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Article

Forage preferences of bighorn sheep (*Ovis canadensis*, Shaw) in Baja California, Mexico

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Abstract:

This research aimed to analyze the food composition and preferences of bighorn sheep in Sierra Juárez and Sierra Santa Isabel during the wet and dry seasons of 2022-2023. To assess forage availability, 17 100-meter-long Canfield lines were implemented. Dietary composition was determined by micro histology of fecal samples, whereas forage and diet diversity were calculated using Shannon's index. Forage selection was evaluated with Ivlev's

index. It was observed that the most common biological forms in the habitat of bighorn sheep were trees and shrubs. In Sierra Juarez and Sierra Santa Isabel, 31 and 43 species of plants were identified in their diet, respectively; trees and shrubs were the most consumed. There were no differences in diet between times and sites. *Larrea tridentata* and *Hibiscus denudatus* were the most frequent in the diet, whereas the preferred ones included *Eriogonum inflatum*, *H. denudatus*, *Horsfordia newberryi*, *Justicia californica*, and *L. tridentata*. These results provide information to establish strategies for conservation and community management of bighorn sheep in Baja California.

Keywords: Wild sheep, Cordillera Molina, Matomí, Desert scrubland, Sierra Santa Isabel, Sierra Juárez.

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Introduction

The desert bighorn sheep (*Ovis canadensis*) is one of two wild sheep species with a natural distribution in North America[1]. It is currently found in the wild in the arid mountainous regions of the southwestern United States of America and northwestern Mexico[2]. Nevertheless, until the second half of the nineteenth century, its natural distribution area extended to the northeastern region of Mexico and included part of the states of Chihuahua, Coahuila, and Nuevo León[3]. This population decrease is due to habitat degradation, poaching, and disease transmission by domestic livestock[1,2]. As a result, the Mexican legislature has classified this species as subject to Special Protection (Pr) since 2010[4].

The bighorn sheep plays an important ecological role by directly influencing vegetation dynamics[5,6] and the nutrient cycle of the ecosystem[7]. Therefore, conservation efforts have focused on preserving its natural habitat to promote the development and establishment of its populations[8]. To achieve this objective, it is necessary to understand the use it makes of different types of forage, which allows to understand its adaptability capacity to variations in its availability and quality[9]. Likewise, knowledge about the diet also allows the identification of the key foraging areas of the species, which is important information for its conservation[8,9,10].

Several studies have been carried out in North America on the feeding habits of the bighorn sheep[8,11,12], in which it is described as an opportunistic consumer with a preference for shrubs and herbs depending on their availability[6,8,9]. However, in the Baja California

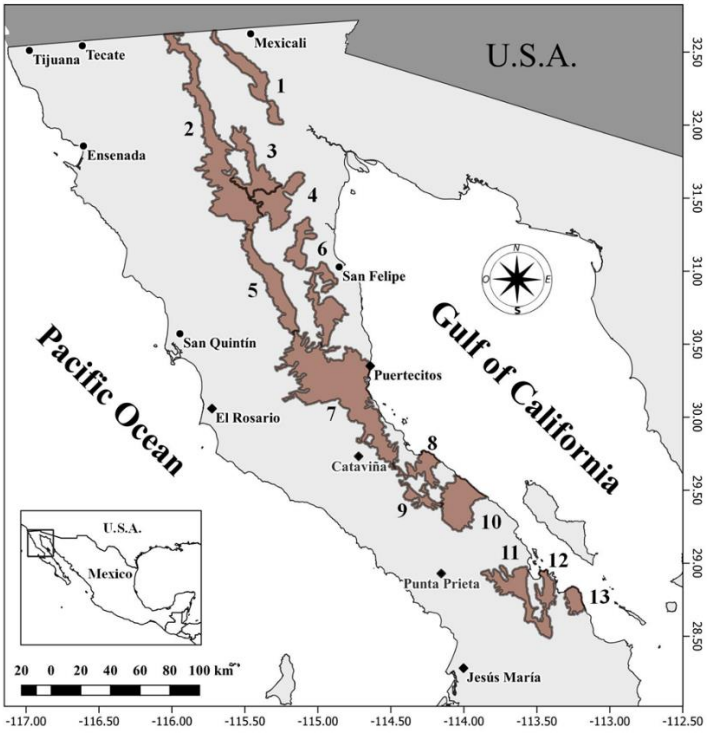
peninsula, its forage habits have been little studied and most studies are based on direct observation or analysis of stomach contents[13], which are not representative of total food consumption, but are valuable because they indicate a significant consumption of grasses in a highly arid region. Therefore, the present study aimed to identify and compare the composition of the diet of bighorn sheep through microhistological analyses in two mountain systems of Baja California, Mexico.

