and fruits of actively growing shrubs; whole shoots or parts of forbs and grasses reported in previous studies as constituting mule deer foods were collected. Plants commonly encountered along the pellet group and vegetation transects (Appendix A) also were collected and preserved for later identification.

Field identification of plants was done with the help of Elmore (1976), Gay (1984), Lebgue and Allred (1985), and Stubbendieck et al. (1992). Plants that could not be identified in the field were identified in the herbarium by Dr. Kelly Allred, NMSU Department of Animal and Range Sciences. Identified plants were weighed and each dried to a constant weight.

Preparation of the Mounting Medium

Aqueous Kaiser glycerine jelly was prepared from 52 ml of water in which 8 g gelatin was soaked for 1-2 hrs, then 50 ml glycerine and 0.01 g thimerosal preservative were added. The mixture was warmed in a water bath at 65-75°C for 10-15 minutes. The content was stirred until a homogeneous jelly was formed.

Preparation of Slides

Each dried plant specimen was ground in a Wiley mill through a 1-mm (20 mesh) screen reducing all fragments to a uniform size, and stored in marked bottles. Similarly, each pellet sample was ground and stored. Reference slides and diet sample analysis slides were prepared from these samples as in Sparks and Malechek (1968) and modified by Holechek (1982). Mounting was done with Kaiser glycerine jelly.

Three spatulas from a ground plant specimen or pellet sample were soaked in 30 ml of boiling water for 10 minutes, put in a 120-size sieve and washed with hot tap water for 3-5 minutes to remove dirt and fine plant particles. This subsample was then soaked in 20 ml bleach (sodium hypochlorite) for 5 minutes to remove plant pigments and stains. It was rewashed in the 120-size sieve with hot tap water and rinsed until the odor of the bleach disappeared. Excess water was removed from the sample by gathering it into a lump on the sieve, and squeezing water from it by firmly pressing with the back of the spatula. A small amount of the specimen was packed with the wooden end of a teasing needle into the 5mm wide hole in a lead slab pre-positioned on a clean microscope slide. This ensured equal amounts of the specimen were used in the preparation of all slides. Excess water was blotted from the slide to avoid formation of air bubbles between the microscope slide and cover slip.

Fourteen drops of light Kaiser glycerine jelly were added to the sample on the slide. Since the jelly thickens rapidly on exposure, it was quickly mixed with the specimen (using the teasing needle) until the fragments were uniformly distributed. The mixture was rapidly and evenly spread with the teasing needle across the slide to the size of a 24 mm X 50 mm glass microscope cover slip. The cover slip was lowered at an angle and dropped on the slide. Five slides were prepared and mounted for each plant species or diet sample, put on slide trays and stored in a slide cabinet to dry at room temperature for 2 weeks. Once the mounting jelly hardened the cover slip was sealed with a thin ring of clear nail polish and left to dry for a day. The dry slides were stored for reference or diet sample analysis.

Identification of Plant Fragments

Identification of plant species from fragments present in mule deer feces was based on the characteristics of epidermal tissues of those plants or plant parts (Crocker 1959, Davies 1959, Storr 1961). Those characteristics included: 1) trichomes (absent, present); 2) the type of trichome (Fahn 1982) (glandular, nonglandular, simple unicellular, multicellular, squamiform, shaggy, branched); 3) epidermal cell morphology and leaf venation pattern (Zyznar and Urness 1969); 4) types of stomatal complex (Stebbins and Khush 1961, Stace 1965); and 5) number, size, shape, and arrangement of subsidiary cells relative to the guard cells (Dabo et al. 1986); 6) cilica cells, ciloco-suberous cells, asperities (prickles, microhair, and macrohair). Metcalfe and Chalk (1950), Esau (1958), Cutter (1969), Hansen et al. (1971), and Howard and Samuel (1979) also were used in the identification of plant fragments.

Botanical Composition Estimation

To attain the accuracy required to estimate botanical composition of simulated and actual diets, the author was trained following Holechek and Gross (1982a). Two accuracy tests were conducted with a total of 6 simulated diets composed of various numbers and quantities of 21 species of shrubs, forbs and grasses unknown to the author. Five slides were prepared for each composited diet where the mean similarity index, using Kulczinsky's formula, was above 90%, and an approximately 1:1 ratio of actual:estimated botanical composition was observed (Appendix B). The simulated diets were compounded from plant species known to constitute the diets of mule deer and those commonly found in CRLRR.

Quantification of Diet Botanical Composition

Analysis of the slides followed a procedure similar to that of Sparks and Malechek (1968), while quantification was by the frequency addition procedure

(Holechek and Gross (1982b) using the formula: W = Y x 100 / Z where W = composition by species; Y = number of occurrences of a species; Z = total occurrences of all the species in the diet. Twenty microscope fields delineated by 100X-200X magnification (Holechek and Valdez 1985) were systematically located and read for each of the 5 slides. Thus, the number of slides and frequency observation were determined after Holechek and Vavra (1981). Fragments of each plant species observed in a field were identified using the epidermal characteristics. Tissues other than epidermal, as well as those trichomes not attached to epidermal tissues, were not regarded as being diagnostic of a specie's presence. From these criteria a species was recorded as present or absent in each field.

Statistical Procedure

Diet botanical composition was analyzed as a completely randomized design with repeated measures. Seasons (4) and vegetation types (2) were treated as the measurements and treatments, respectively. Pellet group transects (36) were regarded as replicates. Least Significant Difference (LSD) tests were conducted for means separation. General Linear Model procedure used ANOVA to detect variations between vegetation types, among seasons and vegetation type/season interaction.

