

Home range and habitat use by desert mule deer in altered habitats

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Alterations of desert mule deer (*Odocoileus hemionus eremicus*) habitat in Sonora, Mexico include overgrazing by livestock, additions of water sources, and transformation of desert scrub into pastures of exotic buffelgrass (*Cenchrus ciliaris*). No previous research has been conducted to understand how mule deer respond to these alterations. We studied radiocollared mule deer from April 2002-June 2004 to evaluate home range sizes and habitat use of altered habitats in central and western Sonora, Mexico. Sizes of home ranges were larger in the more arid environments of western Sonora ($27.3 \text{ km}^2 \pm 2.6 \text{ [SE]}$) than in central Sonora ($14.5 \text{ km}^2 \pm 2.0 \text{ [SE]}$). During summer, mule deer home ranges were smaller than in any other season in western and central Sonora. There was no statistical difference in the size of home ranges of mule deer in areas with buffelgrass when compared to the size of home ranges of deer using native scrub vegetation. Desert mule deer did not use the vegetation associations in proportion to their availability, but selected xeroriparian vegetation and sites closer to water in both areas. Thermal cover was greater at deer sites than random sites in most seasons. Vegetation cover was greater and gravel cover less at mule deer locations on one area in one season. Desert mule deer used altered areas with buffelgrass; however, they selected sites with larger amount of shrubs or trees that supplied thermal cover. Researchers and managers should focus conservation efforts to identify threshold limits of altered habitats, determine differences in mule deer densities, and evaluate productivity and survival rates of desert mule deer in relation to those alterations.

Key words: buffelgrass, *Cenchrus ciliaris*, habitat, Mexico, mule deer, *Odocoileus hemionus*, Sonora, water sources

Desert mule deer (*Odocoileus hemionus eremicus*) are an important big game species in North America and inhabit parts of the Sonoran and Chihuahuan deserts in the southwestern United States and northwestern Mexico (Heffelfinger 2000, 2006). Population trends, productivity, and performance of mule deer have been well documented in the United States (Kie and Czech 2000, Avey et al. 2003). On the contrary, there is a lack of literature on the status or trend of mule deer populations, and on condition of mule deer habitat in Mexico.

The central and western regions of Sonora, Mexico have distinctive biotic characteristics (Brown 1994). In addition, landscapes in these regions have been altered to enhance cattle management (Camou-Healy 1994). Alterations to the habitat of desert mule deer include transformation of the desert scrub into pasture for exotic buffelgrass (*Cenchrus ciliaris*), overgrazing by livestock, and establishment of artificial sources of water.

Buffelgrass was introduced into the Southwest to stabilize soil against erosion (Martin et al. 1998) and provide additional forage for cattle (Holt 1985). This exotic graminoid dominates indigenous grasses (Ibarra et al. 1995). By the early 1990s, buffelgrass was present in 10% (1,200,000 ha) of Sonoran rangeland (Yetman and Burquez 1994) and there are estimates that buffelgrass occurs on >1,600,000 ha (Burquez-Montijo et al. 2002) of rangeland. In fact, the conditions of desert mule deer habitat in Sonora have been modified to favor cattle production since the 1960s. About 20% of the mule deer range in Sonora has been altered by shrub-removal, and then establishing buffelgrass pastures. There is no primary literature showing the effect of these habitat alterations on mule deer.

The objectives of our study were to (1) determine home range sizes of desert mule deer, and differences among seasons and areas of central and western Sonora that have been altered with plantations of buffelgrass; (2) determine the use of natural and altered components of habitat by desert mule deer; and, (3) identify differences in the characteristics between selected sites and random sites in altered habitat of desert mule deer.

MATERIALS AND METHODS

Study areas.—This study was conducted in 2 areas of the Lower Sonoran Desert in the central and western Sonora, Mexico (Figure 1). The first area included Rancho La Jubaivena and adjacent lands. This area is located 54 km north of Hermosillo in the central region of Sonora (29° 34' and 29° 41' N, 111° 12' and 111° 18' W; CETENAL 1974). Size of the area was 24,155 ha and elevations ranged from 500–650 m. Average annual precipitation was 320 mm (Centro de Investigaciones Pecuarias del Estado de Sonora 1989). Precipitation was bimodally distributed: approximately 60% occurred between July and September, and about 40% occurred between November and March. The remaining months usually were dry. Summer rainfall occurred as thunderstorms that were frequently localized, and were of high intensity. Annual mean temperature was 23°C. Daytime temperatures averaged 34°C, but frequently exceed 40°C in June through August. Night-time temperatures averaged 8°C in winter, and approached 0°C in December, January, and February.