Material and methods

Description of the study area

The study was conducted from November 2021 to November 2022, in Sierra Juarez and Santa Isabel mountain ranges, in the northern and central regions of the state of Baja California, respectively (Figure 1). These areas represent a continuous habitat for bighorn sheep, as they include rugged topography, canyons, and steep slopes[14,15]. Sierra Juarez has an area of 42,364 ha and is located between the cities of Tecate and Mexicali; Santa Isabel covers an area of 65,961 ha on the coast of the Gulf of California, 90 km south of the port city of San Felipe[15]. These areas belong to the San Felipe desert ecoregion, where microphyllous desert scrubland predominates, characterized by plant species such as creosote bush (*Larrea tridentata*), white bursage (*Ambrosia dumosa*), buggywhip (*Fouquieria splendens*), desert agave (*Agave deserti*), and ironwood (*Olneya tesota*)[16]. The average annual temperature ranges between 12 and 22 °C. The average monthly rainfall ranges between 0.0 mm and 0.8 mm and occurs throughout the year; nevertheless, the winter months are the wettest[17].

Figure 1: Main mountain systems in the state of Baja California, Mexico (2. Sierra Juarez; 7. Sierra Santa Isabel)



Forage availability assessment

Forage availability was assessed by the frequency of each plant species by site and season of the year (dry and wet). To do this, the line intercept or Canfield method was used. To reduce the error and increase the representation of the sampling, an accumulation curve was generated to estimate the number of potential species in each ejido according to the Jackknife[18] and Chao 2[19] estimators, using the statistical package EstimateS V. 9.1.0. In total, the evaluation was carried out on 17 lines of 100 meters in length according to the accumulation curve: in Sierra Juarez, four lines were established during the dry season (May and August 2022) and four during the wet season (November 2022); and in Sierra Santa Isabel, four lines were placed in the dry season (April and November 2022) and five in the wet season (June and January 2022). In each one, all the plants that intersected the line were identified, counted, and classified according to their species, linear cover, height, and biological form (trees, shrubs, herbs, grasses, and succulents)[20]. The distribution of the lines was determined based on the information provided by the members of each ejido on the plant species consumed by the bighorn sheep, the identification of areas with topography associated with the presence of the bighorn sheep, and the direct observations generated during the prospecting tours carried out by the team of the Wildlife Management and Conservation Laboratory of the Autonomous University of Baja California. The data

collected made it possible to calculate the frequency of availability by plant species, study site, and season of the year using the following equation:

$$Availability\ of\ species\ i\ (\%) = \left(\frac{No.\ of\ lines\ that\ contain\ species\ i}{Total\ number\ of\ lines\ in\ the\ site}\right)\ x\ 100$$

Forage composition, diversity and selection

To identify the species that constitute the diet of bighorn sheep, the microhistological technique was used, which involves the identification of patterns of cellular structures of the plant epidermis in fecal samples[21]. A reference catalogue consisting of a collection of photographs of plant cell structures was created. To do this, plant samples including flowers, leaves, and stems were collected in the same places where the fecal samples were obtained. The collected plants were pressed and then taxonomically identified with the help of the herbarium collection of the Autonomous University of Baja California (BCMEX), the Baja California plant guide[22], the Naturalista platform, and consultations with experts. To prepare the reference catalog, the plants were processed in a Wiley mill, model Thomas tp4276 m004, with a mesh size 20 (1 mm); they were then rinsed with 20 mL of 5 % sodium hypochlorite (commercial chlorine) and mounted on slides. The slides were observed under a high-end digital microscope with a 10X objective to identify and photograph diagnostic cellular structures: trichomes, stomata, crystals, epidermis arrangement, etc.[21]

One hundred ninety-five (195) fresh fecal samples were randomly collected in both mountain ranges during the dry and wet seasons according to the methodology suggested by Anthony and Smith[23]. Prior to histological analysis of fecal samples, five subsamples were randomly taken at each site and sampling season to form composite samples. The composite samples were rinsed using the same procedure used for the plant samples and distributed on five slides per season and per site (20 in total). To ensure the homogeneity of the sample quantity in each slide, a metal slide with holes of 7 mm diameter was used[21,24]. In each slide, cell structures were identified and counted in 20 fields (400 in total) under a microscope. Finally, the identified species were classified according to their temporal variation (rainy or dry), growth form (shrub, tree, herb, grass, or succulent), and frequency of appearance[25,21]. These analyses were carried out in the Department of Zootechnics of the Autonomous University of Baja California Sur.

