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Desert mule deer and forage resources in southwest Arizona

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The University of Arizona, 1992

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DESERT MULE DEER AND FORAGE RESOURCES
IN SOUTHWEST ARIZONA

by
Steven Keith Albert

A Thesis Submitted to the Faculty of the
SCHOOL OF RENEWABLE NATURAL RESOURCES
In Partial Fulfillment of the Requirements
For the Degree of
MASTER OF SCIENCE WITH A
MAJOR IN WILDLIFE AND FISHERIES SCIENCE
In the Graduate College
THE UNIVERSITY OF ARIZONA

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ABSTRACT

I measured digestible protein consumed by 4 (2 M, 2 F) captive desert mule deer (Odocoileus hemionus crooki). Deer were fed native forage collected from the Belmont Mountains, Arizona. Intake of forage differed significantly ($P < 0.05$) between sexes in every season. Intake of digestible protein for both sexes was highest in fall. Males and females consumed the least amount of digestible protein in spring and summer, respectively. Significant ($P < 0.05$) differences of forage biomass were recorded among all vegetation associations, sites, and seasons in the Belmont Mountains. The most forage biomass was available in winter, the least in spring. Washes contained significantly ($P < 0.05$) more forage biomass than flats in every season. Desert mule deer in the Belmont Mountains are close to the nutritional carrying capacity of the range. Other efforts to increase the deer population may not be effective if the forage base is not increased.

INTRODUCTION

Populations of mule deer in southwestern Arizona have historically been lower than in other parts of their range (Julander and Low 1976). Home range size for deer increases as the distance between necessary resources such as food or water increases (MacNab 1963, Mackie et al. 1983). Home ranges for mule deer in some semi-desert ranges may be as large as 21 km² (Mackie et al. 1983); however, Krausman (1985) and Rautenstrauch and Krausman (1989) reported yearly home ranges for desert mule deer in southern Arizona (a highly xeric environment) as 172 and 121 km², respectively.

If an animal population does not exhibit compensatory mortality, then any factor (either density dependent or density independent) that holds an animal population down may limit the population (Mackie et al. 1982, Ricklefs 1990, Sinclair 1991). For ungulates, the most often cited limiting factors are food (Edwards and Fowle 1955, Caughley 1980, MacNab 1985), water (Urness 1981, Leopold and Krausman 1991), predation (Mech 1970, Connolly 1981, Ricklefs 1990) or disease (Bergerud 1971, Woolf 1978, Connolly 1981). Vegetation in southern Arizona is sparse, and has been cited as possibly limiting to mule deer populations (Urness 1981); however, research has not been conducted to examine this

possibility.

One logical approach to the identification of a limiting factor is to analyze potential factors, one at a time, and estimate their respective ability to support a given deer population. If the amount of available food or nutrients on the range is at or close to the needs of the population, then it is possible that forage is a limiting factor. If, on the other hand, the supply of available nutrients is well above the needs of the population, forage may not be limiting. If forage is limiting, a more conclusive test would be to increase the amount of available forage and gauge the response of the population, with an increase in numbers supporting the hypothesis of food limitation.

Although there are many interpretations of the term "carrying capacity" (e.g. Edwards and Fowle 1955, Mautz 1978, Caughley 1980, Dasmann 1981, Ricklefs 1990) I use Dasmann's (1981) definition of subsistence density: the upper limit at which a population can be sustained by the ability of the habitat to provide food for support of the population.

The first approaches analyzing wildlife range carrying capacity were usually based on quantification of the amount of available forage biomass divided by the needs of a given number of animals (Mautz 1978). This approach is lacking,

however, because it does not take into account the nutritional quality of vegetation measured, which may change significantly from season to season (Dietz and Nagy 1976, Mazaika 1989, Krausman et al. 1990). More recently, attempts have been made to quantify wildlife range carrying capacity based on the nutritional aspects of the available forage (Wallmo et al. 1977, Hobbs et al 1982). Some of the more commonly used measurements of forage nutrition are crude protein, calories, and metabolizable energy (Mautz 1978). Digestible protein is an essential component of deer nutrition (Short 1981) and I use this as a measure of forage quality.

My objectives were: 1) to quantify the consumption of forage biomass and digestible protein by captive desert mule deer; 2) to estimate the carrying capacity for mule deer in the Belmont Mountains, Arizona; and 3) by comparing 1 and 2, evaluate the adequacy of the range to support the current population of desert mule deer, and determine if forage is a limiting factor.

STUDY AREA

The study was conducted in the Belmont Mountains (264 km²), Maricopa County, Arizona. Elevations ranged from 415 m on the desert lowlands to 1,042 m at Sugarloaf Mountain.

