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Diet and sexual segregation of bighorn sheep (*Ovis canadensis mexicana* Merriam) in Sonora, Mexico

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ABSTRACT

Objective: To determine the diet of the bighorn sheep and identify differences in its composition between sexes and periods (reproductive and segregation).

Design/methodology/approach: The study was conducted at the UMA Rancho Noche Buena, Hermosillo, Sonora, Mexico. To determine the plant species in the bighorn sheep feces the micro histological technique and a cell catalog of plants from the study area were used. From the diet information, the relative frequency, the Shannon-Weaver diversity index and the Kulczynski similarity index by sex and period (reproductive and segregation) were determined.

Results: The diet of the bighorn sheep included 40 plant species, being herbaceous (36.1±4.4%) and grasses (26.8±8.9%) the most common. The male diet during the segregation period was mainly composed of grasses (36.2%) and female diet by herbaceous (30%) and grasses (29.8%). There were no differences in the diversity of the diets in males and females during the segregation period (H´=1.0), overall, their diets were very similar (80%).

Limitations/implications: Collect a greater number of fecal samples by sex and period (reproductive and segregation) and to analyze the nutritional content of the plants consumed by bighorn sheep.

Findings/conclusions: In this study, the sexual segregation exhibited by the bighorn sheep was not due to food preferences.

Key words: diversity, fecal sample, similarity.

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INTRODUCTION

The bighorn sheep (*Ovis canadensis mexicana* M.) is a species that has high ecological and economic values. However, illegal hunting, habitat destruction and competition with exotic and feral species have restricted the distribution of their populations to the state of Sonora (Wehausen, 1996; Creeden and Graham, 1997). The Official Mexican Norms classify it as a species subject to special protection (Diario Oficial de la Federación [DOF], 2010). This species has developed survival strategies, specifically sexual segregation, which occurs at the end of the reproductive season when the groups of adult males separate from the groups of females, offspring, and juveniles (Bleich *et al*., 1997; Barboza and Bowyer, 2000). It is established that during segregation, males, to regain their body condition (after the reproduction period) and establish dominance over other males, require higher food diversity and of better nutritional quality. In contrast, females select safer sites, but with low forage abundance and lower nutritional quality (Main *et al*., 1996; Tarango *et al*., 2002). The sexual segregation exhibited by wild

herbivores has implications on nutrient cycling, ecological succession and species diversity in the ecosystems (Bowyer *et al*., 2001; Espinosa *et al*. 2006; Jansen *et al*., 2009).

Although bighorn sheep has been widely studied in the United States (Festa-Bianchet, 1988; Wehausen, 1996; Bowyer *et al*., 2001; McKinney and Smith, 2007), in Mexico the reported research works for this species are few (Tarango *et al*., 2002; Guerrero *et al*., 2003; Guerrero-Cárdenas *et al*., 2016). In this regard, in Sonora, it has been documented that during the segregation period male and female diets were similar, indicating that this behaviour was not related to food preferences (Tarango *et al*., 2002). Understanding the causes of sexual segregation is important to implement specific habitat management and improvement actions for males and females (Bowyer *et al*., 2001; Pérez-Barbería *et al*., 2007). Therefore, the objective of this study was to identify the composition of the bighorn sheep's diet by sex and period (reproductive and segregation) in the Wildlife Conservation Management Unit (UMA) Rancho Noche Buena at Hermosillo, Sonora, Mexico. In this study, it was assumed that the composition of the diet of males and females during the period of sexual segregation was different.

MATERIALS AND METHODS

The study was conducted from August 2014 to August 2015, at the Wildlife Conservation Management Unit (UMA) Rancho Noche Buena (29° 07' 58.67" N, 112° 02' 11.48" W), located at Hermosillo, Sonora, Mexico (Figure 1). It has a 5,063-ha extension, an arid-warm climate, an elevation between 200 m and 800 m.a.s.l. In it, bighorn sheep inhabits and is used as a game species. The dominant vegetation type is microphyllous desert scrub. The mean annual precipitation is 365.7 mm, with rains from July to September, the average relative humidity is 43% and mean annual temperature 24.8 °C, with a maximum of 48.5 °C in August and a minimum of −4 °C in January (López *et al*., 1999).