Data analysis

The composition of the diet was expressed in a matrix where the frequencies of each plant species were included according to the biological form, the time of year, and the site[26]. In

addition, the diversity of the diet by site and season of the year was evaluated with Shannon's[27] diversity index. To find out if there is a difference in diet diversity by time of year at each study site, the non-parametric Mann-Whitney U test ($\alpha \leq 0.05$) was applied using the statistical software PAST 4.0. The degree of selectivity of forage intake (FSI) was determined based on the availability and consumption of each plant species according to Ivlev's [28] selection index, using the following equation:

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

Where: *Ei* is Ivlev's selection index; *r(i)* is the relative frequency of species *i* in the diet; and *p(i)* is the relative frequency of species *i* in the habitat.

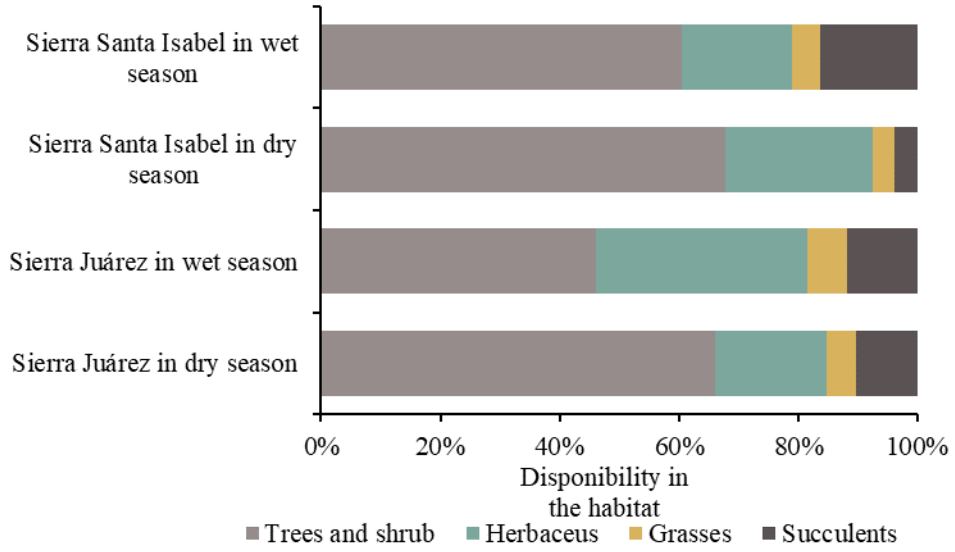
Ivlev's selection values range from -1 (rejection or negative selection of a species) to 1 (preference or positive selection), whereas a value of 0 implies random food consumption or in proportion to its availability. In this regard, Stuth[29] categorizes the values of this index as follows: species with an FSI greater than 0.35 were preferred over other available species; from -0.35 to 0.35, maintenance species or species consumed in proportion to their availability; finally, species avoided with an FSI less than -0.35.

Results and discussion

Vegetation cover assessment

In Sierra Juarez and Sierra Santa Isabel, the habitat of bighorn sheep was characterized by a high availability of tree and shrub species, and a lower frequency of grasses (Figure 2). Species availability varied by site and time of year ($P<0.05$). In Sierra Juarez, 52 species belonging to 23 taxonomic families were identified, the main ones were: *Asteraceae* (7), *Cactaceae* (5), *Fabaceae* (5), and *Asparagaceae* (4). The diversity of plant species in this mountain range was greater in the wet season ($H'= 3.69$) than in the dry season ($H'= 3.43$). In Santa Isabel, 55 species corresponding to 21 taxonomic families were identified, of which *Asteraceae* (9), *Cactaceae* (6), *Fabaceae* (6), and *Euphorbiaceae* (5) were the most common. Plant diversity in Sierra Santa Isabel in the wet season ($H'= 3.89$) was higher than in the dry season ($H'= 3.55$). Maintaining a high diversity of forage in the sheep's habitat is important because there is no single species that covers all nutritional requirements[27].