Mean annual precipitation was approximately 20 cm in the Belmont Mountains (Krausman 1985), mostly occurring during the July-September monsoon season or during occasional winter storms (Reitan and Green 1968). Winters were mild, with nighttime temperatures occasionally dropping below 0 C. Summers were hot, with midday temperatures sometimes exceeding 45 C.

Vegetation in the desert flats consisted primarily of creosote bush (Larrea tridentata) and triangle-leaf bursage (Ambrosia deltoidea), with the washes dominated by little-leaf paloverde (Cercidium microphyllum) and ironwood (Olneya testota). Extensive areas of desert pavement (flat cobbled areas that remain free of vegetation for most of the year) were common in the lowlands. As elevation and/or northern exposure increased, the density of range ratany (Krameria parvifolia), brittle-bush (Encelia farinosa), and buckwheat (Eriogonum spp.) increased. Winter and late summer rains provided sufficient water for a temporary flush of forbs and grasses. Other ungulates were sympatric with desert mule

deer in the Belmont Mountains. A small population of wild burros (Equus asinus) inhabited the west end of the mountain range, and ≥ 1 group of collared peccaries (Dicotyles tajacu) was present on the east end. Both species consumed plants that were also present in the diets of desert mule deer (Sowls 1978, Krausman et al. 1989). Additionally, black-tailed jackrabbits (Lepus californicus) and desert cottontails (Sylvilagus audubonii) inhabit the study area, and may consume plant species present in the diets of desert mule deer (Chapman et al. 1982, Dunn et al. 1982).

METHODS

I identified forage species prevalent in the diets of desert mule deer from previous studies (e.g., Anthony 1976, Urness 1981, Krausman et al. 1989) or from visual observations of foraging deer. From this list, I selected 3-5 species/season (Table 1) that were abundant enough on the study area for me to collect within 72 hours and supply ≥ 60 deer days of food, with each species being available to deer ad libitum. I collected > 300 kg (wet weight) each season. Vegetation was hand-clipped with pruning shears, double-bagged in polyethylene plastic bags, kept in the shade, and stored at -20°C within 36 hours, except during winter, when vegetation was not frozen until 72 hours after collection. I fed all forages to the deer as clipped, except ironwood, which was ground using a Vogel Nursery Thresher (Gallagher et al. 1988) to facilitate storage and handling.

I conducted feeding trials at the University of Arizona's Wildlife Facility in Tucson. Four captive desert mule deer (2 M, 2 F) were fed increasing amounts of native forage over a period of 4 days, until the native forage constituted 100% of their diet. Deer were fed 100% native forage for 5 days prior to the start of each feeding trial to stabilize the rumen microflora (Hudson and White 1985).

Table 1. Seasonal crude protein composition of plants fed to penned desert mule deer, Tucson, Arizona, 1991.

Season ^a /forage	% crude protein
Winter	
Jojoba	8.5
Ironwood	10.8
Globe mallow (<u>Sphaeralcea orcuttii</u>)	11.5
Spring	
Jojoba	12.8
Buckwheat	3.8
Globe mallow	17.6
Range ratany	9.4
Brittlebush	14.4
Summer	
Jojoba	14.6
Ironwood	19.1
Globe mallow	12.4
Range ratany	9.5
Buckwheat	4.5
Fall	
Jojoba	11.4
Ironwood	15.3
Globe mallow	15.6
Range ratany	11.1

^aWinter = 1 Jan-31 Mar, spring = 1 Apr-30 Jun, summer = 1 Jul-30 Sep, fall = 1 Oct-31 Dec.

I provided all forage species to deer ad libitum. Between trials, deer were maintained on a diet of alfalfa hay and mixed grain (67% sorghum, 20% ground alfalfa, 8% molasses, 5% cottonseed meal, salt). Winter feeding trials were conducted with a Calan gate system for feeding captive ungulates (Mazaika and Krausman 1988), but this method proved unsatisfactory because the smaller leaved forages (e.g., ironwood) sifted to the bottom of the feeding trough, and may not have been as available to the deer as the larger leaved forages. Additionally, when all the deer were kept in the same pen, behavioral interactions may have inhibited some deer from feeding. For the other seasons, I kept all deer in separate 10-m x 15-m pens. I weighed each forage species and placed them in separate bowls. Feeders were stocked with approximately 150% (by weight) of the expected daily consumption of each deer to ensure ad libitum free choice, checked twice daily, and supplemented as necessary. I collected and weighed forage every day at the same time (1630 in winter, 1500 in spring, 0600 in summer, 1400 in fall) $\pm$ 30 minutes, and calculated the amount eaten by each deer by subtraction of the remaining forage from the initial quantity supplied. I calculated weights on a dry-weight basis to eliminate bias from evaporative water loss. Drinking water was available to deer ad libitum. Shade was provided by mesquite (Prosopis juliflora) trees. These

trees produce pods that are sometimes eaten by desert mule deer, although no deer were observed eating pods during any of the feeding trials.

