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Evaluation of pocket gopher diet in a perennial productive area

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The desert pocket gopher (*Geomys arenarius*) is a fossorial herbivorous rodent of the family Geomyidae. Its distribution range is restricted to New Mexico and Texas, in the United States of America, and northern Chihuahua, in México. The Médanos de Samalayuca Flora and Fauna Protection Area (MSFFPA) is located in northern Chihuahua. Different economic activities are carried out in this region, mainly irrigated crops of pecans (*Carya illinoinensis*). Populations of *G. arenarius* have been recorded within these areas. Therefore, the objective of this work was to define the extent of the trophic niche and the changes in the physical condition of *G. arenarius* in a ranch within the MSFFPA over three contrasting seasons (dry, wet, and post-wet). Forty *G. arenarius* specimens were collected from Arantxa Ranch. Morphometric measurements and the weight of collected individuals were recorded, and the digestive tract was removed to prepare histological slides. Seven 25 m^2-quadrants were established, and the species of the vegetation cover were recorded and collected for reference. The Seasonal Fitness Index (IK) and Levin's Niche Breadth Index were calculated. Males had higher average measurements and weight than females. The IK was 2.82 ± 0.47 in males and 2.64 ± 0.61 in females. Significant differences in the IK between seasons were only found in females. The correlation between IK and plant cover was strong for males and females. The diet mainly comprised *Physalis hederifolia*, *Dimorphocarpa wislizeni,* and *Cenchrus incertus*. Levin's index showed that *G. arenarius* is a specialist rodent. Sexual dimorphism was evident, with males larger than females. The physical condition index of gophers is influenced by resource availability. In other studies, this parameter has been related to changes in food availability. It has been reported that gophers tend to feed mainly on crops; however, pecan cultivation was not a major element in the diet of the desert pocket gopher, as it feeds on the vegetation associated with crops. Gophers are considered generalists; nonetheless, the present study showed that *G. arenarius* is a specialist, although this may be a consequence of anthropogenic activities.

La tuza arenera (*Geomys arenarius*) es un roedor herbívoro fosorial perteneciente a la familia Geomyidae. Tiene una distribución restringida a Nuevo México y Texas en los Estados Unidos de América y en México al norte de Chihuahua. En el Área de Protección de Flora y Fauna Médanos de Samalayuca (APFFMS), que se ubica al norte de Chihuahua, se realizan diferentes actividades económicas destacando el cultivo por riego de nuez de pecán (*Carya illinoinensis*). Dentro de estas zonas de cultivo se han registrado poblaciones de *G. arenarius*. Por lo cual, el objetivo del presente trabajo es definir la amplitud de nicho trófico y cambios en la condición física de *G. arenarius* en un rancho dentro del APFFMS en tres temporadas (seca, húmeda y posthúmeda) con diferentes grados de humedad. Se obtuvieron un total de 40 ejemplares de *G. arenarius* del Rancho Arantxa, se registraron las medidas morfométricas y el peso, se extrajo el tracto digestivo para la elaboración de laminillas microhistológicas. Se establecieron siete cuadrantes de 25 m^2 donde se registró la cobertura de las especies vegetales y se colectó el material botánico para elaborar material de referencia. Se calculó el índice de condición física y el índice de amplitud de nicho de Levins. El promedio de las medidas y peso de los machos fue mayor al de las hembras. El IK en machos fue de 2.82 ± 0.47 y en hembras de 2.64 ± 0.61, no se detectaron diferencias estadísticamente significativas en el IK de los machos por temporada y se detectaron diferencias estadísticamente significativas en el IK por temporada en hembras. La correlación entre el IK y la cobertura para los machos y hembras fue fuerte. La dieta estuvo conformada principalmente por *Physalis hederifolia*, *Dimorphocarpa wislizeni* y *Cenchrus incertus*. El índice de Levins evidenció que *G. arenarius* es un roedor especialista. El dimorfismo sexual fue evidente al ser los machos de mayor talla que las hembras. El índice de condición física de las tuzas se ve influenciada por la disponibilidad de recursos en otros estudios se ha relacionado este parámetro con cambios en la disponibilidad de alimento. Se ha reportado que las tuzas suelen alimentarse principalmente de los cultivos, aunque para la tuza arenera, el cultivo de nogal no representó un elemento importante en la dieta y ésta se alimentó de la vegetación asociada a la parcela agrícola. Las tuzas son consideradas generalistas, sin embargo, en el presente estudio *G. arenarius* evidenció ser especialista, aunque este podría ser efecto de las actividades antropogénicas.