Figure 2: Seasonal variation in forage availability (%) in relation to site, time of year, and biological form of plant growth

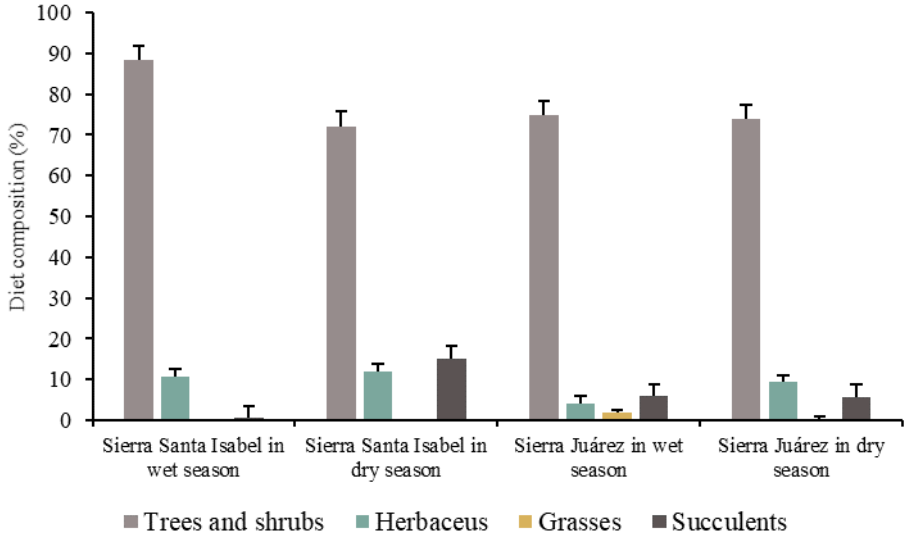


Fifty-two species were recorded in Sierra Juarez, but the Chao 2 and Jacknife diversity estimators predict a richness of 63 species (82.9 % effectiveness) and 69 species (75.7 % effectiveness), respectively. In Sierra Santa Isabel, 55 plant species were identified, but the Chao 2 estimator calculates a potential richness of 66 species (88.5 % effectiveness), whereas 70 species (78.4 % effectiveness) are estimated with the Jacknife estimator.

Diet composition and diversity

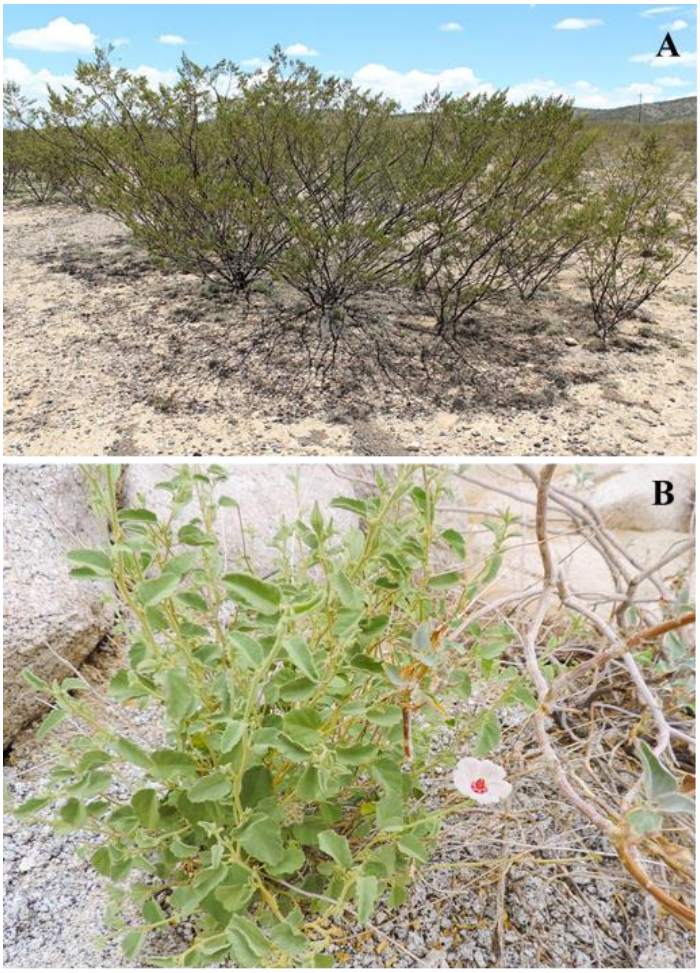
Wild herbivores are adapted to the consumption of a wide variety of forage types, depending on environmental gradients that influence food availability[30]. In this regard, 31 species that make up the diet of the bighorn sheep population in Sierra Juarez were recorded. Twenty-five (25) species were identified during the dry season, whereas the consumption amounted to 27 species in the wet season (Table 1). The biological forms with the highest consumption were trees and shrubs, with a frequency of consumption of 74.7 % and 73.8 % in the wet and dry seasons, respectively. Herbaceous plants represented 4.11 % of the diet in the wet season and 9.39 % in the dry season. The contribution of grasses to the diet was higher during the wet season (1.77 %), whereas that of succulents was more notable in the dry season (5.64 %; Figure 3). Although Shannon's diversity index showed higher values during the wet season (*H'*= 3.05) than during the dry season (*H'*= 2.97), no differences were found in dietary diversity between the two times of the year.