When a significant ($P \leq 0.05$) F-test occurred for variations among seasons and seasons/vegetation type interactions. Diet data were pooled as follows: (a) by vegetation types within each season then segregated into forage classes and species to compare composition of each species in the 2 vegetation types and (b) across vegetation types and seasons for the overall compositions.

Vegetation data were analyzed as completely randomized design with factorial arrangement ANOVA. Vegetation types (2) were treated as factors and each pair of vegetation transects (36 pairs) was treated as a replicate. Level of significance was at $P \leq 0.05$.

RESULTS AND DISCUSSION

Habitat Inventories

Vegetation was sampled in September 1993 using the line point method to determine the availability of each forage species. Bare ground and litter comprised 68.5% of the cover. Covers of browse, forbs and grasses are presented in Tables 2 and 3. Similarly, Berry (1992) observed that bare ground and litter constituted 66% of the hits at CRLRR.

Except for forbs, mean percentages for all cover types (Table 2) differed (P<0.05) between vegetation types. Bare ground and grass covers were higher (P<0.05) in the grasslands than in woodlands. Litter and browse covers were positively associated and were lower (P<0.05) in the grasslands than woodlands. At the species level, Juniperus mononsperma, Xanthocephalum sarothrae, and Bouteloua gracilis differed (P<0.05) between vegetation types. ANOVA failed (P>0.05) to detect differences for the rest of plant species (Table 3).

Based on cover, an approximation of the range condition in the grasslands, following Dyksterhuis'(1949) approach, was rated high fair. Using forage value rating (preferred, desirable, or low) for the woodlands, Pieper (1995) assessed the understory forage as desirable.

Table 2. Percentage by cover types in the grasslands, pinyon-juniper woodlands and in all locations at CRLRR.

Cover type	Grasslands	Pinyon/juniper	Overall
Bare ground	61.6a[1]	49.1b	55.4
Forbs	2.3a	1.6a	2.0
Grass	21.0a	13.4b	17.2
Litter	6.5a	19.5b	13.0
Browse	8.6a	16.4b	12.4
Total cover	**100.00**	**100.00**	**100.00**

1 Percentage cover in the same row followed by different letters are significantly different ($P \leq 0.05$).

Browse

Shrubs, predominantly Juniperus monosperma, were less abundant ($P<0.05$) in the grasslands than in the woodlands. They mainly occupied the southern areas of the ranch (Harrington 1992) and a rocky outcrop in northwest Johnson and northeast North Johnson pastures in association with Pinyon-Channery loam soils.

In decreasing order of abundance (≥1%) browse species constituting vegetational cover and composition were: Juniperus monosperma, Xanthocephalum sarothrae, Yucca spp., Pinus edulis, and Quercus spp. The rest contributed traces (Table 3). Juniperus monosperma and

Table 3. Percent cover and botanical composition of forbs in the grasslands, pinyon-juniper woodlands and in all locations at CRLRR.

Cover type/ Species	Grasslands		Pinyon/juniper		Overall	
	cover	compo-sition	cover	compo-sition	cover	compo-sition
Browse						
Artemisia bigelovii	0.2a	0.5α	0.0	0.0	0.1	0.3
Juniperus monosperma	1.2a	3.7α	13.4b	43.4α	7.4	23.6
Fallugia paradoxa	t	t	t	t	t	t
Opuntia spp.	0.1	1.9	0.6	1.2	0.1	1.6
Pinus edulis	0.3	1.1	0.8	2.5	0.6	1.2
Quercus undulata	0.0	0.0	0.2	0.5	0.1	0.3
Rhus trilobata	0.2	0.5	0.0	0.0	0.1	0.3
Xanthocephalum sarothrae	4.5a	14.1α	0.7b	2.3α	2.6	8.2
Yucca spp.	1.6	5.0	0.7	2.3	1.2	3.7
Nolina microcarpa	t	t	t	t	t	t
Lycium pallidum	t	t	t	t	t	t
Miscellaneous browse	0.6	1.8	0.5	1.6	0.6	1.7
Total Browse	8.6b	27.0α	16.6a	52.3α	12.6	39.7
Forbs						
Astragalus spp	t	t	t	t	t	t
Eriogonum wrightii	0.0	0.1	0.2	0.4	0.1	0.3
Senecio longilobus	1.0	3.2	0.1	0.4	0.6	1.8
Psectis angustifolia	0.2	0.5	0.3	1.0	0.3	0.8
Salsola kali	0.0	0.1	0.1	0.4	0.1	0.3
Solanum elaeagnifolium	t	t	t	t	t	t
Sphaeralcea coccinea	0.1	0.2	0.2	0.5	0.2	0.4
Euphorbia micromera	t	t	t	t	t	t
Zinnia grandiflora	t	t	t	t	t	t
Ceratoides lanata	t	t	t	t	t	t
Unknown forb	0.6	1.9	0.4	1.2	0.5	1.6
Miscellaneous forbs	0.3	1.1	0.2	1.5	0.3	0.8
Total Forbs	2.3	7.2	1.5	4.9	1.9	6.1
Grasses						
Ambrosia spp.	t	t	t	t	t	t
Aristida spp.	2.3	7.1	1.3	4.0	1.8	5.6
Bouteloua curtipendula	2.0	6.1	0.9	3.0	1.5	4.6
Bouteloua eriopoda	t	t	t	t	t	t
Bouteloua gracilis	10.1a	31.8α	3.7b	11.9α	6.9	21.9
Bouteloua hirsuta	1.5	4.5	1.6	5.1	1.5	4.8
Eragrostis spp.	t	t	t	t	t	t
Eriopoda spp.	0.1	0.4	0.0	0.0	0.1	0.2
Heterotheca spp.	t	t	t	t	t	t
Hilaria jamesii	t	t	t	t	t	t
Lycurus phleoides	3.4	10.5	3.6	11.6	3.5	11.1
Muhlenbergia spp.	t	t	t	t	t	t
Muhlenbergia richardsonis	t	t	t	t	t	t
Panicum obtusum	t	t	t	t	t	t
Sporobolus cryptandrus	t	t	t	t	t	t
Thelesperma spp.	t	t	t	t	t	t
Portulaca spp.	t	t	t	t	t	t
Miscellaneous grass	1.8	5.5	2.3	7.3	2.1	6.4
Total Grasses	21.0a	65.8α	13.4b	42.8α	17.2	54.3
Grand Total	31.9	100	31.5	100	31.7	100

1 Within the same row values of cover followed by different Latin letters are significantly different (P<0.05).
2 Within the same row values for composition followed by different Greek letters are significantly different (P<0.05).
t=traces *Within the same row values of cover or composition not followed by any letter are not significantly different.