Vegetation was representative of the arbosuffrutescent desert scrub in the Plains of Sonora Subdivision of the Sonoran Desert (Shreve and Wiggins 1964, Brown 1994). We followed Shreve and Wiggins (1964) for scientific nomenclature and United States Department of Agriculture–National Resources Conservation Service PLANTS database, Version 3.5 (<http://plants.usda.gov>) for common names of plants. Shrubs and small to

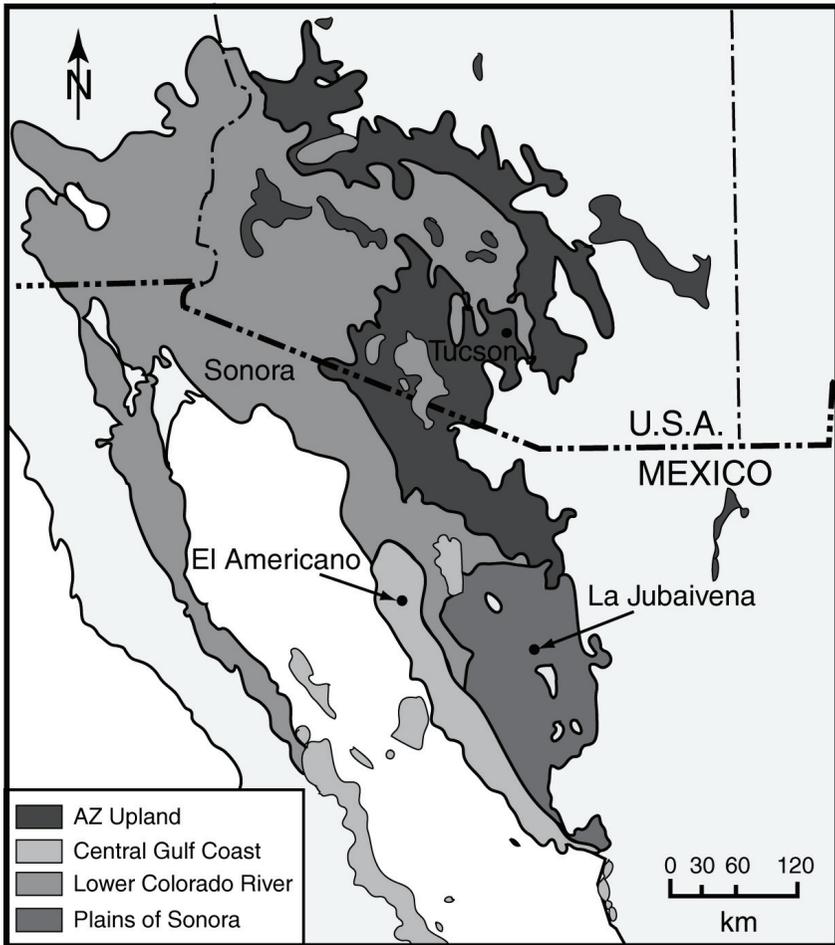


FIGURE 1.—Locations of the study areas for analyses of home range and habitat use in altered habitats by desert mule deer, central and western Sonora, Mexico, 2002–2004.

medium sized trees dominated overstory vegetation. Common species were ironwood (*Olneya tesota*), mesquite (*Prosopis velutina*), paloverde (*Parkinsonia* spp.), bird-of-paradise (*Caesalpinia pumila*), brittle bush (*Encelia farinosa*), snakewood (*Condalia* spp.), and catclaw mimosa (*Mimosa laxiflora*). Understory vegetation was represented by perennial herbaceous species including tidentromia (*Tidentromia lanuginosa*), milkweeds (*Euphorbia* spp.), and grasses including false grama (*Bouteloua diversispicula*), spidergrass (*Aristida ternipes*), sixweeks threeawn (*Aristida adscensionis*), false sideoats (*Bouteloua reflexa*) and bristlegrass (*Setaria macrostachya*). Cacti were present, but sparse. Common cacti were organ pipe cactus (*Stenocereus thurberi*), and chainfruit cholla (*Opuntia fulgida*). The core of the study area comprised 10,500 ha of native arbosuffrutescent scrub surrounded by buffelgrass pastures. Native vegetation has been severely grazed (Holechek and Galt 2000) by cattle. Understory vegetation was scarce and bare ground appeared on extensive areas where erosion was evident. We identified 4 major vegetation associations: mesquite – bird-of-paradise – xeroriparian, ironwood – brittle bush – plains, elephant tree (*Pachycormus discolor*) – catclaw mimosa – foothills, and buffelgrass pastures in the study area (Figure 2).