Figure 3: Composition of the bighorn sheep diet in relation to the site, time of year, and biological form of the forage (vertical lines on the bars indicate the standard error)



The bighorn sheep population in Sierra Santa Isabel fed on 43 species. The diet consisted of 36 species during the dry season, and the consumption was 29 species in the wet season. Tree and shrub species predominated in the diet during the two seasons of the year: 88.22 % in the wet season and 72.12 % in the dry season, respectively. In addition, 10.76 % were herbaceous species in the wet season and 12.12 % in the dry season. A difference of 15.15 % ($P<0.05$) was observed in the consumption of succulents between the wet and dry seasons (Figure 3). Shannon's diversity index showed similar values in the composition of the diet in the wet ($H'= 3.28$) and dry ($H'= 3.14$) seasons; this is mainly due to the fact that the highest percentage of consumption corresponds to perennial species. In both study sites, the species with the highest frequency in the diet were *Hibiscus denudatus* and *L. tridentata* (Figure 4).

Figure 4: Most frequent species in the diet of bighorn sheep in Sierra Juarez and Sierra Santa Isabel



A. Creosote bush (*Larrea tridentata*), of the family Zygophyllaceae (photograph by National Forestry Commission); B. paleface (*Hibiscus denudatus*), of the family Malvaceae (photograph by James Varnell). Both are species of perennial shrubs native to Mexico.

Studies on the feeding habits of bighorn sheep in North America reveal a high diversity of species in the diet of these animals. Monson and Sumner[31] point out that up to 110 species of plants have been identified in the diet of bighorn sheep in desert areas. In the United States of America, specifically in Arizona[32], they reported the presence of 58 species of plants in the diet, whereas in California[33], they found that sheep fed on 32 different species. In regions of the northern United States and southern Canada, it has been documented that the feeding of Rocky Mountain bighorn sheep (*O. c. canadensis*) comprises up to 200 plant species[33,34].

Sierra Juarez showed the lowest number of species in the diet of bighorn sheep compared to other studies carried out in the Sonoran Desert. In Sonora, 41 species were identified in Sierra El Viejo, Caborca[5]; another study[9] found 40 species in Sierra Noche Buena, Hermosillo; and O'Farril *et al*[35] reported 39 species of plants in the diet of the sheep from Isla Tiburon. In the Baja California Peninsula[36], it was documented that the diet of bighorn sheep in Sierra

San Pedro Mártir, Ensenada, is composed of 72 species of plants; an annual consumption of 47 species was documented in Sierra El Mechudo, Baja California Sur[8]. In Coahuila, Gastelum-Mendoza *et al*[6] found an annual consumption of 50 species. These results are similar to the results of this study in terms of the number of species consumed by bighorn sheep in Sierra Santa Isabel[43].

Variations in diet composition can be attributed to physiographic and climatic variations in the habitat. In this research work, it was observed that the places where bighorn sheep live are generally rocky, open, and with limited vegetation cover. This finding coincides with a study on the diet of mule deer in southern Arizona[37], where high temperatures and low rainfall were observed, which directly influenced the metabolism of the plants, causing their drying in a short time.

The intensity of herbivory on some species can have a negative impact on vegetation dynamics. In this regard, the species identified in the diet of bighorn sheep were classified as decreasing or basic (those with higher consumption that decrease their availability due to high herbivory pressure) and increasing or emergent (those with lower consumption that increase their availability due to low herbivory pressure)[30,38].

According to the composition of the diet of bighorn sheep in Sierra Juarez, *H. denudatus* and *L. tridentata* were classified as basic species, which together contributed 21.82 % of the annual diet. However, these species only represented 6.5 % of the total species richness that make up the diet. Likewise, 11 species were considered as emergent species, which together contributed 9.87 % of the diet and 35.5 % of the richness of species consumed. In the population of Sierra Santa Isabel, *H. denudatus*, *L. tridentata*, *Solanum hindsianum*, *Condea emoryi*, and *Eriogonum inflatum* were considered as basic species, which together represented 40.48 % of the annual diet, but only 11.63 % of the total richness of species that make up the diet. On the contrary, 15 species were considered to be increasing, since together they contributed 9.8 % of the annual diet, and 13 of them each contributed less than 1 % of the diet. These species can be considered emergent and are important in periods of low availability of basic species[6]. For example, *Amaranthus palmeri*, *Atriplex barclayana*, *Senegalia greggii*, and *Krameria erecta* (Table 1).