Diet composition and diversity

The micro histological technique was used to identify the composition of the diet of the bighorn sheep. It consists of comparing and quantifying the plant structures included in a reference catalog and the observed structures in fecal samples of bighorn sheep (Fracker and Brischle, 1944; Sparks and Malechek, 1968, Holechek *et al*., 1982).

To prepare the catalog, plant species samples were collected from the bighorn sheep distribution sites within the study area. These were classified by biological form (shrubs, arboreal, herbaceous, grasses and succulents), family and species. Sheep feces were collected in field trips during the reproductive period (only during May 2015 due to the sheep hunting season) and the sexual segregation period (October 2014, June and July 2015), during which the sheep were observed and located with Leica® 15×56 binoculars, at distances of between 700 m and 900 m. Once the sheep were located, they were followed with a Swarovski® 60×85 telescope, until they were seen defecating. Subsequently those feces were collected, each sample was recorded, noting the date, sex, period, and then processed in the laboratory.

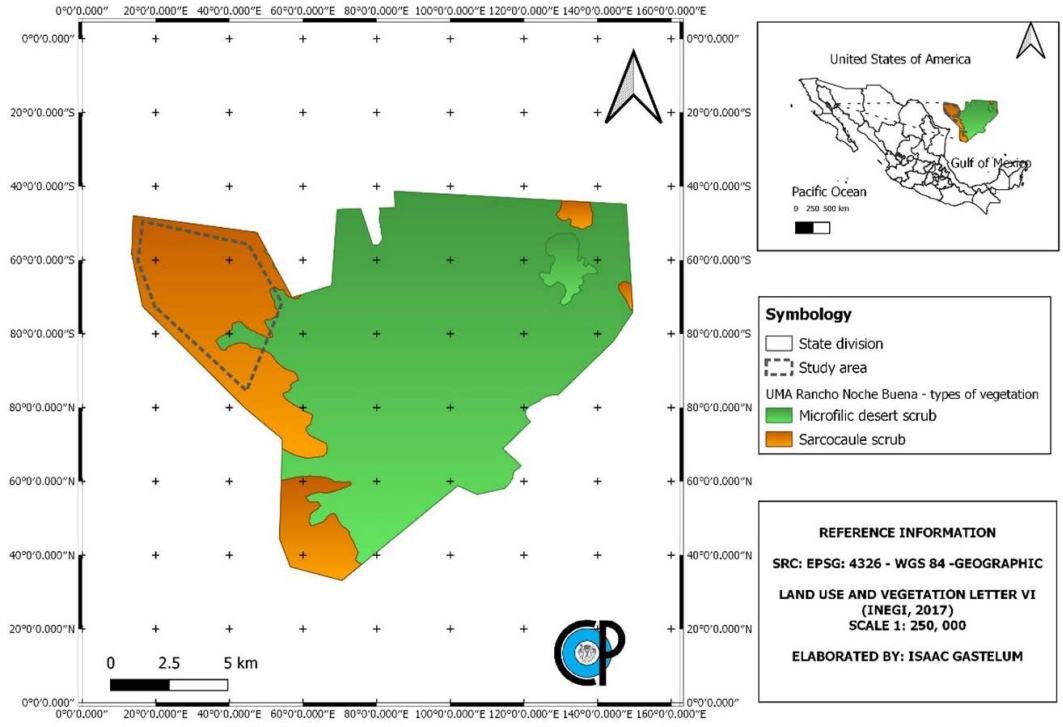

Figure 1. Location and types of vegetation in the UMA Rancho Noche Buena, municipality of Hermosillo, Sonora, Mexico.

The assessment of the bighorn sheep diet was done by collecting, preparing and analyzing seven samples from males and 12 from females during the reproductive period and five samples from males and nine from females during the segregation period. From each fecal group, classified by sex and period, a composite sample was prepared for micro histological analysis. From each sample, five slides were prepared and ten fields per slide were observed with a Leica® DM 4000B microscope with 10X objective and 10X ocular.