Xanthocephalum sarothrae coverage differed (P<0.05) between vegetation types, but other browse species did not (Table 3).

Juniperus monosperma was mainly observed in the steep slopes and rocky outcrops in the southern portion of the ranch. Xanthocephalum sarothrae was predominantly found in the low lying flat to gently sloping grasslands of the ranch. Percentage cover, composition and distribution of browse between vegetation types are presented in (Table 3).

Forbs

Data pooled across vegetation types showed that forbs constituted 1.8% of the ranch's cover. No single forb species sampled contributed >1% of the overall cover. Species that contributed most forb cover and composition were Senecio longilobus, Pectis angustifolia, Sphaeralcia coccinea, and unidentified forbs. Several other species each contributed traces to the overall cover (Table 3). ANOVA did not detect significant differences(P>0.05) between vegetation types for forbs.

Grasses

Grasses occurred mainly in the open, flat to gently sloping grassland areas where they comprised more cover (P<0.05) than in the woodlands. In descending order (>1%) grasses that contributed to overall cover were: *Bouteloua gracilis*, *Lycurus phleoides*, *Aristida* spp., *Bouteloua hirsuta* and *Bouteloua curtipendula*. Other grass species contributed only traces (Table 3).

Bouteloua gracilis contributed more (P<0.05) cover in the grasslands than woodlands because of the influence of *Juniperus monosperma* and *Pinus edulis* which dominated the woodlands. Jameson (1966) observed that *Juniperus* spp. and *Pinus* spp. influence the growth of *Bouteloua gracilis* by competing for water, shading, rainfall interception, litter and phytotoxic root exudates. No differences between vegetation types (P>0.05) was detected for other grass species (Table 3).

Because of annual variations in precipitation (Fig. 2) and their effects on forage production generalization of these results could be misleading. Powell and Box (1966) and Vavra and Sneva (1978) observed that variations in precipitation influence both plant production and availability for mule deer. Therefore, interpretation of these result should be done cautiously.

Mule Deer Diets

Data from microscopic analysis of fecal samples showed that 9 species varied among seasons, 3 differed between vegetation types (P<0.05) and exhibited vegetation type/season interactions. At the forage class level browse and forbs exhibited similar variations (Table 4). Hence, data were not pooled across vegetation types to seasons. At CRLRR the overall mule deer diets were predominantly browse (77%) followed by forbs (21%) and grasses (2%)(Table 4). While seasonal grass ingestion was relatively consistent, browse and forb utilization differed ($P<0.05$) between vegetation types (Table 4) and among seasons (Fig. 4).

Several studies conducted in New Mexico and elsewhere to determine food habits of mule deer generally agree with this study that browse constitutes a major part of the diets (Anderson et al. 1965, Boeker et al. 1972, Hansen et al. 1977, Hunt 1978, Kasworm et al. 1984, Mahgoub et al. 1984, Mahgoub et al. 1987). However, at the genus or species level, mule deer diets differ between localities, apparently depending on the availability of forage species and the preference of deer. Anderson et al. (1965), Boeker et al. (1972), and Mahgoub et al. (1987) reported Cercocarpus breviflorus as an important forage species in the Guadalupe Mountains, Fort Bayard and Fort Stanton, respectively. I did not find it occurring at CRLRR and did not observe it in deer diets there. On the other hand Juniperus spp. was selected more at CRLRR than in Anderson et al. (1965),

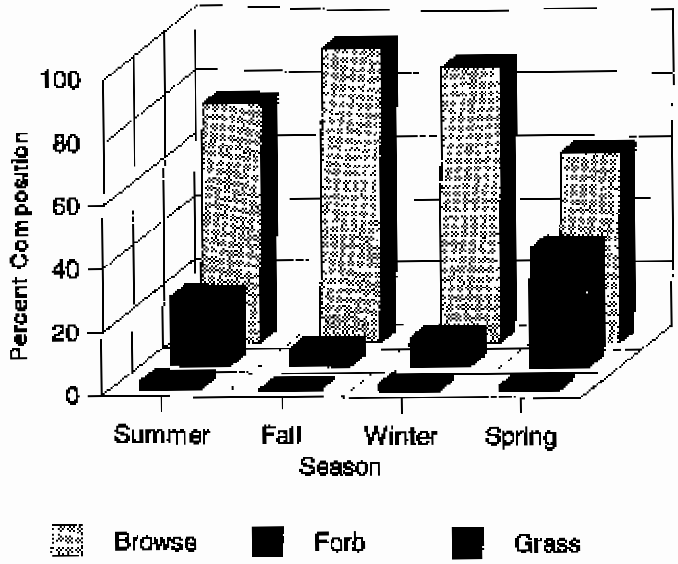

Fig.4 Trends in seasonal utilization of browse, forbs and grasses by mule deer at CRLRR, New Mexico (summer 1993-spring 1994).

Boeker et al. (1972) and Mahgoub et al. (1987) despite its occurrence in their study areas.