Tree and shrub species were the basis of the bighorn sheep's diet (Figure 3). This result coincides with other studies on the feeding habits of this species in North America[8,9,35]. The importance of shrub and tree species in the sheep's diet is due to the fact that they are forages available throughout the year[6]. Likewise, Bolen and Robinson[39] state that wild herbivores in arid areas prefer to browse shrubs and trees because they contain more digestible nutrients than other grass species. According to some researchers[40], shrubs in arid areas accumulate nutrient reserves during their growth for the formation of new tissues, resulting in a higher concentration of crude protein compared to some grasses and grasses.

Forage selection varied by site and time of year ($P<0.05$). In Sierra Juarez, during the dry season, the bighorn sheep preferred the consumption of *H. denudatus*, *L. tridentata*, and *E. inflatum*; in contrast, in the wet season, it preferred *Bebbia juncea* and *Justicia californica*. In the dry season, it avoided consuming *Cylindropuntia ramosissima*, *Ephedra californica*, and *Sphaeralcea ambigua*; and during the wet season, the species it avoided were *Neltuma glandulosa* and *Krameria bicolor* (Table 2). Some of these species are avoided because they have structures that prevent their optimal consumption, for example, thorns, pubescence, or high wax content in their leaves and stems[30]. It should be noted that uncommon species in the sheep diet were identified, such as *Washingtonia* sp. and *Typha domingensis* (Table 1), which grow in wet substrates around natural water sources.

A significant difference ($P<0.05$) was identified between the availability and consumption of herbaceous species. Although these were highly available, particularly in Sierra Juarez (Figure 2), they were not observed in high percentages of consumption (Figure 4). Herbaceous plants, especially annual species, tend to be less consumed by wild herbivores in arid areas[5,6,9] since their availability is closely linked to humidity and rainfall. As a result, their presence in vegetation cover is limited to short periods of the year. Although previous studies indicate that herbaceous plants are more common in the diet of herbivores during the wet season[6,30], in the present study, the highest percentages of occurrence in diets were detected during the dry season. This can be explained by the existence of oases in the study areas, which provide sufficient humidity for the growth of herbs throughout the year. Although their contribution to the overall diet was low, herbaceous species play a crucial role in the nutrition of bighorn sheep. These plants offer 35 to 40 % more energy, similar protein levels, and 40 to 45 % more phosphorus compared to shrubs in northern Mexico[12]. In addition, they are particularly relevant during the breeding season. Gastelum-Mendoza *et al*[9] reported that both males and females of bighorn sheep consumed mainly herbaceous species during this period in Sierra Noche Buena, Sonora, with a consumption of 38.6 and 47.6 %, respectively. Finally, although herbaceous plants were not highly consumed in general, a significant preference for *E. inflatum* was observed in Sierra Santa Isabel throughout the year (Table 3).

Although the digestive physiology of bighorn sheep is adapted for the digestion of grasses[41], which tend to have high fiber content and relatively low digestibility during most of the year[8,30], these were not significant components in the composition of their diet (Figure 3). In this regard, Brown *et al*[34] point out that wild mountain sheep populations in Nevada, USA, consume between 62 and 81 % of grasses compared to desert sheep populations. This is due to a greater availability of shrubs and trees in the Sonoran Desert[42]. This coincides with previous findings in Sierra El Mechudo, Baja California Sur, where only two species of grasses were identified in the diet[8]. Similarly, in the state of Sonora, studies conducted by Tarango *et al*[5] in Sierra El Viejo and by O'Farrill *et al*[35] on Tiburon Island reported that grasses represented only 5 % of the diet. Nonetheless, more recent research found a grass contribution of 26.8 % in Sierra Noche Buena, Sonora[9] and 17.21 % in a rosetophyllous desert scrubland in Coahuila[6]. It is also pointed out[30] that in the arid areas of northern

Mexico, grasses have a high content of cellulose and hemicellulose, which limits their nutritional value and reduces their consumption by wild herbivores. In this sense, it is mentioned[12] that *Aristida adscensionis* presents neutral detergent fiber values (composed of cellulose, hemicellulose, and lignin) of 61.3 % in 2010 and 79.6 % in 2011 in the diet of sheep from Sierra El Mechudo, Baja California Sur. These values suggest that it is a species of grass with low digestibility[43].