The species percentage within the diet by sex and period was calculated by relative frequency following Fracker and Brischle (1944). Species diversity in the diet was calculated using the Shannon-Weaver index (1949). To determine the degree of similarity between diets by sex and period, the Kulczynski index (1928) was calculated using the Past 3.0 statistical software.

RESULTS AND DISCUSSION

The bighorn sheep diet, considering the two periods, reproductive and segregation, was composed of 40 species grouped in 20 families. It has been documented that bighorn sheep in northern latitudes consume a greater number of species. For example, in the northern United States and southern Canada, a consumption of more than 200 species is reported (Brown *et al.*, 1977; Seegmiller and Ohmart 1981). In contrast, in Arizona (Krausman *et al.*, 1989) and California (Seegmiller and Ohmart, 1981) a bighorn sheep diet with a smaller number of plants (58 and 32, respectively) has been recorded. In

Caborca, Sonora, Mexico, the sheep consumed 41 species (Tarango *et al*., 2002), in Baja California Sur 47 (Guerrero *et al*., 2016) and in Coahuila 49 species (Gastelum, 2020).

Males consumed 31 species and females consumed an equal number, from which, nine species were consumed only by males and another nine only by females (Table 1). Males during the reproductive period consumed more herbaceous species (38.6%) and in the segregation period more grasses (36.2%) (Figure 2).

The females during the segregation period mainly consumed herbaceous (30%) and grasses (29.8%); and more herbaceous in the reproductive period (47.6%) (Figure 2). During the segregation period, *Aristida adscensionis* (Figure 3) predominated in male (20.7%) and female diets (27.2%) (Table 1).

Although the diet of males and females in the segregation period was similar (IS=80), grasses were more important for males. In this regard, Ruckstuhl and Neuhaus (2000) mention that the digestive tract of males is more adapted to digest fibrous food with a low digestibility percentage, such as grasses (Figure 3). This has also been documented in other bovids, such as the American bison (*Bison bison* L.) in Kansas, United States (Post *et al*., 2001).

The composition of the diet of wild herbivores depends on the availability of forage (Morrison *et al*., 1992). For example, in the Sonoran Desert and much of North America, shrub species represent the sheep's diet basis because they are available throughout the year (Sandoval, 1979; Watts, 1979; Leopold and Krausman, 1991). In addition to shrubs, the grasses that sprout annually are species preferred by sheep, mainly because of their nutritional content and a high digestibility (Tarango *et al*., 2002; McKinney and Smith, 2007). In this regard, during the reproductive period, the consumption of herbaceous plants by males and females increased, since it is in spring when the regrowth of these annual plants begins; during this period, males and females used the steepest portions of the mountains, where the humidity conditions in the canyons favor their availability. Although the female diet was the most diverse during the reproductive period (H´=1.2), no differences were observed between their diets and that of males in the segregation period (H´=1.0) (Figure 2).

The greater diet diversity in the reproductive period could be due to the rain's onset in May and the greater forage availability (López *et al*., 1999). The diet similarity was greater (IS=96) between males in the segregation period and females in the reproductive period (Table 2). In contrast, the diet of segregated males and males in the reproductive period registered greater differences (IS=67) (Table 2).

Table 1. Composition of the diet of male and female bighorn sheep by family, species, and period in the UMA Rancho Noche Buena, Sonora, Mexico.