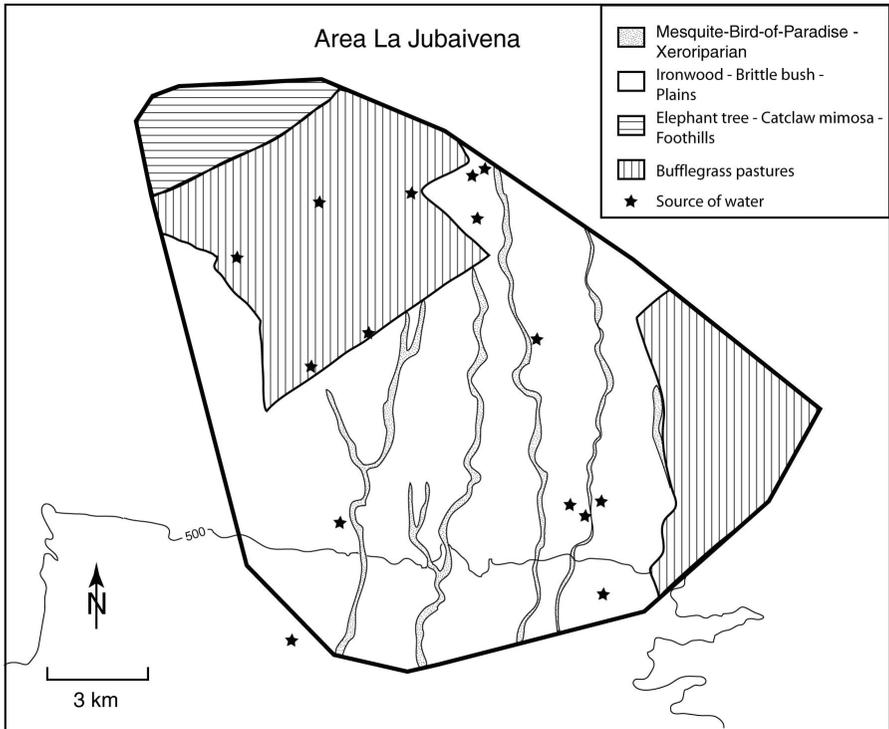


FIGURE 2.—Vegetation associations and location of water sources available to desert mule deer in the La Jubaivena study area, central Sonora, Mexico, 2002–2004.

The second area included Rancho El Americano and adjacent lands. This ranch was located 25 km north of Puerto Libertad in Pitiquito, Sonora, (30° 00' and 30° 17' N, 112° 17' and 112° 43' W). This area encompassed 83,000 ha where physiognomic and vegetation characteristics represent 2 of the subdivisions of the Sonoran Desert. The southern and western portions of the area of study were coastal plains inclined to the sea that were part of the Central Gulf Coast Subdivision of the Sonoran Desert (Shreve and Wiggins 1964, Brown 1994). The central and northern portions of Rancho El Americano were coastal plains that merged into rough terrain and northern plains characteristic of the Lower Colorado River Valley Subdivision (Shreve and Wiggins 1964, Brown 1994). Elevation ranged from 150–500 m in coastal plains and from 500–750 m in desert mountain ranges (i.e., Sierra Aguirre and Sierra Picu). Precipitation was bimodal, with 70% occurring in summer months. Average annual precipitation was 180 mm. Annual mean temperature was 23°C.

Vegetation in coastal plains was characteristic of the sarcocaulous desert scrub and vegetation in foothills and northern plains was microphyllous desert scrub (Shreve and Wiggins 1964, Brown 1994). Common plants in the sarcocaulous desert scrub included elephant tree, bursera (*Bursera hindsiana*), limberbush (*Jatropha cuneata*, *J. cinerea*), creosote bush (*Larrea tridentata*), burrobush (*Ambrosia dumosa*), and brittle bush, and the cacti etcho (*Pachycereus pringlei*), chainfruit cholla and teddy bear cholla (*Opuntia bigelovii*).

Microphyllous desert scrub in foothills and northern plains included creosote bush, ocotillo (*Fouquieria splendens*), paloverde (*Parkinsonia florida*, and *P. microphylla*),

triangleleaf bursage (*Ambrosia deltoidea*), burrobush, brittle bush, and limberbush. Common cacti were organ pipe cactus, saguaro (*Carnegie gigantea*), barrel cactus (*Ferocactus acanthodes*) and teddy bear cholla. Small and localized areas converted to buffelgrass represented 1% of the study area. Performance and natural dispersion of buffelgrass was limited in the area because of lower precipitation. We identified 6 major vegetation associations in this area: mesquite – ironwood – xeroriparian, elephant tree – limberbush – northern foothills, creosote bush – paloverde – hills, creosote bush – Franseria spp – plains, creosote bush – Etcho – coastal plains, and buffelgrass pastures (Figure 3).