In Sierra Santa Isabel, the contribution of succulent species to the diet of bighorn sheep was greater than in Sierra Juarez (Figure 3) and varied depending on the time of year ($P<0.05$); with greater consumption of these plants in the dry season. Succulent species do not represent a high nutritional contribution for the sheep[12], but they are important elements in the diet as an important source of water in the dry season[5,6,30] when it requires a minimum water intake equivalent to 4 or 5 % of its body weight[42]. The relevance of nopales, magueys, and biznagas in the sheep's diet has been reported in different studies: in Sonora, in Sierra El Viejo, the frequency of succulent consumption was 18 %[5,9]; in Sierra El Mechudo, it was 0.2 %[8]; in Sierra San Pedro Mártir, Baja California, it was 12 %[44].

Conclusions and implications

In Sierra Juarez and Sierra Santa Isabel, bighorn sheep fed mainly on tree and shrub species. For their part, succulents were important species in the diet during the dry season. Although no significant differences in diet diversity were detected between the two mountain ranges, the key species in the bighorn sheep diet were different between sites. In Sierra Juarez, the main species consumed were *E. inflatum*, *H. denudatus*, *J. californica*, and *L. tridentata*; whereas in Sierra Santa Isabel, they were *E. inflatum*, *H. denudatus*, *Horsfordia newberryi*, and *L. tridentata*. These results are important to identify and delimit priority foraging areas for bighorn sheep populations, as well as to guide the design of community strategies for the management of forage species in the state of Baja California. In addition, it is recommended to complement these findings with a bromatological analysis of the main species consumed to assess their nutritional quality and their impact on the health of bighorn sheep populations.

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Conflict of interest

The authors declare that they have no conflict of interest.

Table 1: Composition of the diet of bighorn sheep according to the relative frequency of the species identified in fecal samples, collection site, and time of year

Biological form	Family	Species	Sierra Santa Isabel		Sierra Juarez	
			Wet season (%)	Dry season (%)	Wet season (%)	Dry season (%)
Trees and shrubs	*Acanthaceae*	*Justicia californica*	3.08		7.06	0.47
	Amaranthaceae	*Amaranthus palmeri*	0.51			
	Amaranthaceae	*Atriplex barclayana*	0.51			
	Amaranthaceae	*Atriplex hymenelytra*	3.59			0.47
	Apocynaceae	*Asclepias subulata*		0.61		
	Arecaceae	*Washingtonia* sp.	2.07		1.18	1.41
	Asparagaceae	*Yucca* sp.			1.18	
	Asteraceae	*Ambrosia dumosa*	5.13	3.64	4.71	5.16
	Asteraceae	*Bebbia juncea*	3.08	3.03	7.06	3.29
	Asteraceae	*Encelia farinosa*	7.69	3.03	5.29	6.51
	Asteraceae	*Peucephyllum schottii*		0.61		
	Asteraceae	*Stephanomeria* sp.			1.76	0.47
	Burseraceae	*Bursera hindsiana*	1.03	3.03		
	Burseraceae	*Bursera microphylla*	3.59	2.42	1.76	4.23
	Ephedraceae	*Ephedra californica*	0.51	0.61	4.12	0.47
	Euphorbiaceae	*Croton californicus*	0.51	1.21		
	Euphorbiaceae	*Ditaxis lanceolata*	3.08	0.61	2.35	8.82
	Euphorbiaceae	*Euphorbia lomelii*		3.03		
	Fabaceae	*Astragalus* sp.	2.56		2.35	3.76
	Fabaceae	*Hoffmannseggia microphylla*	0.51	0.61		
	Fabaceae	*Neltuma glandulosa*	1.54	0.61	1.18	3.76
	Fabaceae	*Parkinsonia microphylla*	0.51	3.03	2.35	2.82
	Fabaceae	*Psorothamnus emoryi*		0.61		
	Fabaceae	*Senegalia greggii*	0.51			0.45
	Fouquieriaceae	*Fouquieria splendens*	3.59		4.12	
	Juncaceae	*Juncus acutus*	0.51	3.03		
	Krameriaceae	*Krameria bicolor*	2.05		1.76	

