AP AGRO PRODUCTIVIDAD

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Forage diversity and selection in white-tailed deer (*Odocoileus virginianus Texanus* MEARNS) in Coahuila, Mexico

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ABSTRACT

Objective: To identify diet diversity and selection among white-tailed deer (*Odocoileus virginianus texanus* Mearns) at UMA Rancho San Juan, Monclova, Coahuila, Mexico, from October 2018 to August 2019.

Design/methodology/approach: The composition of the white-tailed deer's diet was identified by applying the microhistological technique. The line interception method was used to estimate the seasonal availability of forage. Diet and forage diversity were established based on the Shannon index, while their relation was identified using a simple linear regression. Diet selection was determined using the chi-squared test and Ivlev's electivity index.

Results: We identified 49 species and 20 families in the diet, which comprised 49.84% shrubs, 18.38% succulents, 16.02% herbaceous plants, and 15.72% grasses. Deer selected *Opuntia engelmannii*, consumed *Acacia rigidula* and *Cenchrus ciliaris* in proportion to their availability, and consumed *Acacia berlandieri*, *Jatropha dioica*, and *Karwinskia humboldtiana* below their availability.

Study Limitations/Implications: This line of research should be further pursued, including nutritional quality aspects of the forage and diet variations between sampling years. We also recommend fostering the presence of herbaceous plants through habitat improvement techniques.

Conclusions: No relation was found between diet and forage diversity. When forage diversity decreased, grass intake increased.

Key words: Line interception method, availability, Ivlev, desert scrub, microhistological technique.

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INTRODUCTION

The white-tailed deer (*Odocoileus virginianus texanus* Mearns) is the most important game species in Mexico. Although they inhabit widely diverse ecosystems (Villarreal *et al.*, 2014), white-tailed deer are mainly associated with the desert scrubs of northeastern

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Mexico (Mandujano *et al*., 2010; Gastelum-Mendoza *et al*., 2020). Unlike other herbivores, they are selective ruminants that feed on forage depending on food type and availability, physiological state, and density-dependent factors (Ramírez, 2004). White-tailed deer's tendency to prefer shrubs and herbaceous plants to other types of forage has been well documented, as has the fact that habitat conditions have a direct influence on their selection of certain plant groups (Gallina, 1993; Ramírez *et al*., 1997; Ramírez, 2004). Likewise, foraging intensity on certain plant species directly affects the habitat's carrying capacity (Ramírez *et al*., 1997; Fulbright and Ortega-Santos, 2007).

The white-tailed deer's foraging habits have been studied in Mexico and the United States. In northern Mexico, for instance, 51 species are considered important for their diet (Villarreal, 1999). Ramírez (2004) reports that 79 plant species make up the deer's diet in northeastern Mexico. Although white-tailed deer feed on a large number of plants, most of them belong to just a few species (Quinton and Horejsi, 1977; Murden and Risenhoover, 1993; Pietz, 2000). In habitats with a high diversity of foraging species, deer can consume over 160 different species. However, 50% of their diet can consist of less than 10% of the said species (Chamrad and Box, 1968). In the State of Durango, only 18 out of the 135 species consumed by deer were found in more than 1% of the diet (Gallina, 1984). In the South Texas Plains region (USA), 10 out of 83 consumed species comprised 53% of the diet (Everitt and Drawe, 1974). Although the Texan white-tailed deer is the most important game species in northeastern Mexico, its foraging habits in the State of Coahuila have not been studied. In order to provide the white-tailed deer's handlers with the information they need to improve this species' habitat —focusing on its *in situ* conservation—, this study sought to determine the deer's diet composition and diversity, as well as the way in which it selects its food depending on availability.

MATERIALS AND METHODS

Study area description

The study was conducted at the Unidad de Manejo para la Conservación de la Vida Silvestre (UMA) [Wildlife Conservation Management Unit] Rancho San Juan (26° 49' 31.11" N, 101° 01' 57.77" W), located in the municipality of Monclova, Coahuila, Mexico (Figure 1), 38 km in a straight line east of the municipality's capital and 43 km west of the municipality of Candela. The predominant vegetation type is the microphyllous desert scrub (Rzedowski, 1978). The climate is dry (BS_0hw), with an annual average temperature of 21 °C. Annual rainfall varies between 200 and 900 mm. Elevation fluctuates between 600 and 1,000 m.a.s.l (García, 2004). An area of 1,532.14 ha within the UMA is allocated for the handling of Texan white-tailed deer (26° 48' 09.96" N, 101° 00' 15.77" W).