I collected fecal samples for digestibility analysis 3X/season for each deer. I pooled the samples for each deer in a season.

I weighed all deer at the start and finish of each feeding trial. Deer were immobilized with a 2:1 mixture of Ketamine hydrochloride (HCl) to Xylazine HCl, hobbled, blindfolded, and weighed. The effects of the drug were reversed with Yohimbine HCl. Measurements of forage intake began >36 hours after the deer were up and mobile.

I calculated nitrogen content of forage for protein content calculations with a C-N-S analyzer using gas-solid chromatography (Carlos Erba Corp. 1991). Lignin content for analysis of digestibility was made with the Van Soest forage fiber analysis (U.S. Dep. Agriculture 1970) by the University of Arizona Animal Sciences Department.

Most research on methods used to estimate biomass has recommended a double sampling procedure to develop a relationship between a simple, fast estimate and a smaller, more precise measurement (Wallmo and Regelin 1981, Ruyle 1991). I used the dry-weight rank method ('t Mannetje and Haydock 1963) for estimating percent composition of vegetation species, and the comparative yield method

(Haydock and Shaw 1975) for estimating biomass of each species. I identified 3 vegetation associations in the Belmont Mountains: mountains, bajadas, and lowlands. I identified 2 sites within each association: washes and flats. I generated a stratified random sample of universal transverse mercator points, and ran transects in the flats due north from each random point. I measured 50 1-m² quadrats, 20 m apart, on each transect. At the end of approximately every other transect in the flats, a random direction was selected by spinning a pencil in the air over a flat spot, and the first wash encountered in the direction of the pencil point was sampled. Washes sampled ranged in size from <2 m across to >30 m. Vegetation in the washes was more dense along the margins than in the middle. To ensure equal sample representation of all parts of a wash, I sampled the left margin, center, and right margin of each wash. I used a non-mapping technique (Marcum and Loftsgaarden 1980) with 575 random points (Thompson 1987) to estimate percent area covered by each vegetation association and site.

I divided the year into winter (1 Jan-31 Mar), spring (1 Apr-30 Jun), summer (1 Jul-30 Sep), and fall (1 Oct-31 Dec). These periods roughly coincide with predominant seasonal rainfall patterns in southern Arizona (Reitan and

Green 1968). I conducted feeding trials and forage biomass estimates once each season. Plant names are from Lehr (1978).

I built a model of nutritional carrying capacity by comparing the needs of a given number of deer to the availability of palatable nutrients. For forage needs I used 3 steps.

- 1) Digestible protein needs of captive deer were calculated.
- 2) Consumption of forage by penned deer probably underestimates the amount used by free-ranging deer, as locomotion uses more energy than limited movement (Hudson and White 1985). A 50 kg animal that travels 10 km/day (the approx wt and rate of travel of mule deer) (Eberhardt et al. 1984) uses 35% more energy than standard metabolic rate (Hudson and White 1985). Estimates of the digestible protein needs for wild deer were therefore increased by 35%.

- 3) The digestible protein needs were pro-rated by estimated sex and fawn:doe ratios (T. Supplee, Ariz. Game and Fish, pers. commun.) to reflect the population composition of desert mule deer in the Belmont Mountains.

To estimate forage availability, I used 3 additional steps.

- 1) Field biomass of only the seasonal forages fed to deer was calculated from transects. This effectively

eliminated from consideration all biomass in the field that is not eaten by desert mule deer (e.g. creosote-bush, which makes up > 75% of the biomass in some vegetation associations in some seasons).

2) This number was multiplied by 0.25 to get an index of availability. Some studies have shown that browse species are able to tolerate 80-90% utilization of the current year's growth (McConnell and Smith 1977, Wallmo and Regelin 1981, Conrad et al. 1985), or $\geq 50\%$ of the total biomass of the plant (Schmutz 1978). However, studies in more xeric environments indicate many plants may not be able to tolerate such heavy use. Roundy and Ruyle (1989) found that jojoba twigs grew an average of 38% per year. Because total use of the annual growth often leads to degradation of a plant (Wallmo and Regelin 1981), I estimated 25% of the total biomass as available to deer.

3) This number was divided by the proportion that these forages make up in the seasonal diets of desert mule deer in the Harquahala Mountains, 30 km. northwest of the Belmont Mountains (Krausman et al. 1989).

I compared differences of biomass consumption, crude protein consumption, and seasonal forage biomass availability using the Bonferroni multiple comparisons procedure at the 95% confidence level (DeVore and Peck 1986).