Summer Diets

Diversity of forage species comprising summer diets was second highest. Ten browse species, 22 forbs and small amounts of grasses were observed in mule deer feces during summer. Of these, 7 browse and 3 forb species contributed ≥1% (Table 4). Apparently this diversity occurred because the forages were still green and largely available, despite their advancing phenological stages.

In summer, the second lowest browse ingestion ($P<0.05$) after spring was observed, yet it dominated mule deer diets in both grasslands and woodlands with higher

Table 4. Seasonal botanical composition of mule deer diets by species comprising 1% or more of the diet in at least one vegetation type, and showing vegetation type/season interactions, CRLRR.

Forage species	Summer 1993 GL	Summer 1993 PJ	Fall 1993 GL	Fall 1993 PJ	Winter 1994 GL	Winter 1994 PJ	Spring 1994 GL	Spring 1994 PJ	Overall
Browse									
Artemisia bigelovii	3.1a[1]	1.5a	4.1a	2.4a	15.7c	5.9b	5.9a	5.6c	5.5
Juniperus monosperma	35.3c*[2]	53.4b*	57.9a*	50.8ab*	45.3c*	47.0b*	25.9c*	34.1c*	44.0
Opuntia imbricata	0.3a	0.1a	3.1a	0.7a	4.4a	1.9a	0.2a	0.1a	1.4
Pinus edulis	0.9b	5.2b	1.2a	13.1a	5.5a	15.0a	2.2b	3.2b	6.4
Quercus undulata	1.6a	7.3a	0.0*	15.8	0.2	0.0	2.2a	9.6a	4.5
Rhus trilobata	4.5a	0.0c	1.3	0.1	0.0	0.0	10.6b	3.4a	2.6
Xanthocephalum sarothrae	1.9a	3.5a	4.6a	2.3a	0.0	0.0	0.0	3.0	1.5
Yucca glauca	5.4a	6.6a	8.4a	3.7a	14.0b	18.9b	7.1a	5.8a	9.5
Miscellaneous browse	2.0	7.3	0.0	0.8	0.5	0.4	0.5	0.5	1.3
Total browse	**57.8b***	**85.3b***	**85.0a***	**95.5a***	**85.5a***	**89.0ab***	**54.6b***	**62.7c***	**77.2**
Forbs									
Draba spp.	0.1	0.0	0.0	0.0	1.0a	3.2a	0.8a	1.4a	0.9
Gaura coccinea	8.4b	4.4b	3.3a	0.1a	3.0a	1.2a	19.1c	10.7c	5.2
Helianthus petiolaris	0.7a*	0.5a*	2.2b*	0.0b*	0.1	0.0	0.2a*	0.1a*	0.5
Lesquerella spp	2.9a	1.0a	1.4a	1.8a	2.1a	1.7a	5.1b	10.6b	3.1
Marrubium vulgare	0.4a	0.4a	0.1	0.0	0.6a	1.3a	0.0	0.0	0.2
Melampodium leucanthum	1.0*	0.8*	0.0	0.0	0.0	0.1	0.5*	0.8*	0.3
Salsola kali	4.4a	0.7a	0.0	0.0	0.0	0.0	4.1a	4.4a	[illegible]
Sphaeralcea coccinea	1.2a	0.4a	2.0a	0.2a	0.2	0.0	1.5a	2.2a	1.0
Verbena bipinnatifida	0.5b	0.2b	4.4a	0.9a	0.0	0.0	0.1b	0.3b	0.9
Miscellaneous forbs	7.5	4.1	2.9	0.5	0.5	1.1	18.7	4.3	6.9
Total forbs	**38.1b***	**12.6a***	**14.3a***	**4.0a***	**11.5a***	**8.5a***	**42.4b***	**35.8b***	**21.2**
Grasses	**4.1a**	**2.1a**	**0.7a**	**0.5a**	**3.0a**	**2.5a**	**3.0a**	**1.5a**	**2.2**
Grand Total	**100******	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

1 Among seasons values in the same vegetation type and row followed by different Latin letters are different (P<0.05).
2 Within each season, values in the same row followed by different Greek letters are significantly different (P<0.05). *Values in the same row and vegetation type not followed by any letter have not been included in the ANOVA due to insufficient data.
**** Grand totals are rounded to the nearest whole number. GL= Grassland. PJ=Pinyon-juniper woodlands.**

amounts in the woodlands ($P<0.05$). Browse was succeeded in percent composition by forbs which showed the second highest ingestion after spring (Table 4), and constituted the second most important forage class in both vegetation types. Higher utilization ($P<0.05$) was noted in the grasslands because forbs were more abundant there than in the woodlands. Boeker et al. (1972) observed that availability influenced forage selection by mule deer.

Even though grasses composed the greatest percentage of cover, they were the least important food group, showing no difference between vegetation types (Table 4) and among seasons. Relative to their availability, mule deer apparently had little preference for grasses during summer. In order of decreasing importance (>1%) Juniperus monosperma, Yucca glauca, Quercus undulata, Xanthocephalum sarothrae and miscellaneous browse were observed in grassland and woodland diets. Juniperus monosperma comprised less percentage of the diets ($P<0.05$) in the grasslands than woodlands, and varied among seasons. Other forages did not differ between vegetation types (Table 4).

Gaura coccinea and miscellaneous forbs were important (>1%) in both vegetation types. Meleampodium leucanthus, Salsola kali and Sphaeralcia coccinea were important in the grasslands. Except for Meleampodium leucanthus forbs did not differ ($P>0.05$) between vegetation types (Table 4).