Forage availability

An herbivore's food selection is expressed as the relation between each species' contribution to its diet and their availability in the habitat (Strauss, 1979). The said relation was assessed using Canfield's line interception method (1941). To this end, 18 lines of 25 m of length each were randomly placed for each season: autumn (October 2018), winter (February 2019), spring (May 2019), and summer (August 2019). In all cases,

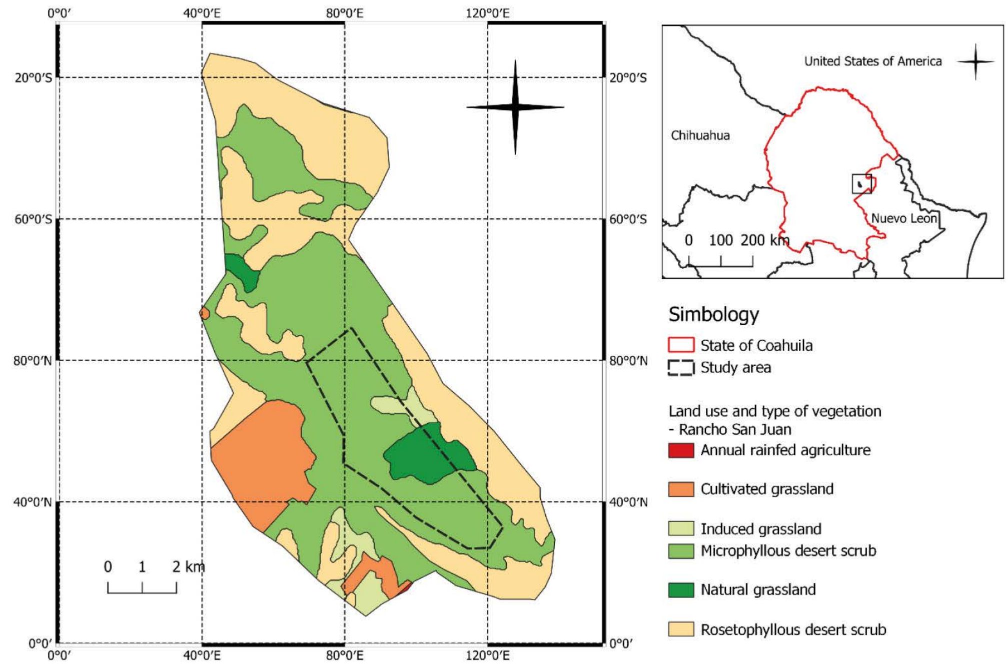

Figure 1. Location of the study area and the vegetation types at UMA Rancho San Juan, Monclova, Coahuila, Mexico.

the plants intercepting the lines were quantified. The species were classified according to their biological form as bushy, herbaceous, grasses, and succulents. Their availability was expressed as each species' relative frequency per season, according to the following formula (Curtis and Mclntosh, 1951):

$$Relative\ frequency = \left(\frac{Number\ of\ lines\ containing\ species\ i}{Total\ number\ of\ lines\ in\ the\ season} \right) * 100$$

Diet diversity and selection

In order to establish the composition of the white-tailed deer's diet, we used the microhistological technique, which identifies fragments of plant epidermis in fecal samples (Sparks and Malechek, 1968; Peña and Habib, 1980). With this aim, 50 white-tailed deer fecal groups were collected per season: autumn (October 2018), winter (February 2019), spring (May 2019), and summer (August 2019). Likewise, we compiled a photographic reference catalog of 150 plant species and their characteristic cell structures. The fecal samples were placed in paper bags, labeled, and dried in an INOX oven (120VAC, 60HZ) at 75 °C during 48 h. Subsequently, they were grinded in a Wiley mill and grouped in four composite samples (one per season). These were diluted with sodium hypochlorite, according to the procedure described by Sparks and Malechek (1968). Finally, they were placed on 20 microscope slides (five per each composite sample), using a metal plate with 7-mm-diameter holes, in order to homogenize the sample size in each slide. Twenty fields of view per slide were observed under the microscope at 100x magnification, in order to identify and count the plant cell structures. The identified plant species were classified according to their biological form as: shrubs, herbaceous, grasses, and succulents. The results were expressed as the relative frequency of each plant species in the diet, following Peña and Habib (1980).