Family	Species	Reproductive period (%)		Segregation period (%)	
		Males	Females	Males	Females
Trees					
Fabaceae	*Acacia willardiana*	2.2	1.7	4.7	9.8
Burseraceae	*Bursera microphylla*	0.7	0.8		0.9
Fabaceae	*Cercidium microphyllum*	9.7	9.2	11.4	5.5
Fabaceae	*Olneya tesota*	2.2		0.5	
Shrubs					
Burseraceae	*Bursera laxiflora*	0.7			
Rhamnaceae	*Colubrina glabra*	1.5			
Rhamnaceae	*Condalia globosa*		1.7		0.9
Asteraceae	*Encelia farinosa*				0.9
Fabaceae	*Hoffmannseggia densiflora*				0.4
Labiatae	*Hyptis emoryi*	0.7			
Euphorbiaceae	*Jatropha cardiophylla*				0.4
Euphorbiaceae	*Jatropha cinerea*			0.5	
Euphorbiaceae	*Jatropha cuneata*				1.7
Acantahaceae	*Justicia candicans*	1.5	5	1	1.7
Malvaceae	*Kosteletzkya malvavizcana*		0.8	0.5	
Krameriaceae	*Krameria erecta*			2.6	
Krameriaceae	*Krameria grayi*		2.5		3.8
Zygophyllaceae	*Larrea tridentata*	0.7			
Solanaceae	*Lycium brevipes*		2.5		0.4
Fabaceae	*Mimosa laxiflora*	1.5	6.7	1.6	3.4
Fabaceae	*Senna covesii*	0.7			0.9
Buxaceae	*Simmondsia chinensis*	7.5	3.3	8.8	7.2
Forbs					
Malvaceae	*Abutilon incanum*	0.7	6.7	0.5	2.6
Amaranthaceae	*Alternanthera pungens*		0.8		0.9
Asteraceae	*Ambrosia confertiflora*		1.7	2.6	0
Primulaceae	*Anagallis arvensis*		4.2		1.7
Malvaceae	*Anoda cristata*	7.5	14.2	4.1	2.6
Sapinadaceae	*Cardiospermum corindum*	1.5	0.8	0.5	
Ranunculaceae	*Clematis drummondii*	4.5	0.8	2.1	
Fabaceae	*Dalea emoryi*	1.5	1.7		1.3
Solanaceae	*Datura disocolor*	0.7		1.6	
Euphorbiaceae	*Ditaxis lanceolata*	1.5	1.7	1	3.4
Asteraceae	*Dyssodia concinna*	0.7			
Malvaceae	*Herissantia crispa*	3.7	4.2	4.7	1.3
Malvaceae	*Hibiscus denudatus*	2.2		0.5	
Malpighiaceae	*Janusia gracilis*	2.2	0.8		
Asteraceae	*Verbesina encelioides*	11.9	10	10.4	16.2
Grasses					
Poaceae	*Aristida adscensionis*	12.7	11.7	20.7	27.2
Poaceae	*Bouteloua barbata*	13.4	3.3	15.5	2.6
Succulents					
Cactaceae	*Lemaireocereus thurberi*		0.8	1.6	0.9

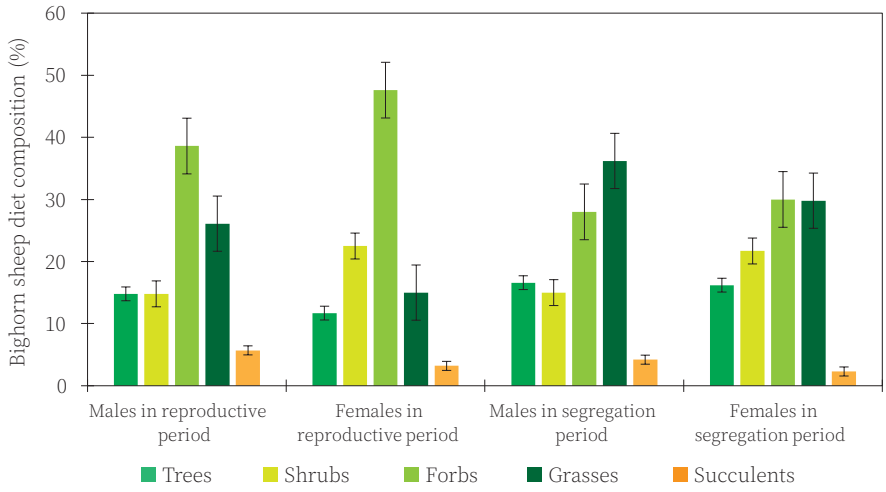

Figure 2. Composition of the bighorn sheep diet by sex, period (reproductive and segregation) and biological form at the UMA Rancho Noche Buena, Hermosillo, Sonora, Mexico.