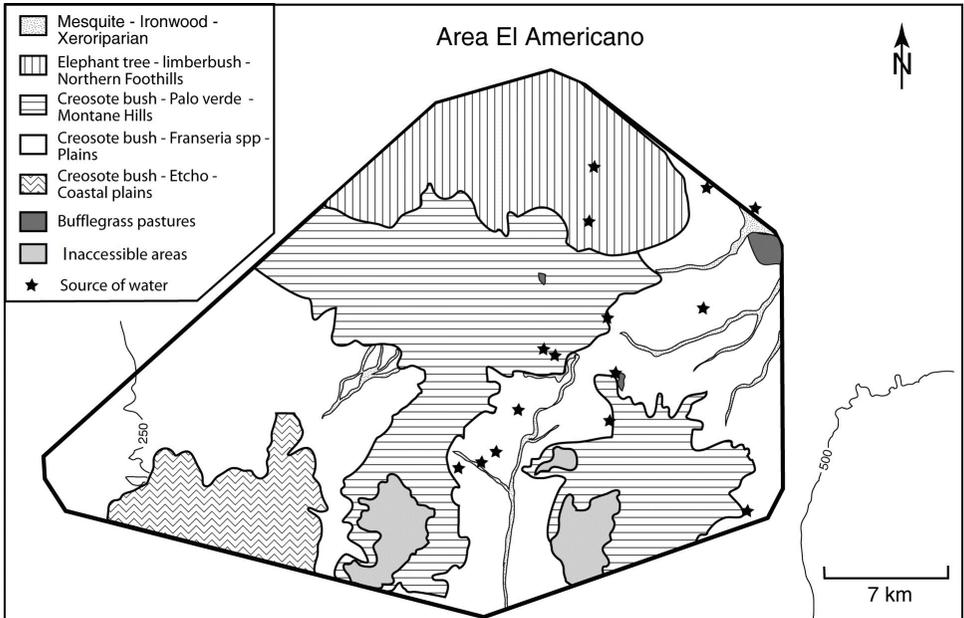


FIGURE 3.—Vegetation associations and location of water sources available to desert mule deer in the El Americano study area, western Sonora, Mexico, 2002–2004.

Cattle grazing was a common practice year-round in both areas, but stocking rates were lower in El Americano, where rangeland offered a comparatively reduced amount of forage for livestock. Free standing water (15 sources in each area) was available for desert mule deer. Large- and medium-sized mammals other than mule deer and cattle present in both areas included Coues white-tailed deer (*Odocoileus virginianus couesi*), collared peccary (*Pecari tajacu*), mountain lion (*Puma concolor*), coyote (*Canis latrans*), antelope jackrabbit (*Lepus alleni*), and desert cottontail (*Sylvilagus audubonii*). Feral burros (*Equus asinus*) and black-tailed jackrabbits (*Lepus californicus*) were also present in El Americano.

We determined seasons for our study areas from bimodal precipitation and temperature regimes (Krausman 1985). The seasons were cold-wet (winter: January–March), hot-dry (spring: April–June), hot-wet (summer: July–September), and cold-dry (autumn: October–December).

Methods.—We captured adult female mule deer in April 2002 with a net-gun fired from a helicopter (Krausman et al. 1985). We attached VHF radiocollars (MOD-500) with mortality sensors (S6A, 4 h; Telonics, Mesa, Arizona) to the neck of each animal. We

monitored marked deer from April 2002–June 2004. Ground locations involved visual contact of radiocollared mule deer and were made ≥ 4 times each month (i.e., we attempted to locate each deer once a week) using a Model TR-2 receiver and hand-held H-antennas (model RA-1AK, Telonics, Mesa, Arizona). We made aerial locations 1 time/month from a Cessna 182 aircraft equipped with a Model TR-2 receiver, an antenna switch selector, and directional H-antennas (model RA-2AK, Telonics, Mesa, Arizona) mounted on each wing strut. We assumed aerial location error of 200 m and followed recommendations in aerial tracking according to Krausman et al. (1984). We determined geographic coordinates of all locations of mule deer with a Geographic Position System (eTrex, Garmin, Olathe, Kansas, USA) and plotted each one on cartographic images using ArcView 3.2 (Environmental Systems Research Institute 1996). When mule deer were located from the ground, we recorded information on the vegetation association. For $\geq 20\%$ of locations in every season we evaluated plant composition, thermal cover (i.e., vegetation ≥ 75 cm high that provided shade for a deer), and ground cover (i.e., percent of ground covered by organic litter), gravel (i.e., rocks < 25 mm in diameter), and stones (i.e., rocks ≥ 25 mm in diameter). Locations for vegetation measurements represented the proportional amount of time deer spent in each vegetation association (i.e., if an association made up 25% of the area, 25% of vegetation measurements were obtained in that area). We used the point intercept method (Heady et al. 1959) and measured vegetation along a 40-m line centered at mule deer locations. We determined the direction of the line randomly. For comparison, we randomly selected a paired location 100 m from the selected location and collected data in the same manner. We used logistic regression to compare site characteristics between selected and random locations. We discriminated site characteristics with $P > 0.10$, and conducted comparisons using Wilcoxon tests.