To establish forage selection, we compared the availability of the species in each season and their contribution to the deer's diet. This was quantified according to two analyses. The first one was based on the chi-squared test ($\alpha \leq 0.05$), used to estimate the differences between the percentage of the plant in the diet and its availability in the habitat; and the second one was based on Ivlev's electivity index (Strauss, 1979) according to the following formula:

$$Ei = \frac{\left[r(i) - p(i)\right]}{\left[r(i) + p(i)\right]}$$

Where: Ei = Forage selectivity index; $r(i)$ = Relative frequency of species i in the diet; $p(i)$=Relative frequency of species i in the habitat.

The values for this index were classified according to Stuth (1991): >0.35, preferred plants (*S*); -0.35 to 0.35, plants consumed in proportion to their availability (*P*);<-1.0, avoided plants (*E*). The diversity of diet and vegetative cover was estimated using the Shannon diversity index (1948); both were then compared by means of a simple linear regression model.

RESULTS AND DISCUSSION

We identified 49 species and 20 families in the white-tailed deer's diet (Table 1). However, 50.23% of the diet included only seven species (*Acacia rigidula*, *Erioneuron pulchellum*, *Eysenhardtia texana*, *Leucophyllum frutescens*, *Opuntia engelmannii*, *Opuntia leptocaulis*, and *Prosopis glandulosa*). The most common families in the diet were Poaceae, Fabaceae, and Asteraceae. The annual diet comprised 49.84% brush species, 18.38% succulents, 16.02% herbaceous plants, and 15.72% grasses. Brush species were predominant in the diet during the four seasons. Herbaceous plants were more common in winter, grasses in summer, and succulents in spring (Figure 2). Herbaceous plants were the only group selected by the white-tailed deer for its diet ($\chi^2=44.43$, $P<0.05$), which proves the deer's preference for this plant group.

No values over 20% were identified for grasses in the diet; therefore, no preliminary indicators of habitat overuse and poor nutrition were observed (Kie *et al.*, 1980). *Opuntia engelmannii* was the most consumed among the succulent species (Table 1 and Figure 3). We were also able to infer that white-tailed deer avoided consuming succulents in summer ($\chi^2=68$, $P<0.05$). During the rest of the year, succulents were proportionally consumed. Although water requirements usually increase in summer (Ramírez, 2004), UMA has ten artificial water sources that cover these requirements, therefore reducing the intake of prickly pears. Moreover, we identified filler plant species that were consumed depending on their availability; this category included *Acacia rigidula*, *Cenchrus ciliaris*, and *Eysenhardtia texana*. Meanwhile, the most avoided species were *Acacia berlandieri*, *Euphorbia antisyphilitica*,

Table 1. Seasonal composition of the white-tailed deer's diet per biological form, family, and species at UMA Rancho San Juan, municipality of Monclova, Coahuila, Mexico.