Keywords: Gopher pocket; NPA; Samalayuca; vegetation; walnut.

Introduction

The desert pocket gopher (*Geomys arenarius*) is an herbivorous rodent of the family Geomyidae (Williams and Baker 1974). Its distribution is restricted to the states of New Mexico and Texas in the United States and northern Chihuahua in México (Anderson 1972; Chambers *et al.* 2009). This species usually builds its burrows in sandy soils (>40 %) and avoids clay, gravel, or stone (Mauk *et al.* 1999). Gophers live near water bodies (rivers, ponds, irrigation canals) and agricultural areas (Lacher *et al.* 2019). These organisms feed mainly on leaves, roots, tubers, wood, bark, seeds, grains,

nuts, fruits, and flowers of different plant species (Templeton 2006). Gophers cause significant damage to crops within their range (Monge 1999; Witmer *et al.* 1999; Engeman and Witmer 2000; Monge 2013; Baldwin *et al.* 2013), although they have been reported to feed mainly on the herbaceous plants and grass encountered while tunneling (Myers and Vaughan 1965; Foster and Stubbendieck 1980; Luce *et al.* 1980; Williams and Cameron 1986).

The Médanos de Samalayuca Flora and Fauna Protection Area (MSFFPA) is a Natural Protected Area (NPA) located in northern Chihuahua, México. It has a program that includes the management and sustainable use of wildlife, including the implementation of population ecology studies (CONANP 2013). Different economic activities are carried out within this NPA, most notably irrigated crops of pecans (*Carya illinoinensis*), where a population of *G. arenarius* is established successfully. There is a conflict between this species and local farmers, who consider it a pest. Damages to the irrigation system and crops are attributed to gophers, as they are suspected of feeding on the roots of walnut trees, thus affecting the establishment, health, and production of these plants. Consequently, pest control is conducted using traps to reduce the abundance of gophers within crop areas. It is hypothesized that gophers are generalists that feed mainly on the vegetation associated with crops and that changes in plant cover affect the physical condition of this species. Therefore, the objective of this study was to define the extent of the trophic niche, changes in the physical condition of *G. arenarius* throughout the year, and whether they are actively feeding on walnut tree roots.

Materials and methods

Study area. The Arantxa Ranch comprises 1000 ha and is located within the Médanos de Samalayuca Flora and Fauna Protection Area at coordinates 31° 12' 2.13" N, -106° 28' 11.36" W (Figure 1). The prevailing climate is very dry, with warm summer and cold winter, mean annual temperature of 15 ºC to 25 °C, and mean annual precipitation of 212 mm (Enríquez-Anchondo 2003).

The soil is sandy, originally covered by microphyllous desert shrubland (CONANP 2013). This vegetation has been replaced by irrigated crops of vines (*Vitis vinifera*), pistachios (*Pistacia vera*), and pecans (*Carya illinoinensis*); the latter is the most important crop, covering 400 ha. The vegetation associated with crops is mainly composed of species of the families Poaceae, Asteraceae, Solanaceae, and Boraginaceae.