In general these results are consistent with those of Anderson et al. (1965) who used stomach content analysis to determine that during summer mule deer in the Guadalupe Mountains of New Mexico mainly ate browse (62%) and forbs (34%). Grasses were the least important forage class. They observed that Quercus undulata, Rhus trilobata, Juniperus spp., unidentified forbs, Dyssod paposa, Euphorbia spp. Trifolium spp. and Verbena wrightii were the most important food items.

Likewise Boeker et al. (1972), using stomach content analysis, reported that browse (58%) dominated mule deer diets during summer succeeded by forbs (42%). They reported that Quercus spp. and Garrya wrightii were used fairly consistently.

In a similar study Mahgoub et al. (1987), who used fecal analysis, found that during summer mule deer at Fort Stanton in south-central New Mexico, mainly ate browse (72.8%). Forbs and grasses constituted 25.3% and 1.8% of the diets, respectively. Important browse species there were: Quercus undulata, Rhus trilobata, Juniperus spp. Falugia paradoxa, Cercocarpus breviflorus and Pinus edulis.

Fall Diets

Fall diets were the least diverse including only 9 browse species, 11 forbs and small amounts of grasses. Of these, 8 browse and 4 forbs comprised ≥1% (Table 4). Advanced phenological stages of most forages during the season could explain the observed lack of diversity. Springfield and Reynold (1951), Beck (1975), and Holechek et al. (1982a) observed that cattle diets were more diverse when plants were young and growing, but fewer species were selected when plants reached maturity.

In fall, 21 of 36 transects were sampled. Five were sampled from grasslands and 16 from woodlands. Browse ingestion was higher ($P<0.05$) in fall than summer and spring, but its utilization during fall did not differ significantly from winter. Browse was ingested less in the grasslands ($P<0.05$) than woodlands (Table 4).

During fall, forbs utilization was greater in the grasslands than woodlands. It showed lower ($P<0.05$) ingestion in fall than any other season. Grass ingestion did not differ between vegetation types or among seasons. Generally forbs and grasses were least utilized in fall than any other season (Table 4). Apparently the ingestion of forbs decreased because forbs became more fibrous and less nutritious during fall. Holechek et al. (1982b) similarly attributed the decline in forb ingestion by cattle to the advancement of their phenological stages with grazing season. Conversely, because browse remained abundant its utilization was high.

In both vegetation types *Juniperus monosperma*, *Artemisia bigelovii*, *Xanthocephalum sarothrae*, *Yucca glauca* and *Pinus edulis* were important (≥1%) browse species ingested (Table 4). Of the forbs ingested, *Lesquerella* spp. was important in both vegetation types. The remaining species were utilized less (Table 4).

As in this study, Anderson et al. (1965) reported that in fall mule deer diets were predominantly browse (71.2%) followed by forbs (28.4%). They found that important dietary browse species were *Quercus undulata*, *Cercocarpus breviflorus* and *Juniperus* spp. They also observed *Linum* spp., unidentified forbs, lichen and *Melampodium leucanthum* as important food items.

Boeker et al. (1972) found that browse (86%) dominated mule deer diets during fall. Forbs and grasses were less important. Similarly, Mahgoub et al. (1987) showed that in fall and winter mule deer at Fort Stanton mainly ate browse (80.1%) followed by forbs (18.9%) and grasses (1.1%). They reported that *Yucca* spp. ingestion increased during this period and that the most important browse species eaten were *Quercus undulata*, *Juniperus* spp. and *Rhus trilobata*.

Winter Diets

During winter, mule deer diets had the second lowest diversity. At that time, the diet was comprised of 11 browse species, 18 forbs and small amounts of grasses. Of these, 5 browse and 3 forbs were important (≥1%).

In winter, the second largest browse ingestion in any season was observed in both vegetation types. Probably this high ingestion of browse in winter was because forbs and grasses were dry and new regrowth had not begun. Therefore, browse was still the most abundant succulent forage available to mule deer. For the same reason the second lowest forb consumption after fall was observed in winter. Grasses were important (≥1%) in both vegetation types. During winter no significant differences (P>0.05) were detected between vegetation types for all browse, forb and grass species (Table 4).

Important browse species (≥1%) from both vegetation types were: *Juniperus monosperma*, *Yucca glauca*, *Pinus edulis*, *Artemisia bigelovii* and *Opuntia imbricata* (Table 4). *Rhus trilobata* was apparently not ingested because the leaves were not available.

Draba spp., *Lesquerella* spp. and miscellaneous forbs were important diet components in both vegetation types. *Marubium vulgare* was only important in the woodlands. The rest of the forbs eaten constituted traces in both vegetation types. Grasses comprised >1% in both vegetation types (Table 4).

Like this study, Anderson et al. (1965) reported that during winter mule deer diets were predominantly browse followed by forbs. Grasses were the least important forage class. They found that of browse species ingested *Juniperus* spp., *Yuccas* spp. and *Cercocarpus breviflorus* were the most important. Important forbs were unidentified species, *Linum* spp., *Coreopsis tinctoria* and lichen.

Boeker et al. (1972) observed that in winter browse (94%) dominated Fort Bayard mule deer diets. They found that *Cercocarpus breviflorus*, *Quercus undulata* and *Garrya wrightii* were the most important browse ingested. As in this study they also observed that *Rhus trilobata* was not eaten during winter since the leaves were not available. Stephenson et al. (1985) found that mule deer winter diets in the San Antonio Mountains in north-central New Mexico were predominantly browse. Forbs and grasses were less important.

Spring Diets

Spring diets consisted of 11 browse species, 23 forbs and small quantities of grasses. Of these, 6 browse and 5 forbs constituted ≥1%. Spring diets were the most diverse. Previous studies have shown high diversities in diet composition because of the abundance of young growing forage plants (Springfield and Reynold 1951, Beck 1975, Holechek et al. 1982a).