Family	Species	Season (2018-2019)			
		Spring (%)	Summer (%)	Autumn (%)	Winter (%)
Shrubs					
Fabaceae	*Acacia berlandieri*	0.28	0.29		
Fabaceae	*Acacia farnesiana*	0.28	0.57	0.65	
Fabaceae	*Acacia rigidula*	11.29	12.57	6.94	4.51
Verbenaceae	*Aloysia macrostachya*	1.1	1.71	0.65	0.23
Asteraceae	*Baccharis texana*	1.65	0.57	1.3	
Bignoniaceae	*Chilopsis linearis*	0.83			
Euphorbiaceae	*Croton punctatus*			4.12	5.19
Euphorbiaceae	*Croton torreyanus*	0.83	1.14	9.33	5.87
Ebenaceae	*Diospyros texana*		0.57		
Ephedraceae	*Ephedra pedunculata*	1.1			0.23
Euphorbiaceae	*Euphorbia antisyphilitica*	3.86	0.57	1.74	7.67
Fabaceae	*Eysenhardtia texana*	8.54	7.43	11.28	1.81
Oleaceae	*Forestiera angustifolia*	1.65		4.12	0.45
Zygophyllaceae	*Guaiacum angustifolium*	7.16	3.14	0.43	0.23
Asteraceae	*Gymnosperma glutinosum*			0.22	
Asteraceae	*Hymenoxys odorata*		0.29	0.43	
Euphorbiaceae	*Jatropha dioica*		0.29		
Rhamnaceae	*Karwinskia humboldtiana*		0.29		0.23
Krameriaceae	*Krameria erecta*		2	0.22	
Zygophyllaceae	*Larrea tridentata*		0.86	0.22	1.13
Scrophulariaceae	*Leucophyllum frutescens*	1.93	0.57	5.42	1.61
Verbenaceae	*Lippia graveolens*		0.57		
Fabaceae	*Mimosa zygophylla*	3.31	2	3.9	1.81
Fabaceae	*Prosopis glandulosa*	5.23	7.43	1.52	4.29
Solanaceae	*Solanum elaeagnifolium*	0.83		0.22	0.68
Rhamnaceae	*Ziziphus obtusifolia*		6.86	2.17	
Herbaceous					
Malvaceae	*Abutilon wrightii*	2.2	1.71	2.82	0.45
Asteraceae	*Acourtia runcinata*	0.28			
Nyctaginaceae	*Allionia incarnata*	0.55	1.43	1.8	7.9
Asteraceae	*Ambrosia dumosa*	0.28		3.47	4.74
Fabaceae	*Dalea bicolor*	0.55	4.29	1.74	1.13
Convolvulaceae	*Evolvulus alsinoides*		1.14	0.65	0.23
Fabaceae	*Medicago sativa*	2.75	4.29	1.74	4.29
Asteraceae	*Parthenium argentatum*		0.29		
Asteraceae	*Parthenium sp.*	0.55			2.3
Brassicaceae	*Physaria fendleri*				3.16
Boraginaceae	*Tiquilia canescens*		2.29	2.82	3.39
Grasses					
Poaceae	*Aristida adscensionis*		1.14	1.3	0.23
Poaceae	*Aristida purpurea*	1.65		3.9	0.23
Poaceae	*Bouteloua curtipendula*			1.95	
Poaceae	*Bouteloua hirsuta*	0.55		1.95	1.58
Poaceae	*Cenchrus ciliaris*	3.3	4.29	2.39	1.81
Poaceae	*Cynodon dactylon*	0.83		0.22	0.45
Poaceae	*Heteropogon contortus*	1.1	6.57	0.22	0.45
Poaceae	*Hilaria mutica*		0.57		
Poaceae	*Erioneuron pulchellum*	9.37	16	0.22	0.9
Succulents					
Cactaceae	*Opuntia engelmannii*	18.73	4.29	15.4	14.9
Cactaceae	*Opuntia leptocaulis*	7.71	2	3.4	7
Cactaceae	*Opuntia microdasys*			0.22	0.23

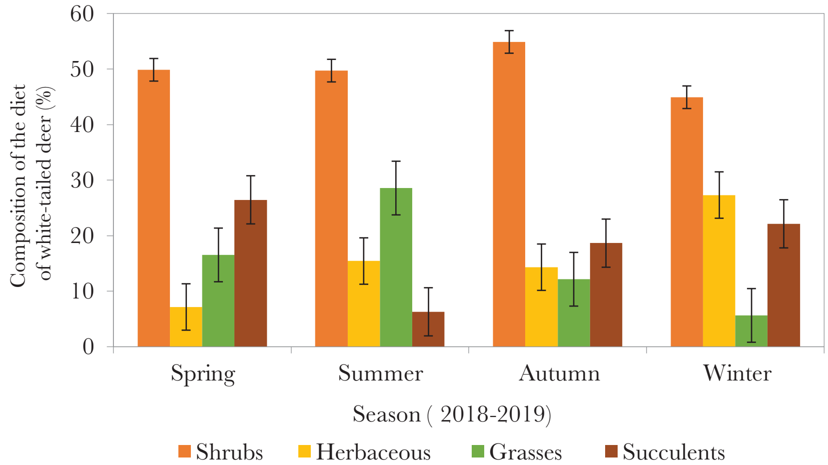

Figure 2. Seasonal composition of the white-tailed deer's diet according to the biological form of plants at UMA Rancho San Juan, Monclova, Coahuila, Mexico (the vertical lines over the bars indicate the typical error).

Figure 3. Evidence of the white-tailed deer grazing on *Opuntia engelmannii* at UMA Rancho San Juan, Monclova, Coahuila, Mexico.

Jatropha dioica, and *Karwinskia humboldtiana*. The only preferred species was *Opuntia engelmannii* (Table 2).