We calculated home range of desert mule deer during each season in both study areas. We used the minimum convex polygon (MCP) through the MCP extension in ArcView 3.2. We followed established procedures (Mares et al. 1980) to obtain an adequate number of locations and minimize bias. We compared home range sizes among seasons and study areas using Wilcoxon and Kruskal-Wallis tests.

The area of every vegetation association was calculated with ArcView 3.2. We used chi-square contingency table analyses to test the null hypothesis that mule deer used vegetation associations in proportion to their availability (Neu et al. 1974, Byers et al. 1984) by comparing the total number of observations of deer in each study area with the total area of each vegetation association. When we found a difference ($P \leq 0.05$) between expected and observed use, we calculated Bonferroni confidence intervals to determine whether percentage use of each vegetation association was significantly greater or less than its percentage availability (Neu et al. 1974, Byers et al. 1984). We plotted individual selection variability (Thomas and Taylor 1990) for each vegetation association in both study areas.

We used ArcView 3.2 to calculate distance of every deer location to the nearest source of water. We generated the same number of random locations and determined if deer locations were closer to water sources than random points. We used analysis of variance with Tukey-Kramer (Honestly Significant Difference) tests ($P < 0.05$) for comparisons between areas and among seasons.

RESULTS

We captured and collared 19 female mule deer in La Jubaivena and 14 female mule deer in El Americano. We obtained 1,175 locations of radiocollared mule deer in La Jubaivena and 829 locations of radiocollared mule deer in El Americano. We calculated seasonal home ranges for each deer that had ≥ 14 locations/season. Access to both areas was restricted during winter due to hunting, and we did not have enough data to calculate home ranges in winter for La Jubaivena. Overall, sizes of annual home ranges were larger in El Americano ($27.3 \text{ km}^2 \pm 2.6 [SE]$) than La Jubaivena ($14.5 \text{ km}^2 \pm 2.0 [SE]$) (Kruskal-Wallis $\chi^2_6 = 17.98, P = 0.006$). During summer, mule deer home ranges were smaller ($P < 0.05$) than any other season in both areas (Table 1). There was no difference ($P > 0.05$) in sizes of mule deer home ranges between spring (6.0 km^2) and autumn (7.6 km^2) in La Jubaivena. Conversely, home range sizes in winter (12.3 km^2) and spring (10.1 km^2) were larger ($P < 0.05$) than summer (5.1 km^2) and autumn (6.9 km^2) in El Americano (Table 1).

TABLE 1.—Seasonal home ranges (km^2) of desert mule deer in central and western Sonora, Mexico, 2002–2004.

	Study areas							
	La Jubaivena, Sonora, Mexico ^a				El Americano, Sonora, Mexico			
	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn
Mean	---	6.04	4.45 ^b	7.63	12.31	10.08	5.06 ^b	6.92
SE	---	0.75	0.55	0.85	3.02	2.41	0.48	2.07
Range	---	1.3 - 11.2	1.3 - 8.7	2.4 - 15.2	1.3 - 36.6	3.6 - 32.3	3.1 - 9.1	2.1 - 14.3
No. animals	---	18	18	17	11	11	13	6
No. locations	---	334	286	321	172	236	262	84

^a Home range sizes were different between areas (Kruskal-Wallis $\chi^2 = 17.98, 6 \text{ df}, P = 0.006$).

^b Statistically different ($P < 0.05$) among seasons in the same area.

During capture operations in La Jubaivena, 4 of 19 deer were captured inside buffelgrass pastures. These animals were subsequently located 235 times. All but 2 locations were inside the perimeters of the buffelgrass plantations. Therefore, we compared the home ranges of the deer inside buffelgrass areas to the rest of the collared mule deer in La Jubaivena. There was no difference (Kruskal-Wallis, $\chi^2_1 = 0.28, P = 0.60$) in the size of home ranges of mule deer from inside buffelgrass areas ($5.16 \text{ km}^2 \pm 0.95 [SE]$) when compared with the size of home ranges of the other collared deer ($6.16 \text{ km}^2 \pm 0.51 [SE]$) in La Jubaivena.

We determined the boundaries of each study area by connecting all the outermost locations of collared deer and adding a zone of half the mean traveled distance registered between individual locations, and used that information to examine habitat use. We defined 24,155 ha for La Jubaivena (Figure 2) and 83,036 ha for El Americano (Figure 3). Buffelgrass made up 32 and 1% of the study areas in La Jubaivena and El Americano, respectively (Table 2 Table 3).

TABLE 2.—Utilization-availability of vegetation associations used by desert mule deer in the La Jubaivena study area, western Sonora, Mexico, 2002–2004.