In spring, browse ingestion was lower ($P<0.05$) than any other season yet, it dominated in both vegetation types with higher ($P<0.05$) compositions in the woodlands. This decrease was compensated for by increased forb ingestion which was higher ($P<0.05$) in spring than any other season. During spring grasses were important food items in the 2 vegetation types between which it did not differ statistically (Table 4).

Fresh growth of more nutritious forbs and grasses could explain the observed shift in favor of forbs. Dietz et al. (1958) and Anderson et al. (1965) suggested that tender parts of green growing plants have higher food value per unit volume to deer than dead plants and deer tended to select those nutritious and easily digested plants or their parts.

Juniperus monosperma, Quercus undulata, Rhus trilobata, Yucca glauca, Artemisia bigelovii, and Pinus *edulis* were important (>1%) browse forage in both vegetation types (Table 4). *Juniperus monosperma* ingestion was lower ($P<0.05$) in the grasslands than woodlands (Table 4).

Important forbs ingested in both vegetation types were: *Gaura coccinea*, *Lesquerella* spp., *Salsola kali* *Sphaeralcia coccinea* and miscellaneous forbs. *Draba* spp. was important in the woodlands. *Marubium vulgare* was not utilized in spring. The other ingested forbs comprised traces in both vegetation types. During spring no significant differences in use between vegetation type were observed for any forbs or grasses (Table 4).

These results are generally consistent with Anderson et al. (1965) who reported that in spring mule deer diets in the Guadalupe Mountains were predominantly browse (68%) followed by forbs (31%). They reported that *Quercus undulata* and *Yucca* spp. were the most important forages.

Similarly, Boeker et al. (1972) reported that during spring mule deer in Fort Bayard ingested mainly browse, but forb utilization increased since it was the period of their greatest availability.

Mahgoub et al. (1987) reported that during spring browse (84.1%) dominated mule deer diets at Fort Stanton.

Forbs (14.1%) and grasses (1.7%) were consumed to much lesser extent.

Possible Sources of Bias

Estimating botanical composition of the diets of herbivores such as mule deer by fecal analysis may be biased by several factors. Such factors include: differential digestibility of forage species (Anthony and Smith 1974, Dearden et al. 1975, Holechek et al. 1982), ease of identification of fragments of various forage species (Havstad and Donart 1978) and turnover rates among different dietary components. Presence of woody material (Holechek and Valdez 1985a, 1985b), observer error (Holechek et al. 1982), procedures used in calculating the diet botanical composition (Holechek and Gross 1982b) and sample preparation (Vavra and Holechek 1980) may also bias the estimates of herbivore diets.

Smith and Shandruk (1979) suggested that some species may become unidentifiable in the feces. They also observed fewer species in the intestinal and site feces than in the rumen, and that shrubs and grasses were overestimated while forbs were underestimated by fecal analysis. Slater and Jones (1971) observed that, in the course of digestion, some forage species became unrecognizable in the feces and others were so fragmented that they were overestimated.

Owen (1975) suggested that other species may be differentially fragmented so their ingested proportion may differ from that observed in the feces. Sanders et al. (1980) suggested that fecal analysis may overestimate species with dense stellate hairs or trichomes.

Dearden et al. (1975), Vavra et al. (1978), Vavra and Holechek (1980), and McInnis et al. (1983) suggested that the use of fecal analysis to estimate diet composition tended to underestimate the incidences of forbs, while some grasses and browse species are overestimated. Further, Bartolomé et al. (1995) suggested that fecal analysis technique tended to underestimate forbs and overestimate grasses, but estimated shrubs correctly. Therefore, results based on fecal analysis techniques have to be interpreted with these sources of bias in mind.

This study did not test the effect of years on vegetation production and availability which could influence diet botanical composition from one year to another. Hence, the interpretation and application of its results have to be done within these limits.

Despite these demerits, fecal analysis has become a widely used technique for estimating diet composition of herbivores. This is because it allows for unlimited sampling, does not interfere with the normal habits of the study animal and has particular value where the animal ranges extensively over mixed plant communities. Further, it is the only feasible procedure for studying endangered, secretive or highly valued animals (Crocker 1959, Ward 1970, Anthony and Smith 1974).

Hansen et al. (1971), Johnson and Pearson (1981), Holechek et al. (1985), and Mohamad et al. (1995) demonstrated the merits of this technique for the estimation of diet botanical composition of herbivores.

Availability and Utilization of Important Forage Species

Browse

In a descending order important (≥1%) browse species eaten by mule deer at CRLRR during the study period were: Juniperus mononsperma, Yucca glauca, Pinus edulis, Quercus undulata, Artemisia bigelovii, Rhus trilobata, miscellaneous browse, Opuntia imbricata and Xanthocephalum sarothrae. During summer the ingestion of Juniperus monosperma, Yucca glauca, Xanthocephalum sarothrae, Pinus edulis and Opuntia imbricata appeared to be relative to their availability. Quercus undulata and Rhus trilobata were apparently preferred (Table 5).

Data indicated significant variations among seasons for Artemisia bigelovii, Juniperus mononsperma, Pinus edulis, Rhus trilobata and Yucca glauca. However, Juniperus monosperma, Yucca glauca and Artemisia *bigelovii* remained important (≥1%) food items in both vegetation types throughout the study period (Table 4). These variations are influenced by the season dependent phenological stages, age and availability of forbs (Springfield and Reynold 1951, Beck 1982, Holechek et al. 1982b.)

In general the utilization of *Juniperus monosperma*, *Yucca glauca*, *Pinus edulis* and *Opuntia imbricata* were higher in fall and winter because forbs were either too fibrous and less nutritious or were dry and unavailable to mule deer. Hence, mainly browse species which remained green and abundant during fall and winter were eaten. The utilization of *Rhus trilobata*, *Quercus undulata*, *Opuntia imbricata*, *Xanthocephalum sarothrae*, and miscellaneous browse relative to their availability during summer are shown in Table 5.