RESULTS

Males consumed an average of 1.07 ± 0.08 (SE) kg of dry matter in winter, 1.41 ± 0.08 kg in spring, 1.23 ± 0.08 kg in summer, and 1.25 ± 0.09 kg in fall. Females consumed an average of 0.42 ± 0.06 kg in winter, 0.82 ± 0.04 kg in spring, 0.50 ± 0.04 kg in summer, and 0.92 ± 0.06 kg in fall (Table 2). Average daily consumption of forage biomass differed significantly ($P < 0.05$) between males and females in every season. Consumption by both sexes, however, did not always fluctuate significantly from season to season (Table 2). Males consumed an average of 65.6 ± 7.6 g of digestible protein in winter, 55.7 ± 0.40 g in spring, 106.1 g in summer, and 111.6 ± 21.2 g in fall. Females consumed an average of 24.2 ± 7.6 g of digestible protein in winter, 43.2 ± 0.9 g in spring, 14.2 ± 10.6 g in summer, and 50.9 ± 5.3 g in fall (Table 3). Males consumed more digestible protein than females in every season. Consumption by both sexes, however, did not always fluctuate greatly from season to season. Digestible protein intake was summed and averaged for each deer over a season. Because of small sample sizes ($N = 2$ deer of each sex/season) no statistical inferences were made.

Males lost of an average of 3.7 ± 3.1 kg (5.0 ± 3.2 % of body wt)/season and females lost an average of 2.1 ± 1.8

Table 2. Daily dry matter (kg/animal/day) of native forage consumed by penned desert mule deer (2M, 2F), Tucson, Arizona, 1991.

Season ^a	Males			Females		
	<u>N</u> ^b	<u>X̄</u>	SE	<u>N</u>	<u>X̄</u>	SE
Winter	15	1.07Aa ^c	0.08	15	0.42Aab	0.06
Spring	17	1.41a	0.08	18	0.82ac	0.04
Summer	14	1.23	0.08	24	0.50cd	0.04
Fall	18	1.25	0.09	18	0.92bd	0.06

^aWinter = 1 Jan-31 Mar, spring = 1 Apr-30 Jun, summer = 1 Jul-30 Sep, fall = 1 Oct-31 Dec.

^bN = deer days

^cP < 0.05 between sexes in all seasons. Values in columns with the same lower case letter are significantly different (P < 0.05).

Table 3. Daily digestible protein consumption (g/animal/d) by penned desert mule deer (2M, 2F), Tucson, Arizona, 1991.

Season ^a	Males		Females	
	$\bar{X}$	SE	$\bar{X}$	SE
Winter	65.6	7.6	24.2	7.6
Spring	55.7	0.4	43.2	0.9
Summer	106.1	^b	14.2	10.6
Fall	111.6	21.2	50.9	5.3

^aWinter = 1 Jan-31 Mar, spring = 1 Apr-30 Jun, summer = 1 Jul-30 Sep, fall = 1 Oct-31 Dec.

^b $\bar{N}$ = 1 M for summer, no SE calculated

kg (3.9 ± 3.2 % of body wt)/season over the course of the feeding trial (Table 4). One male deer died during the summer feeding trial from causes not related to the study. Summer feeding data are for only 1 male deer. A new male deer of slightly lower body weight was added to the study for the fall feeding trial.

I sampled approximately 3,000 quadrats in the field each season: 3,192 in winter, 3,159 in spring, 2,813 in summer, and 3,027 in fall. The most crude biomass in the field was available in winter (33.2 g/m^2), principally due to the emergence of forbs, such as bladder pod (Lesquerella gordonii), and grasses, such as fluff grass (Erioneuron pulchellum). Spring had the second highest overall available biomass (23.0 g/m^2), followed by fall (16.0 g/m^2), and summer (10.5 g/m^2). Significant differences ($P < 0.05$) were found between every vegetation association and site within seasons. Every vegetation association and site also differed significantly ($P < 0.05$) from season to season (Tables 5 and 6). Flats had the highest concentration of biomass in winter for all 3 vegetation associations, principally due to the emergence of forbs and grass. All 3 vegetation associations in the flats showed a similar pattern of supporting the highest crude biomass in winter, declining into spring and summer, and increasing again in

Table 4. Weight loss (kg) by penned desert mule deer on a diet of native forage, Tucson, Arizona, 1991.

Season ^a	<u>Males</u>		<u>Females</u>	
	Kg lost	% body wt	Kg lost	% body wt
Winter	3.0	4.0	0.5	1.0
Spring	3.6	4.5	4.3	7.5
Summer	15.0 ^b	9.0	2.7	5.5
Fall	3.0	3.5	0.9	1.5

^aWinter = 1 Jan-31 Mar, spring = 1 Apr-30 Jun, summer = 1 Jul-30 Sep, fall = 1 Oct-31 Dec.

^bN = 1 M, 2 F for summer, N = 2 M, 2 F for all other seasons.

Table 5. Estimated forage biomass for desert mule deer in the Belmont Mountains, Arizona, 1991.