	Krameriaceae	*Krameria erecta*	0.51			
	Lamiaceae	*Condea emoryi*	8.21	7.27	5.29	4.63
	Lamiaceae	*Salvia apiana*	0.51			
	Lamiaceae	*Salvia* sp.			1.18	
	Malvaceae	*Hibiscus denudatus*	11.28	7.27	9.41	13.55
	Malvaceae	*Horsfordia newberryi*	3.59	6.67		
	Malvaceae	*Sphaeralcea ambigua*			2.35	0.47
	Polygonaceae	*Eriogonum sp.*	2.05			
	Resedaceae	*Oligomeris linifolia*	1.54	1.21	0.59	
	Simmondsiaceae	*Simmondsia chinensis*	1.03	0.61		
	Solanaceae	*Solanum hindsianum*	8.21	7.85		
	Typhaceae	*Typha domingensis*	1.03			
	Zygophyllaceae	*Larrea tridentata*	6.15	11.52	7.65	13.02
Herbs	*Polygonaceae*	*Eriogonum inflatum*	4.1	9.09	2.35	5.63
	Polygonaceae	*Eriogonum sp.*	2.05			
	Loasaceae	*Eucnide cordata*	0.51			
	Onagraceae	*Chylismia cardiophylla*	4.1	3.03	1.76	3.76
Grasses	*Poaceae*	*Aristida adscensionis*			1.18	
	Poaceae	*Cynodon dactylon*			0.59	0.47
Succulents	*Asparagaceae*	*Agave deserti*	0.51	5.45	4.12	1.41
	Asparagaceae	*Agave* sp.				0.47
	Cactaceae	*Cylindropuntia cholla*		3.64		
	Cactaceae	*Cylindropuntia ramosissima*		3.64		2.35
	Cactaceae	*Opuntia* sp.		2.42	1.76	1.41
Fragments no identified			0.51	0.61	13.54	10.74

Table 2: Types of use and selection of forage by bighorn sheep according to Ivlev's index, site, and time of year

Species	Season	Observed use	Expected use	Ivlev	Type of use
Sierra Juarez					
Cylindropuntia ramosissima	Dry	0.02	0.06	-0.48	A
Ditaxis lanceolata	Wet	0.02	0.01	0.28	P
Ditaxis lanceolata	Dry	0.02	0.01	0.25	P
Encelia farinosa	Wet	0.05	0.05	0	P
Encelia farinosa	Dry	0.07	0.05	0.19	P
Ephedra californica	Dry	0	0.01	-0.56	A
Eriogonum inflatum	Wet	0.02	0.01	0.28	P
Eriogonum inflatum	Dry	0.05	0.01	0.53	**S**
Fouquieria splendens	Wet	0.04	0.02	0.22	P
Hibiscus denudatus	Wet	0.09	0.05	0.28	P
Hibiscus denudatus	Dry	0.14	0.05	0.48	**S**
Justicia californica	Wet	0.07	0.02	0.45	**S**
Krameria bicolor	Wet	0.01	0.03	-0.38	A
Larrea tridentata	Wet	0.07	0.05	0.18	P
Larrea tridentata	Dry	0.15	0.03	0.63	**S**
Neltuma glandulosa	Wet	0.01	0.02	-0.38	A
Opuntia sp.	Dry	0.01	0.01	-0.08	P
Parkinsonia microphylla	Wet	0.02	0.02	-0.05	P
Sphaeralcea ambigua	Wet	0.02	0.01	0.28	P
Sphaeralcea ambigua	Dry	0	0.01	-0.56	A
Sierra Santa Isabel					
Ditaxis lanceolata	Wet	0.03	0.02	0.13	P
Ditaxis lanceolata	Dry	0	0.01	-0.51	A
Encelia farinosa	Wet	0.07	0.05	0.13	P
Encelia farinosa	Dry	0.03	0.05	-0.3	P
Eriogonum inflatum	Wet	0.04	0.01	0.55	**S**
Eriogonum inflatum	Dry	0.09	0.03	0.41	**S**
Fouquieria splendens	Wet	0.03	0.04	-0.12	P
Hibiscus denudatus	Wet	0.11	0.02	0.65	**S**
Hibiscus denudatus	Dry	0.07	0.05	0.12	P

Horsfordia newberryi	Wet	0.03	0.03	0.01	P
Horsfordia newberryi	Dry	0.06	0.01	0.55	**S**
Larrea tridentata	Wet	0.06	0.02	0.45	**S**
Larrea tridentata	Dry	0.11	0.05	0.34	P
Parkinsonia microphylla	Wet	0	0.04	-0.8	A
Parkinsonia microphylla	Dry	0.03	0.07	-0.42	A

Type of use: proportional (P), selected (S) and avoided (A).

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