Forbs

In a decreasing order forb species ingested by mule deer during the sudy period were: miscellaneous forbs, *Gaura coccinea*, *Lesquerella* spp., *Salsola kali*, *Draba* spp., *Sphaeralcea coccinea*, *Melampodium leucanthum*, *Marubium vulgare* and *Verbena bipinnatifida*. Heavier utilization of forbs were recorded in spring when

Table 5. Vegetation composition by forage species and their respective dietary composition during summer 1993, CRLRR.

Forage species	Veg. composition	Diet composition	Ratio of Veg. composition:Diet composition
Browse			
Artemisia bigelovii	0.2	2.0	1:10
Juniperus monosperma	30.1	46.8	1:1.6
Opuntia imbricata	0.2	0.2	1:1
Pinus edulis	2.0	3.6	1:1.8
Quercus undulata	0.4	6.3	1:15.8
Rhus trilobata	0.2	2.0	1:12.4
Xanthocephalum sarothrae	6.2	3.0	1:0.5
Yucca spp.	3.2	6.1	1:1.9
Miscellaneous browse	1.7**	5.4	-
Forbs			
Draba spp.	*	0.1	-
Gaura coccinea	*	5.9	-
Lesquerella spp.	*	0.9	-
Marubium vulgare	*	0.4	-
Meleampodium leucanthus	*	2.0	-
Salsola kali	0.3	2.1	1:6.7
Sphaeralcia coccinea	0.4	0.7	1:1.8
Verbena bipinnatifida	0.3	0.3	1:1
Miscellaneous forbs	2.4**	10.8	-
grasses	50.5**	2.8	-

* Species which were either only identified in the fecal material or contributed traces lumped under miscellaneous forbs or browse hence, their respective availability:utilization ratios not be computed.

** Not all grass, miscellaneous forbs and browse species ingested were identified. Therefore their availability were not equated with utilization.

they were young and nutritious (Springfield and Reynold 1951, Beck 1972, Holechek et al. 1982b). As their phenological stages advanced forb ingestion began to decline in summer.

Grasses

Grass as a forage class was less utilized than it was available (Table 5). Its ingestion remained low and fairly consistent in both vegetation types (Table 4). Since the phenological stages and availability of forb and grass species vary among seasons, the data presented (Table 5) may not apply to other seasons. Therefore, interpretation of these results have to be done with caution.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

Data indicated differences between pinyon-juniper woodlands and grasslands for vegetation cover and composition. In general mule deer diets varied with the seasons and in some cases there were differences (in deer diet botanical composition) between the grasslands and pinyon-juniper woodlands.

Several conclusions may be drawn from the study.

1. Vegetation at CRLRR is sparsely distributed with more bare ground in the grasslands than woodlands.
2. The range condition in the grasslands was a high fair.
3. Litter was positively associated with the pinyon-juniper stands and was negatively associated with Bouteloua gracilis.
4. Mule deer diets at CRLRR are mainly comprised of browse, with Juniperus monosperma being the most important, during all seasons even in the open grasslands.
5. One-seed juniper remained the most important forage species, even in summer and spring when other food sources were available.

As such it may be concluded that it is not an alternative emergency food source eaten only when more preferable species are not available, but is a staple year-round forage species.

6. At CRLRR small quantities of several forb species cumulatively constitute an important component of deer diets, particularly during spring and summer.
7. Despite the fact that grasses comprised half of the vegetational composition in the ranch during summer it consistently comprised small amounts of the deer diets in all seasons.
8. During summer, the ingestion of some species by deer were proportional to their availability, others were selected in proportions that exceeded their availability and others were ingested in lesser proportions than they were available.

Wildlife and range managers may derive some important management implications from this study. From the above conclusions it appears that brush control mainly implies one-seed juniper control. This also means reduction of the most important year-round staple food source for mule deer. Therefore, if deer numbers at CRLRR are to be maintained or enhanced, habitat management should be planned with one-seed juniper and other important species (Table 4) in mind.

This study did not address the question of what pinyon-juniper density will provide optimum cover and nutritional requirements of deer, while allowing for the growth of enough herbaceous plants required by cattle, sheep and mule deer, particularly during spring and summer. Therefore, it is recommended that an investigation be conducted to determine an appropriate thinning of dense pinyon-juniper stands to provide the optimum habitat requirement to accommodate deer and livestock.

The production of high body mass and quality trophy requires that mule deer habitats should provide forages that meet the nutritional requirements for such yields. At CRLRR the nutritional qualities of mule deer forages have not been investigated. Therefore, it is recommended that research should be conducted to determine the nutritional values of the forage species ingested by mule deer.

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APPENDICES

Appendix A

List of plants encountered at Corona Range and Livestock Research Ranch.

Latin Name	**Common Name**
	Grasses
Aristida harvedii	Threeawn
Aristida purpurea	Purple threeawn
Bouteloua curtipendula	Sideoat grama
Bouteloua eriopoda	Black grama
Bouteloua gracilis	Blue grama
Bouteloua hirsuta	Hairy grama
Bouteloua simplex	Mat grama
Hillaria jamesii	Galleta
Lycurus phleoides	Wolftail
Muhlenbergia montana	Mountain muhly
Muhlenbergia eludens	Fine muhly
Muhlenbergia richardsonis	Mat muhly
Muhlenbergia pungens	Muhly
Muhlenbergia torreyi	Ring muhly
Munora squarrosa	False buffalograss
Panicum obtusum	Vine mesquite
Seteria reflexa	Bristlegrass
Setaria viridis	Green bristlegrass
Sitanion jubatum	Big sqirreltail
Sporobolus cryptandrus	Sand dropseed
Stipa neomexicana	New Mexico feathergrass
Chloris verticilata	Windmill grass
Cenchrus incerta	Coast sanbur
Erogrostis barselieri	Lovegrass

Appendix A continued.