Shrub grazing is the base of the white-tailed deer's diet (Gallina, 1993; Ramírez *et al.*, 1996). Particularly in the southeastern United States and northeastern Mexico, where a seasonal shortage of herbaceous vegetation occurs, this kind of deer survives by feeding on a shrub diet (Campbell and Hewitt, 2014). The chi-squared test indicates that there is no difference between contribution of shrubs to the diet and their availability in the habitat. This means that deer consumed these species either randomly or in proportion to their availability. In this regard, Fulbright and Ortega-Santos (2007) mention that the deer's shrub intake serves as a nutritional bridge between periods of herbage availability. White-tailed deer have a strong preference for herbs as compared with grazing, since herbs are generally more digestible and have a higher nutritional value than shrubs (Ramírez *et al.*, 1997; Ramírez, 2004; Fulbright and Ortega-Santos, 2007). However, herbage represented only 16.31% of the annual diet in this study; it was more important for the winter diet and

Table 2. Chi−squared test values ($\alpha \leq 0.05$) in diet composition and forage availability, and Ivlev's electivity index for the white−tailed deer's diet at UMA Rancho San Juan, municipality of Monclova, Coahuila, Mexico.

	Expected use^{+} (%)	**Observed use^{++} (%)**	**Ivlev**	**Type of use^{+++}**
Acacia berlandieri				
Spring	6.18	0.28	−0.91	E
Summer	3.28	0.29	−0.84	E
Autumn	2.66	0.00	−1.00	E
Winter	4.52	0.00	−1.00	E
χ^2=155.15, g. l.=3, P<0.05				
Acacia rigidula				
Spring	6.74	11.29	0.25	P
Summer	4.92	12.57	0.44	S
Autumn	4.79	6.94	0.18	P
Winter	5.03	4.51	−0.05	P
χ^2=7.22, g. l.=3, NS^{+++}				
Cenchrus ciliaris				
Spring	3.93	3.30	−0.09	P
Summer	4.92	4.29	−0.07	P
Autumn	2.13	2.39	0.06	P
Winter	4.02	1.81	−0.38	E
χ^2=2.94, g. l.=3, NS				
Euphorbia antisyphilitica				
Spring	8.99	3.86	−0.40	E
Summer	7.10	0.57	−0.85	E
Autumn	9.04	1.74	−0.68	E
Winter	8.04	7.67	−0.02	P
χ^2=112.27, g. l.=3, P<0.05				
Eysenhardtia texana				
Spring	3.93	8.54	0.37	S
Summer	4.37	7.43	0.26	P
Autumn	4.26	11.28	0.45	S
Winter	2.01	1.81	−0.05	P
χ^2=8.14, g. l.=3, P<0.05				
Forestiera angustifolia				
Spring	2.81	1.65	−0.26	P
Summer	1.09	0.00	−1.00	E
Autumn	0.53	4.12	0.77	S
Winter	1.01	0.45	−0.38	E
χ^2=4.64, g. l.=3, NS				

Table 2. Continues...

	Expected use^{+} (%)	Observed use^{++} (%)	Ivlev	Type of use^{+++}
Guaiacum angustifolium				
Spring	1.69	7.16	0.62	S
Summer	1.09	3.14	0.48	S
Autumn	2.66	0.43	−0.72	E
Winter	2.01	0.23	−0.79	E
χ^2=30.86, g. l.=3, P<0.05				
Jatropha dioica				
Spring	4.49	0.00	−1.00	E
Summer	4.92	0.29	−0.89	E
Autumn	2.66	0.00	−1.00	E
Winter	3.52	0.00	−1.00	E
χ^2=73.92, g. l.=3, P<0.05				
Karwinskia humboldtiana				
Spring	1.69	0.00	−1.00	E
Summer	2.19	0.29	−0.77	E
Autumn	1.60	0.00	−1.00	E
Winter	4.52	0.23	−0.90	E
χ^2=92.47, g. l.=3, P<0.05				
Opuntia engelmannii				
Spring	4.49	18.73	0.61	S
Summer	6.01	4.29	−0.17	P
Autumn	3.19	15.40	0.66	S
Winter	4.02	14.90	0.58	S
χ^2=29.14, g. l.=3, P<0.05				
Opuntia leptocaulis				
Spring	3.37	7.71	0.39	S
Summer	2.19	2.00	−0.04	P
Autumn	2.13	3.40	0.23	P
Winter	0.50	7.00	0.87	S
χ^2=8.97, g. l.=3, P<0.05				