Figure 3. Zacate tres barbas (*Aristida adscensionis*), the most important species in the diet of the bighorn sheep at the UMA Rancho Noche Buena, Hermosillo, Sonora, Mexico (Photograph by N. Dreber).

Table 2. Percentage values of the Kulczynski similarity index (IS) in the males and females diet composition by period (reproductive and segregation) at the UMA Rancho Noche Buena, Hermosillo, Sonora, Mexico.

	Males in segregation period	**Males in reproductive period**	**Females in segregation period**	**Females in reproductive period**
Males in segregation period	100			
Males in reproductive period	67	100		
Females in segregation period	80	73	100	
Females in reproductive period	96	89	75	100

The similarity between the diet of females in the reproductive and segregation period was IS=75. This can be explained by the hypothesis on segregation proposed by Main *et al*. (1996), who propose that females during the segregation period occupy steeper areas and with more visibility to evade predators, at the cost of a less diverse diet and lower nutritional quality. Authors such as Tarango *et al*. (2002), recorded that, once the reproductive season was over, the groups of males (made up of class III and IV males) separated from the females' groups (females, lambs and juvenile males). However, they indicated that, although the groups were spatially separated, they tended to use the same areas at different times (Bleich *et al*., 1997; Tarango *et al*., 2002; Pérez-Barbería *et al*., 2007).

This sheep behaviour during its forage activity could explain the 80% similarity in the diet composition of males and females during the segregation period. In the present research, it was recorded that in the reproductive period the females grouped with class III or IV males, that distributed in lower places of the mountains and foraged in streams. On these sites, shrubs and grasses are more common than in the higher areas. In contrast, during the segregation period, females were in higher areas, generally alone or with other females, lambs, and occasionally juvenile males.

The above is consistent with that reported on sexual segregation in bighorn sheep (Miller and Gaud, 1989; Tarango *et al*., 2002). Although during the reproductive period the females tend to occupy the same sites as in the segregation period (with few plants cover and adequate visibility), males make local trips to these sites in search of reproductive females, to establish dominance and form reproductive groups. Once the reproductive period is over, they separate from the females and look for places where the forage is more abundant and of greater nutritional value (Ruckstuhl and Neuhaus, 2000; Tarango *et al*., 2002). This explains the greater similarity (75%) in the female diet between periods in relation to the male diet (67%).

The results on the similarity of the diet of males and females coincide with that reported by Miller and Gaud (1989) in Arizona, whose similarity varied between 40% and 80%. In the present study, the similarity in the diet composition of segregated males and females was 80%, while between males (segregation period) and females (reproductive period) it was 96%. As already mentioned, in the Sonoran Desert the groups of males in the reproductive period move from their foraging sites to the areas used by the females to establish reproductive groups. However, females tend to occupy the same sites regardless of the reproductive period (Tarango *et al*., 2002).

Based on the results of this research, the hypothesis of the present work that the composition of the diet of segregated males and females was different is rejected. The results of this study can be applied to estimate the carrying capacity in the Sonoran Desert, where the bighorn sheep is the main game species and is preferably extensively managed. It is recommended to continue with this line of research and study the forage availability by season and period, carry out bromatological analyses of the consumed plant species to know their nutritional contribution and probable deficiencies in bighorn sheep individuals. This information is essential to establish management

programs, habitat improvement or supplementation programs according to the needs of the UMA Rancho Noche Buena and its surrounding areas.

CONCLUSIONS

Herbaceous and grasses predominated in the bighorn sheep diet. During the segregation period, males consumed mostly grasses, and females herbaceous and grasses. However, in the reproductive period, herbaceous plants were the main species in the diet of males and females. The similarity of the diets of males and females in the segregation period was high. Therefore, sexual segregation exhibited by the bighorn sheep at the UMA Rancho Noche Buena was not due to forage selection.

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