Latin Name	Common Name
Oryzopsis hymenoides	Indian ricegrass
Panicum obtusum	Vine mesquite
Forbs	
Ambrosia artemisifolia	Ragweed
Astragalus molissimos	Loco weed
Argemone squarrosa	Prickly poppy
Amaranthus hybridus	Pigweed
Castilleja integra	Wholeleaf paintbrush
Chenopodium fremontii	Freemont goosefoot
Euphorbia micromera	Spurge
Eriogonum wrightii	Buckweed
Gaura coccinea	Scarlet gaura
Glandularia bipinnatifida	Dakota vervaiin
Grindelia squarrosa	Gumweed
Helianthus petialaris	Prairie sunflower
Heterotheca villosa	Hairy goldster
Leucelene eriocoides	White aster
Marubium vulgare	Horehound
Melapodium leucanthum	Blackfoot
Mirabilis multiflora	Colorado four-o'cklock
Ratibida columnaris	Praires coneflower
Ratibida targetis	Praires coneflower
Pectis angustifolia	Lemon weed
Portulaca aleracea	Purslane
Plantago patagonica	Wolly plantain
Salsola Kali	Russian thistle
Senecio douglasii	Threadleaf groundsel

Appendix A continued.

Latin Name	Common Name
Senecio ridelii	Groundsel
Solanum elaegonifolium	White silverleaf nightshade
Solanum rostratrum	Nightshade
Sphaeralcia coccinea	Scarlet globemallow
Sphaeralcia angustifolia	Globemallow
Theleospermum longipes	Cota greenthread
Verbena bipinnatifida	Verbena
Verbesina encoloides	Crownbeard
Zinnia grandiflora	Zinnia
Shrubs and Trees	
Artemisia bigelovii	Bigelow's sagebrush
Ceratoides lanata	Winterfat
Fallugia paradoxa	Apache plume
Juniperus monosperma	One-seed juniper
Juniperus deppeana	Alligator juniper
Lycium pallidum	Wolfberry
Pinus edulis	Pinyon pine
Pinus ponderosa	Ponderosa pine
Rhus trilobata	Skunkbrush sumac
Quercus undulata	Wavyleaf oak
Quercus grisea	Gray oak
Xanthocephalum sarothrae	Broom snakeweed
Cacti	
Nolina microcarpa	Bear grass
Opuntia imbricata	Walking-stick cholla

Appendix A continued.

Latin Name	Common Name
Opuntia sp.	Prickly pear
Yucca baccata	Banana yucca
Yucca elata	Soaptree yucca
Yucca glauca	Small soapweed

Appendix B

Actual and estimated botanical composition of six simulated diets.

Mixture/ component	Actual % dry wt.	Estimated % dry wt.	Ratio of actual dry wt:estim. Dry wt.
Mixture I			
Yucca glauca	19.6	24.8	1:1[1]
Pinus edulis	12.9	12.6	1:1
Rhus trilobata	26.4	26.5	1:1
Ratibida spp.	26.4	26.5	1:1
Sphaeralcea coccinea	6.6	8.4	1:1
Juniperus monosperma	8.3	8.0	1:1
Mixture II			
Helianthus petialaris	10.5	8.7	1:1
Gaura coccinea	17.4	20.0	1:1
Chenopodium fremontii	11.9	15.1	1:1
Verbena bipinnatifida	40.0	37.8	1:1
Unknown forb	15.5	14.6	1:1
Dalea formosa	4.6	3.8	1:1
Mixture III			
Pinus edulis	23.4	22.3	1:1
Quercus undulata	15.9	14.4	1:1
Rhus trilobata	11.8	15.1	1:1
Dalea formosa	5.8	4.3	1:1
Gaura coccinea	10.4	12.2	1:1
Verbesina encoloides	25.3	25.2	1:1
Juniperus monosperma	7.4	6.5	1:1
Mixture IV			
Sphaeralcia coccinea	11.4	14.5	1:1

Appendix B continued.

Appendix B continued.

Mixture/ component	Actual % dry wt.	Estimated % dry wt.	Ratio of actual dry wt:estim. Dry wt.
Artemisia bigelovii	6.2	5.0	1:1
Rhus trilobata	14.3	17.2	1:1
Eriogonum wrightii	9.3	10.4	1:1
Machaeranthera spp.	4.1	4.0	1:1
Marubium vulgare	23.6	22.2	1:1
Salsola kali	26.8	22.2	1:1
Unknown forb	4.4	3.9	1:1
Mixture V			
Opuntia imbricata	15.2	11.5	1:1
Yucca glauca	12.7	10.2	1:1
Marubium vulgare	8.2	9.0	1:1
Rhus trilobata	11.5	12.5	1:1
Juniperus monosperma	11.9	13.9	1:1
Gaura coccinea	15.5	14.9	1:1
Quercus undulata	14.5	16.6	1:1
Unknown forb	3.5	3.5	1:1
Mixture VI			
Gaura coccinea	35.7	33.2	1:1
Juniperus monosperma	7.0	6.6	1:1
Sphaeralcea coccinea	8.7	9.0	1:1
Marubium vulgare	10.3	10.0	1:1
Senecio longilobus	8.6	7.0	1:1
Xanthocephalum sarothrae	7.5	10.3	1:1
Machaeranthera spp.	3.1	2.9	1:1
Chenopodium fremontii	12.4	12.9	1:1

1 Ratios are rounded to the nearest whole number.