Vegetation association	Total area (ha)	Relative area (%)	Expected usage	Observed usage	(Obs-Exp) ² ÷Exp	Bonferroni 95% C.I.		Degree of selection
						lower	upper	
Prju-Capu ^a	884	4	43.00	196	544.3667	0.1396	0.1940	(++) S ^c
Olte-Enfa ^b	14,382	60	699.60	698	0.0037	0.5583	0.6298	(-)
Busp-Mila ^c	1,199	5	58.32	2	54.3929	0.0000	0.0047	(-) A
Buffelgrass ^d	7,690	32	374.07	279	24.1637	0.2064	0.2685	(-) A
Total	24,155	100	1,175	1,175				

^a Mesquite – bird-of-paradise – Xeroriparian; ^b Ironwood – brittlebush – Plains; ^c Elephant tree – catclaw mimosa – Foothills; ^d Buffelgrass pastures; ^e (++) S = used > expected, (-) A = used < expected, (+) = used as expected.

TABLE 3.—Utilization-availability of vegetation associations used by desert mule deer in the El Americano study area, central Sonora, Mexico, 2002–2004.

Vegetation association	Total area (ha)	Relative area (%)	Expected usage	Observed usage	(Obs-Exp) ² ÷Exp	Bonferroni 95% CI		Degree of selection
						lower	upper	
Prju-Capu ^a	1,050	1	10.48	63	263.1029	0.0517	0.1003	(++) S ^g
Busp-Jacu ^b	12,679	15	126.58	64	30.9407	0.0527	0.1017	(-) A
Latr-Cemi ^c	26,350	32	263.07	200	15.1201	0.2021	0.2805	(-) A
Latr-Frsp ^d	36,535	44	364.75	493	45.0941	0.5497	0.6397	(++) S
Latr-Papr ^e	5,915	7	59.05	5	49.4765	0.0000	0.0131	(-) A
Buffelgrass ^f	507	1	5.06	4	0.2227	0.0000	0.0112	(-)
Total	83,036	100	829	829				

^a Mesquite – ironwood – Xeroriparian; ^b Elephant tree – limber bush – Northern foothills; ^c Creosote bush – paloverde – Hills; ^d Creosote bush – *Franseria* spp. – Plains; ^e Creosote bush – etcho – Coastal plains; ^f Buffelgrass pastures; ^g (++) S = used > expected, (-) A = used < expected, (+) = used as expected.

Desert mule deer did not use the vegetation associations in proportion to their availability in either study area ($P < 0.001$; Table 2, $\chi^2_3 = 622.9$; Table 3, $\chi^2_5 = 404.0$). In general, desert mule deer selected xeroriparian vegetation in both areas throughout the study (Table 2, Table 3). Vegetation association in plains next to xeroriparian areas was also selected in El Americano (Table 3), and used in proportion to availability in La Jubaivena (Table 2). The buffelgrass area was avoided in La Jubaivena, and used in proportion to availability in El Americano.

The mesquite – bird-of-paradise – xeroriparian association was selected during all seasons in La Jubaivena (Table 4; $\chi^2_3 = 11.1$). The elephant tree – catclaw mimosa – foothills association was consistently avoided. The ironwood – brittlebush – plains association was used in proportion to availability in all seasons. Buffelgrass areas were avoided in most seasons except on summer, when they were used in proportion to availability (Table 4).

In El Americano, the mesquite – ironwood – xeroriparian association was also selected during all seasons (Table 5). The creosote bush – bursage – plains association was selected in spring and summer, and was used in proportion to availability during autumn and winter. The creosote bush – etcho – coastal plains association was consistently avoided during all seasons. The elephant tree – limberbush – northern foothills association was avoided during spring and summer, but was used in proportion to availability during autumn

TABLE 4.—Selection (S) and avoidance (A) of vegetation associations by desert mule deer in the La Jubaivena study area, western Sonora, Mexico, 2002–2004.

Season	χ^2	No. locations	Vegetation association			
			Prju-Capu ^a	Olte-Enfa ^b	Busp-Mila ^c	Buffelgrass ^d
Winter	30.57	174	S ^e	--	A	A
Spring	51.33	255	S	--	A	A
Summer	50.46	267	S	--	A	--
Autumn	100.18	133	S	--	A	A

^a Mesquite – bird-of-paradise – Xeroriparian; ^b Ironwood - brittlebush - Plains; ^c Elephant tree - catclaw mimosa - Foothills; ^d Buffelgrass pastures; ^e S = used > expected, A = used < expected, (--) = used as expected.

TABLE 5.—Selection (S) and avoidance (A) of vegetation associations by desert mule deer in the El Americano study area, central Sonora, Mexico, 2002–2004.