Season ^a	Biomass (g/m ²)
Winter	33.2
Spring	23.0
Summer	10.5
Fall	16.0

^aWinter = 1 Jan-31 Mar, spring = 1 Apr-30 Jun, summer = 1 Jul-30 Sep, fall = 1 Oct-31 Dec.

Table 6. Estimated forage biomass (g/m²) by vegetation association in the Belmont Mountains, Arizona, 1991.

Season ^a	<u>Mountains</u>		<u>Bajadas</u>		<u>Lowlands</u>		<u>Total</u>	
	Flats	Wash	Flats	Wash	Flats	Wash	Flats	Wash
Winter	37	39	29	43	30	41	28	41
Spring	29	70	18	49	10	50	19	57
Summer	6	22	11	28	7	34	8	28
Fall	16	31	17	39	6	47	13	39

^aWinter = 1 Jan-31 Mar, spring = 1 Apr-30 Jun, summer = 1 Jul-30 Sep, fall = 1 Oct-31 Dec.

spring for all 3 vegetation associations, mainly due to the leafing of mesquite and catclaw acacia (Acacia greggii) that grow abundantly along the wash margins. Washes also showed a similar pattern in all 3 vegetation associations: biomass increased to its highest point in spring, declined in summer, and rose slightly again in fall (Table 6). Percent composition of vegetation associations and sites are presented in Appendix A.

Because male and female rates of consumption differed significantly, on site sex and fawn:adult ratios need to be considered. In 1990 the Arizona Department of Game and Fish recorded a sex ratio of 28 males:100 females and 31 fawns:100 females in game management units 43 and 44 (that encompass the Belmont Mountains) (T. Supplee, Ariz. Dep. Game and Fish, pers. commun.). Fawns require approximately 1/2 of the digestible protein of female deer (Short 1981). The Arizona Department of Game and Fish estimated a density of 0.6 deer/km² in 1990 in the area encompassing the Belmont Mountains (T. Supplee, Ariz. Dep. Game and Fish, pers. commun.). This was a high estimate, however, because areas of little potential were not surveyed. K. B. Fox and P. R. Krausman (Univ. Arizona, pers. commun.) censused the deer

consumption from all known free water sources in June 1991. Because the seasonal water consumption rates of desert mule deer are known (Hervert and Krausman 1986, Hazam and Krausman 1988), the amount of water absent from all known water sources may be used to estimate the number of animals present in an area. Using estimated sex and fawn:doe ratios, we estimated a mule deer density of 0.5 deer/km². My model estimated a potential carrying capacity for the Belmont Mountains of 3.5 deer/km² in winter, 1.2 deer/km² in spring, 1.3 deer/km² in summer, and 1.5 deer/km² in fall (Table 7). These estimates may be high, however, because they do not incorporate population and dietary overlap estimates of other sympatric herbivores. The most crucial season is spring, which has the lowest potential carrying capacity, and should therefore set the upper bound of population size if forage is limiting.

Table 7. Seasonal carrying capacity for desert mule deer in the Belmont Mountains, Arizona, 1991.

Season ^a	Carrying capacity (deer/km ²)
Winter	3.5
Spring	1.2
Summer	1.3
Fall	1.5

^aWinter = 1 Jan-31 Mar, spring = 1 Apr-30 Jun, summer = 1 Jul-30 Sep, fall = 1 Oct-31 Dec.

DISCUSSION

The use of penned animals for wildlife research allows more exact measurements of forage consumption than can be made on wild animals. Studies have shown that captive animals, including mule deer, exhibit similar behavior (including feeding behavior) to wild deer (Halford, et al. 1987). Mean daily consumption was consistent with the limited published literature for captive deer in southern Arizona (Nichol 1938). One anomaly, however, was the lack of severely reduced food intake by the penned male deer during the fall rutting season, a trait normally exhibited by wild deer (Wallmo 1978, Short 1981) as they wander in search of females. The penned deer, of course, were unable to wander. The one male deer in the summer season, however, did exhibit the highest weight loss of any deer (6.8 kg) during early September. This may indicate that, even though actual consumption of biomass or digestible protein was not severely curtailed, the deer did consume considerably less than its needs.

Because deer were kept on a high protein, nutritionally balanced diet between feeding trials (i.e. > 85% of the year), weight losses may not necessarily reflect poor nutrition. I compared weights of hunter-killed wild desert mule deer from southwestern Arizona ≥ 2 years old ($N = 23$ M,

9 F) (Krausman et al. 1984) using Moen's (1980) conversion from field dressed to live weight. Even at their lowest fall weights, male and female captive desert mule deer in my study out-weighed wild deer in fall by 4.0% and 17.2%, respectively.