$^{+}$ Expected use: forage availability expressed in relative frequency; $^{++}$ observed use: percentage in diet; $^{+++}$ type of use: selected plants (S), plants consumed in proportion to their availability (P), avoided plants (E), NS=not significant.

less important in spring and summer (Figure 2). Winter herbaceous plants that reproduce from seeds and complete their life cycle in a year are generally absent during the summer in Texas and northern Mexico (Ramírez, 2004; Fulbright and Ortega-Santos, 2007). Moreover, herbage represents only a small fraction of the diet in arid environments such as northeastern Mexico (Arnold and Drawe, 1979). However, in areas with greater rainfall, herbage can be predominant in the white-tailed deer's diet. Navarro *et al.* (2018) found that herbage comprised 70.80% of the deer's diet in Tlachichila, Zacatecas. Likewise, Olguín *et al.* (2017) report that white-tailed deer consumed 36.5% herbage in a thorn scrub in Tamaulipas.

Deer do not usually eat grass, since they cannot efficiently digest mature grasses due to their digestive anatomy (Hanley, 1982). Nevertheless, the deer can efficiently consume regrowths after a rainy period (Fulbright and Ortega-Santos, 2007). Meyer *et al.* (1984) mention that grasses can constitute over 40% of the deer's diet during humid periods. This is a potential explanation for the higher percentage of grasses in spring and summer (Figure 2). Besides, deer did not avoid grass intake during these seasons, as they did in autumn and winter ($\chi^2=68$, $P<0.05$), when grass contribution to their diet was lower (Figure 2).

Succulents, particularly prickly pear (*Opuntia* spp.), are considered buffering species in arid areas, since deer consume them to meet their water requirements (Espino-Barro and Fuentes, 2005). Brush species, such as guajillo (*Acacia berlandieri*) and blackbrush acacia (*Acacia rigidula*), can constitute over 70% of the deer's diet in northeastern Mexico (Ramírez *et al.*, 1996). Still, they only amounted to 8.97% of the deer's annual diet in this study. Nevertheless, succulents as a whole were the most important species in their diet. Deer avoided guajillo throughout the year, while they consumed blackbrush acacia in proportion to its availability (Table 2). Since these plants were not among the deer's preferred species, their nutritional contribution to this animal's diet might be deficient. In this regard, Campbell and Hewitt (2014) found that the concentration of calcium, phosphorus, and sodium in the deer's diet diminished as the guajillo intake increased.

Deer change their plant selection depending on the season: *Eysenhardtia texana*, for instance, was a filler species in the summer and winter diet, while in spring and autumn it was a preferred species; *Forestiera angustifolia* was avoided in summer and winter, regularly consumed in spring, and preferred or selected in autumn; *Guaiacum angustifolium* was preferred in spring and summer, and avoided in autumn and winter. Unlike *Opuntia engelmannii*, tasajillo (*Opuntia leptocaulis*) was only preferred in spring and winter.

Out of the 43 available plant species, 14 are not reported as part of the white-tailed deer's diet (Ramírez, 1989; Ramírez *et al.*, 1997). These can be considered avoided species among white-tailed deer and their function might be related to thermic and escape covers. Although food diversity in the habitat is important to maintain an adequate nutritional diet, no relation between diet and forage diversity was observed ($R^2=0.13$; $P<0.05$). While diet diversity remained relatively constant throughout the year, vegetative cover diversity decreased from spring to winter. According to Ramírez (2004), no plant meets the deer's nutritional needs throughout the year; consequently, deer try to maintain a diverse diet, despite the decrease in forage diversity. However, when forage diversity decreases, deer increase their intake of less palatable plants with a low nutritional quality (*e.g.*, grasses) and decrease their intake of plants with a high protein and nutrient content (*e.g.*, herbaceous species) (Ramírez *et al.*, 1997; Fulbright and Ortega-Santos, 2007).

CONCLUSIONS

Shrub intake turned out to be the foundation of the white-tailed deer's diet. Although not highly available, herbaceous plants were preferred. Besides, a high grass intake was observed. Grasses were randomly selected and might be evidence of a poor forage diversity. *Acacia berlandieri* was avoided and *Acacia rigidula* was proportionally consumed. Diet diversity did not depend on vegetative cover diversity. The study results are relevant to conduct habitat improvements that favor the presence of species preferred by white-tailed deer in the desert scrubs of northeastern Mexico.

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AGRO
PRODUCTIVIDAD