Season	χ^2	No. locations	Vegetation association					
			Prju-Capu ^a	Busp-Jacu ^b	Latr-Cemi ^c	Latr-Frsp ^d	Latr-Papr ^e	Buffelgrass ^f
Winter	74.49	332	S ^g	--	--	--	A	A
Spring	54.75	171	S	A	--	S	A	--
Summer	61.97	361	S	A	A	S	A	--
Autumn	27.78	311	S	--	--	--	A	--

^a Mesquite - ironwood - Xeroriparian; ^b Elephant tree - limber bush - Northern foothills; ^c Creosote bush - paloverde - Hills; ^d Creosote bush - franseria spp. - Plains; ^e Creosote bush - etcho - Coastal plains; ^f Buffelgrass pastures; ^g S = used > expected, A = used < expected, (--) = used as expected.

and winter. Buffelgrass areas were used in proportion to availability in most seasons, with the exception of winter when these areas were avoided (Table 5). Individual mule deer had access to all associations, and showed a high variation in their preferences for vegetation associations in both study areas (Figure 4, Figure 5).

From the logistic regression analyses, we identified thermal cover (estimate = -0.15 ± 0.049 , $\chi^2 = 9.3$, $P = 0.002$), ground cover (estimate = -0.06 ± 0.036 , $\chi^2 = 2.4$, $P = 0.09$), and percentage of gravel covering the substrate (estimate = 0.03 ± 0.018 , $\chi^2 = 2.93$, $P = 0.08$) as the variables that distinguished ($P < 0.10$) locations selected by desert mule deer when compared to random locations. These habitat characteristics varied between areas and among seasons (Table 6).

Consistently, thermal cover was higher ($P < 0.05$) in locations selected by mule deer when compared to random locations in both areas. Thermal cover inside buffelgrass areas (10.5%) was significantly lower ($P < 0.05$) than in locations outside buffelgrass areas (18.4%). Thermal cover was highest in summer in La Jubaivena and highest in autumn in El Americano (Table 6).

With the exception of winter in La Jubaivena, ground cover was higher at sites selected by mule deer than in random locations during all seasons in both areas of study. However, the only significant difference ($P < 0.05$) in ground cover occurred during winter (26.5%) at El Americano.

TABLE 6.—Differences in thermal cover (TC), ground cover (GC), and percentage of gravel covering the ground (Gr) between selected and random sites for desert mule deer in central and western Sonora, Mexico, 2002–2004.

Season and area	Selected			Random		
	TC	GC	Gr	TC	GC	Gr
Winter						
La Jubaivena	10.9*	33.6	4.7	7.0	45.0	5.9
El Americano	19.8	26.5*	23.8	11.2	10.9	35.1
Spring						
La Jubaivena	18.5*	24.3	0.0	3.5	21.0	0.0
El Americano	12.9*	19.5	7.8*	4.1	15.9	22.7
Summer						
La Jubaivena	27.9*	31.5	0.0	12.8	27.7	0.0
El Americano	16.4*	22.3	10.3	6.9	20.5	16.9
Autumn						
La Jubaivena	18.9	28.9	0.0	14.6	26.7	0.0
El Americano	23.5*	15.3	9.3	10.9	14.9	13.5

* Indicates difference ($P < 0.05$) between selected and random sites for the same characteristic.

The presence of gravel in La Jubaivena was detected only in random and selected sites during winter. Percentage of gravel for that area and season was not significantly different ($P > 0.05$). Gravel was present at all sites (i.e., both random and selected sites) at El Americano. Percentage of gravel was lower at selected locations than at random locations during all seasons in that area; however, a significant difference ($P < 0.05$) was reported at selected locations (7.8%) when compared to random locations (22.7%) during spring.

We obtained 1,175 and 829 locations of desert mule deer in La Jubaivena and El Americano, respectively to examine the relationships of deer to the distance to water sources. The average distance of desert mule deer to the nearest source of water was closer ($P < 0.05$) in every season throughout the study than were random locations. At La Jubaivena, mean distances of desert mule deer to nearest water were 1.9 ± 0.07 , 1.5 ± 0.05 , 1.7 ± 0.05 , and 2.0 ± 0.05 km in winter, spring, summer, and autumn, respectively. Distances to a nearest source of water were closer ($P < 0.05$) during spring and summer than during other seasons.

In El Americano, mean distances of desert mule deer to the nearest source of water were 3.5 ± 0.22 , 2.4 ± 0.19 , 2.1 ± 0.18 , and 2.6 ± 0.26 km in winter, spring, summer and autumn, respectively. Mean distance to the nearest water source was less during summer than during any other season, not significantly different ($P > 0.05$) from spring or autumn. During winter, the mean distance to the nearest source of water was larger ($P < 0.05$) than during any other season.

DISCUSSION

Home range size and movements of desert mule deer are influenced by season, habitat, and other factors inherent to the species (Mackie et al. 1982, Anderson and Wallmo 1984, Heffelfinger 2006). Home range size increases as the distance between necessary resources increases. Mackie et al. (1982) reported home ranges in semi-desert ranges as large as 21 km². However, in arid environments home ranges are as large as 8 times that reported by Mackie et al. (1982). Studies in southern Arizona have reported home ranges for desert mule deer ranging from 121 to 172 km² (Krausman 1985, Rautenstrauch and Krausman 1989).