Not all of the biomass present in the field was available or palatable to desert mule deer. Estimating available forage, however, is difficult. Range managers typically estimate that 50% of the biomass is available for consumption (Schmutz 1978). These estimates, however, generally refer to grasses, which are more tolerant of grazing than most browse. Much of the research of plant growth rates done in mesic environments cannot be directly correlated to arid regions, where growth rates of many plants are considerably slower (McGinnies 1968). More research is needed to refine estimates of forage availability of browse species in xeric environments.

My estimates of seasonal carrying capacity demonstrated that there is forage available for more deer than are currently using the range. When such factors as other sympatric herbivores, or sufficient safety margin for drought years is taken into consideration, however, it appears that the range is near carrying capacity for the herbivores present. Additionally, my estimates of carrying capacity may be high because winter-spring rainfall in

southern Arizona was abnormally high in 1991, which probably produced more vegetation than an average year.

Using similar techniques, Mazaika (1989) determined that forage was not a limiting factor for desert mountain sheep (Ovis canadensis mexicana) in the Pusch Ridge Wilderness of the Santa Catalina Mountains, near Tucson, Arizona. The Santa Catalina Mountains, however, are characterized by higher annual rainfall and denser vegetation growth than is typically found in the mountains of southwest Arizona. Extensive areas of desert pavement that characterize much of the lowland areas of southwest Arizona are not found in the Santa Catalina Mountains.

Some researchers have theorized that herbivore diet specialization should occur when resources are abundant, and diet generalization should occur at low food levels (Westoby 1974, Belovsky 1978, Nudds 1980, Brown and Doucet 1991). Desert mule deer in western Arizona may be classified as diet generalists, incorporating up to 30 different species of forage into their diets in a given season (Krausman et al. 1989), or up to 106 different species over the course of a year (Urness 1981). One reason for their diet generalization may be limited quantities of preferred foods. It is also possible that deer ingest a variety of foods to obtain a full complement of nutrients (Jenkins 1982), to avoid the harmful effects of toxic secondary compounds found

in some desert plants (Dietz and Nagy 1976), or to "prime" the rumen bacterial community with strains to break down new ingested compounds as availabilities of food change (Freeland and Janzen 1974).

Several other pieces of circumstantial evidence, however, lend credence to the idea that forage has a potential limiting influence to deer in southern Arizona. First, seasonal rainfall may have dramatic effects on the amount and nutritive quality of forage used by deer (Short 1981, Urness 1981). Anthony (1976) concluded that a year long drought in 1970 was the main factor responsible for a decline in a population of desert mule deer in the San Cayento Mountains in south-central Arizona. He tied the drought to a shift in diet composition from preferred deciduous shrubs to evergreen and drought resistant shrubs. Other studies (Smith and LeCount 1976, Leopold and Krausman 1991) have related rainfall as it affects vegetative production to declines in mule deer recruitment. Wallmo (1978) reported that crude protein in the diet of desert mule deer may fall below the critical 7% level during the spring dry period. Second, K. Fox and P. R. Krausman (unpubl. data) have found that deer in the vicinity of the Belmont mountains will congregate in "green-up" areas (areas where there is a much higher density of vegetation due to water temporarily backing up against the canal levee) along

the Hayden-Rhoads aqueduct. Higher desert mule deer use of these areas suggests a selection for areas of higher vegetation density. Third, annual home ranges reported for desert mule deer in the Belmont mountains may be as high as 172 km² (Krausman 1985, Rautenstrauch and Krausman 1989); i.e., >9 times the size of mule in other semi-arid regions (Mackie et al. 1983). Home ranges of female deer in the Belmont and surrounding mountains generally increases to its greatest area in April-June, usually the season of lowest forage abundance (Krausman 1985). The issue is slightly more complicated for male deer that wander widely during the rut in search of females. Increase in home-range size often indicates a reduced abundance of important habitat elements such as forage (Mackie et al. 1982). Finally, parturition in desert mule deer is timed to coincide with seasonal rainfall (Urness 1981), indicating that the amount of available vegetation plays an important role in the limitation of deer numbers in southern Arizona.

MANAGEMENT IMPLICATIONS

Any vegetation study that encompasses only 1 year is subject to variation. Seasonal rainfall appears to be the primary limiting factor for vegetation in southwest Arizona, and this may change drastically from year to year.

My results indicate that, although there is enough available forage and digestible protein for a slightly higher deer densities, the current deer population in the Belmont mountains, Arizona, is close to equilibrium with its resources. It is possible that >1 factor plays a role in keeping the population at such low densities. However, because it appears that the desert mule deer population is very close to the carrying capacity of the available nutrients of the range, improvements such as predator control or addition of available water may be of dubious value.

APPENDIX A. Seasonal percent composition of vegetation associations and sites in the Belmont Mountains, Arizona, 1991.