Overall in our study, sizes of home ranges were larger in El Americano than in La Jubaivena. El Americano in western Sonora receives lower precipitation and has scarce vegetation when compared to La Jubaivena in central Sonora. Our findings agree with the statements that in more arid environments the mule deer exhibit larger home ranges to obtain their necessary resources (Fox and Krausman 1994, Krausman and Etchberger 1995). During summer, desert mule deer home ranges were smaller than during any other season in both of our study areas. Similar results were obtained by Fox and Krausman (1994), and Krausman and Etchberger (1995) for female mule deer from western Arizona. There were no differences in sizes of home ranges between spring and autumn at La Jubaivena. Conversely, home range sizes in winter and spring were larger than summer and autumn in El Americano. Our results were consistent with the sizes of home ranges reported for mule deer in the Belmont and Big Horn mountains, Arizona (Fox and Krausman 1994).

Buffelgrass areas comprised >30% of the study area at La Jubaivena. Mule deer inhabit those areas all year. There was no difference in the size of home ranges of mule deer inside buffelgrass areas when compared to the size of home ranges of the other collared mule deer. No previous documentation is available with which to compare our results. Plantations of buffelgrass have been present since the 1980s. Although most shrubs and trees were removed in preparation for seeding buffelgrass, a combination of trees and shrubs is present that provides enough resources for some mule deer to stay in those areas.

Desert mule deer selected xeroriparian vegetation and the adjacent plains were selected or used in proportion to availability during spring and summer (warmer seasons) in both areas throughout the study. Tree and shrub cover in those selected areas provide thermal shelter for desert mule deer, especially for pregnant or lactating females. Similar observations were made by Fox and Krausman (1994), who reported that females selected areas with vegetation to protect their fawns from predators and temperature extremes. Tull et al. (2001) also reported that desert mule deer selected bed sites in areas of relatively high thermal cover in all seasons.

Our data indicated that buffelgrass areas were avoided or used in proportion to availability, but were never selected. However, individual variability in proportion of habitat use minus proportion of availability suggests that mule deer selected home ranges with no regard to the availability of buffelgrass pastures. We suggest that the level of reduction in thermal cover and browse in buffelgrass areas does not constrain use of these areas by female mule deer. Four of the 19 collared deer in central Sonora exhibited annual home ranges completely inside buffelgrass areas, even though they had access to the other associations. The home ranges of four other collared deer, which were captured outside buffelgrass areas, included the same buffelgrass areas; one of those was located 48% of the time inside buffelgrass pastures.

Our data also indicate that desert mule deer selected sites closer to water sources than were random locations. Free-standing water was probably the reason that some mule deer stayed in buffelgrass areas. Water has been considered an important limiting factor for desert mule deer (Leopold and Krausman 1991). The amount and distribution of water sources affect the distribution of mule deer in arid environments (Marshall et al 2006). In the southwestern United States, mule deer are usually found within 2.4 km of free water (Hanson and McCulloch 1955, Swank 1958, Boroski and Mossman 1996). Some studies in the desert areas of southwestern Arizona and California reported similar observations where mule deer were significantly closer to water sources during summer (Hervert and Krausman 1986, Ordway and Krausman 1986, Krausman et al. 1989, Rautenstrauch and Krausman 1989, Krausman and Etchberger 1995, Marshall et al. 2005). Ranching has been the main activity in the rangelands of Sonora, Mexico since 1950. Thus, water sources for cattle have been established throughout areas occupied by desert mule deer. Additionally, recent interest by ranchers in managing wildlife populations has added more water sources to mule deer habitat.

We could not conclude that desert mule deer use areas altered with buffelgrass differed from areas without buffelgrass. Our data suggest that desert mule deer used altered areas with buffelgrass, but selected sites with higher thermal cover and that were closer to water sources.

Conditions for desert mule deer in the rangelands of Sonora are different than conditions in other regions of their distribution. Cattle grazing, removal of scrub vegetation, introduction of exotic forages, and the number of artificial water sources have obviously altered natural interactions among mule deer and their habitat. Undoubtedly, the reduction of cover and forage in arid environments represent a major concern for conservation of desert mule deer. Managers should recognize that even in altered habitats, mule deer use areas having cover and forage provided by trees and shrubs. Thus, it is very important to minimize extensive transformation of new areas into open grasslands. Another major concern should be the potential risk of wild fires when increasing buffelgrass stands. Areas where buffelgrass is not grazed may accumulate large loads of dry fuel that cause fires of high intensity. These fires destroy cacti, shrubs, and trees that provide important food and cover for mule deer. It also is important to continue with more research to quantify the level of those alterations, and to further evaluate the performance of mule deer inhabiting the Sonoran Desert. Research and adaptive management should focus on identifying threshold limits of altered habitats, determining differences in mule deer densities, and evaluating the productivity and survival rates of desert mule deer in relation to those alterations.

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