	Winter ^a						Spring ^b						Summer ^c						Fall ^d					
	MF ^e	MW ^f	BF ^g	BW ^h	LF ⁱ	LW ^j	MF	MW	BF	BW	LF	LW	MF	MW	BF	BW	LF	LW	MF	MW	BF	BW	LF	LW
<u><i>Acourtia</i> spp.</u>	.	.	.	.	.	.	.	p ^k	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<u><i>Acacia greggii</i></u>	p	7	.	1	.	.	1	14	.	10	.	10	1	14	p	16	1	5	p	5	p	21	.	13
<u><i>Allium</i> spp.</u>	2	p	1	.	.	.	.	.	.	.	.	.	.	.	.	.	p	.	.	.	.	.	.	.
<u><i>Ambrosia aptera</i></u>	.	1	.	1	.	3	.	5	.	2	.	1	.	7	.	1	.	1	.	p	.	4	.	8
<u><i>Ambrosia deltoidea</i></u>	25	18	41	34	24	39	29	12	40	33	26	24	41	13	4	25	9	3	43	23	45	17	11	20
<u><i>Ambrosia dumosa</i></u>	.	.	.	.	p	.	1	p	.	.	.	.	.	.	.	.	.	p	.	.	.	.	.	.
<u><i>Amsinckia tessellata</i></u>	1	p	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<u><i>Aristida adscensionis</i></u>	p	.	p	.	p	.	p	.	p	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
<u><i>Aristida ternipes</i></u>	p	2	1	p	p	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<u><i>Beloperone californica</i></u>	.	2	.	1	.	.	.	1	.	1	.	.	.	.	.	1	.	.	.	.	.	.	.	.
<u><i>Baccharis sarothroides</i></u>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	p	.
<u><i>Carnegiea gigantea</i></u>	p	.	1	p	1	.	p	.	.	p	p	p	p	1	p	2	1	.	1	p	1	.	.	.
<u><i>Cassia covessii</i></u>	3	.	p	.	.	.	1	1	1	.	.	p	.	.	.	.	1	.	.	.	.	.	.	.
<u><i>Cercidium microphyllum</i></u>	5	12	5	23	2	15	5	7	2	12	1	8	4	9	1	14	1	14	9	17	6	20	p	14
<u><i>Cercidium floridum</i></u>	.	2	.	3	.	.	.	1	.	.	.	.	.	2	.	.	.	.	.	3	.	.	.	.
<u><i>Chorizanthe rigida</i></u>	.	.	1	.	p	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<u><i>Clematis drummondii</i></u>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	p	.	.	.
<u><i>Cryptantha</i> spp.</u>	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

APPENDIX A. (continued)

	Winter						Spring						Summer						Fall					
	MF	MW	BF	BW	LF	LW	MF	MW	BF	BW	LF	LW	MF	MW	BF	BW	LF	LW	MF	MW	BF	BW	LF	LW
<u>Ditaxis lanceolata</u>	.	P	.	.	.	.	P	.	P	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<u>Echinocerus</u> spp.	.	.	P	.	.	.	.	.	.	.	.	.	P	.	P	.	.	P	.	.	.	.	.	.
<u>Encelia farinosa</u>	24	8	5	2	2	2	25	4	8	2	1	1	13	2	1	1	.	1	12	4	10	1	p	p
<u>Ephedra</u> spp.	.	P	.	P	.	.	1	1	.	P	.	P	1	1	1	P	.	.	1	3	P	1	P	.
<u>Eriogonum fasciculatum</u>	4	.	P	1	.	.	3	3	1	P	.	P	6	6	P	P	.	.	2	1	2	3	.	.
<u>Eriogonum trichopes</u>	.	.	.	.	.	.	3	3	1	.	P	.	.	.	.	.	.	.	.	.	.	.	.	.
<u>Eriogonum wrightii</u>	.	4	P	.	.	.	.	.	.	.	.	P	1	1	P	.	P	P	.	.	.	.	.	.
<u>Erioneuron pulchellum</u>	.	.	P	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<u>Eriodion cicutarium</u>	P	P	1	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<u>Erodium texanum</u>	.	.	1	.	P	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<u>Eschscholtzia</u> spp.	P	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<u>Euphorbia pediculifera</u>	.	.	.	.	.	.	.	2	.	P	.	.	.	.	.	.	.	.	.	.	.	.	.	P
<u>Euphorbia polycarpa</u>	1	.	P	.	.	.	2	P	4	P	1	P	2	1	.	.	.	.	.	.	P	.	.	P
<u>Fagonia laevis</u>	P	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<u>Ferocactus</u> spp.	1	.	P	.	.	.	P	.	P	.	.	.	2	1	.	.	1	.	2	.	P	.	P	.
<u>Fouquieria splendens</u>	1	.	P	P	P	.	P	.	1	P	.	.	2	.	P	.	.	.	.	.	.	.	.	.
<u>Galium stellatum</u>	.	.	.	.	.	.	1	1	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.
<u>Haplopappus spinulosus</u>	.	.	P	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

APPENDIX A. (continued)

	Winter						Spring						Summer						Fall					
	MF	MW	BF	BW	LF	LW	MF	MW	BF	BW	LF	LW	MF	MW	BF	BW	LF	LW	MF	MW	BF	BW	LF	LW
<u>Hilaria rigida</u>	.	.	.	.	.	.	1	p	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<u>Horsfordia newberryi</u>	.	.	.	.	.	.	p	.	.	.	.	.	.	.	.	.	.	.	p	.	.	.	.	.
<u>Hymenoclea</u> spp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	p	.	.	.	2
<u>Hyptis emoryi</u>	p	2	.	p	.	p	1	7	.	1	.	.	2	15	p	1	.	.	1	1	p	.	.	.
<u>Krameria parvifolia</u>	p	2	1	1	2	27	2	3	1	1	4	2	4	3	4	2	5	12	3	1	3	1	2	3
<u>Larrea tridentat</u>	10	10	15	12	37	15	13	3	36	17	60	35	17	5	32	17	77	36	21	19	24	14	85	19
<u>Lesquerella gordonii</u>	4	.	14	4	22	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<u>Lupinus</u> spp.	1	.	p	.	.	.	.	.	.	.	.	.	p	.	.	.	.	.	.	.	.	.	.	.
<u>Lycium</u> spp.	2	7	p	6	p	6	1	6	1	3	.	5	p	1	p	p	.	.	2	6	p	3	.	4
<u>Mammillaria</u> spp.	.	p	.	.	.	.	.	.	.	.	.	.	.	.	p	.	.	.	.	.	.	.	.	.
<u>Olneya testota</u>	1	9	2	6	1	13	2	7	1	11	5	4	1	11	2	17	1	20	1	13	3	8	p	8
<u>Opuntia arbuscula</u>	.	.	.	p	.	.	p	.	p	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<u>Opuntia bigelovii</u>	1	.	2	.	5	.	1	.	2	.	p	.	p	.	5	p	4	.	1	.	2	.	.	.
<u>Opuntia phaeacantha</u>	.	.	.	.	p	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<u>Opuntia leptocaulis</u>	.	.	.	p	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	p	.	.	.
<u>Opuntia versicolor</u>	1	.	1	1	p	.	1	p	1	p	1	.	2	2	3	.	2	.	2	.	1	.	p	.
<u>Perityle emoryi</u>	.	.	.	.	.	.	1	.	.	.	.	p	.	.	.	.	.	.	.	.	.	.	.	.
<u>Phacelia</u> spp.	.	p	1	1	p	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

APPENDIX A. (continued)

	Winter						Spring						Summer						Fall					
	MF	MW	BF	BW	LF	LW	MF	MW	BF	BW	LF	LW	MF	MW	BF	BW	LF	LW	MF	MW	BF	BW	LF	LW
<u>Plantago insularis</u>	2	.	p	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<u>Prosopis juliflora</u>	.	.	.	2	.	p	.	2	.	1	.	1	.	2	.	p	.	1	.	.	p	2	.	1
<u>Psilotrophe cooperi</u>	.	.	.	.	.	.	p	p	.	.	.	.	.	.	.	.	.	.	p	.	.	.	.	.
<u>Salazaria mexicana</u>	.	.	.	.	.	.	p	5	.	p	.	p	.	1	.	.	.	.	.	.	.	p	.	3
<u>Salvia dorii</u>	.	.	.	.	.	.	1	2	.	.	.	.	.	1	.	.	.	.	.	1	.	.	.	.
<u>Simmondsia chinensis</u>	1	7	p	.	.	p	p	4	p	.	.	.	.	.	.	1	.	3	.	.	.	.	.	1
<u>Sphaeralcea orcuttii</u>	1	2	1	.	.	.	1	p	.	.	.	p	.	.	.	.	.	.	p	p	.	.	.	.
<u>Trixis californica</u>	.	.	.	.	.	p	1	4	p	3	.	1	1	2	p	1	.	.	.	2	.	.	.	1
<u>Viguiera deltoidea</u>	p	p	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	p	3	.	.
<u>Zizyphus obtusifolia</u>	.	.	.	.	.	.	.	.	.	p	.	p	.	.	.	.	.	.	.	.	.	.	.	.
Unknown	4	1	1	p	.	.	2	1	p	p	1	4	.	.	.	.	.	.	.	p	.	p	.	.

*Winter - 1 Jan-31 Mar

*Spring - 1 Apr-30 Jun

*Summer - 1 Jul-30 Sep

*Fall - 1 Oct-31 Dec

*Mountain Flats

*Mountain Washes

*Bajada Flats

*Bajada Washes

*Lowland Flats

*Lowland Washes

*present, < 0.5 % composition.

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