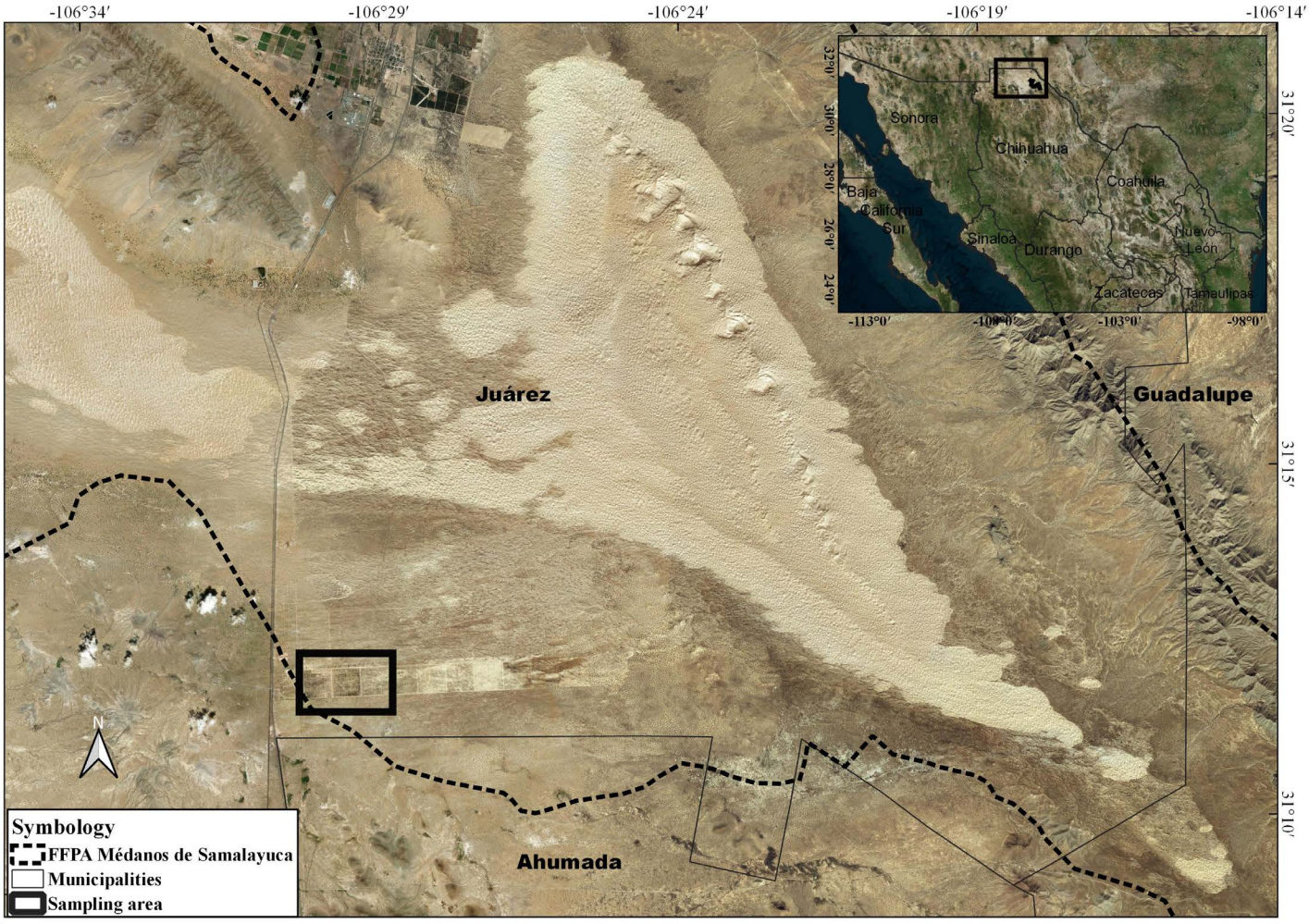

Figure 1. Location of the study area in the Arantxa Ranch within the Médanos de Samalayuca Flora and Fauna Protected Area.

Capture of Geomys arenarius specimens. Eight commercial gopher traps (Sweeney's) were installed along a 1,400 m transect within the crop area in the following seasons: dry (21 to 22 June 2020), wet (26 to 27 September 2020), and post-wet (14 to 15 November 2020). Traps were placed following the methodology by Chávez-León (2017), monitoring and relocating them every 30 minutes for six hours. Simultaneously, we collected the corpses of *G. arenarius* from the trapping conducted by the ranch pest control department.

Fitness Index. This index evaluates the differences between weights according to breed, sex, age, sexual and social status, season, climate, disease, and food, reflecting genotypic, phenotypic, and environmental interactions (Bailey, 1968). It is based on the body weight: length ratio, calculated with the formula: $IK = (W/LC^3) \times 10^{\wedge 5}$, where W = weight (kg) and LC = body length (cm) to the base of the tail, with values ranging from 1 to 10 (Corriale *et al.* 2013). To note, the values of the morphometric and IK measurements correspond to 23 specimens (5 males and 18 females). A total of 17 specimens were excluded, 11 lacking the tail and 6 pregnant or lactating females (4 in the dry season and 2 in the wet season).

The individuals captured were euthanized by cervical dislocation following the Guidelines of the American Society of Mammalogists for the use of wild mammals in research (Sikes and Gannon 2011). Conventional morphometric measurements (total length, tail length, right leg length, and ear length) were recorded using a ruler; the weight was measured with a Pesola® scale, and sex was determined based on the presence/absence of the baculum (Lorenzo *et al.* 2006). The digestive tract was removed, placed in a flask containing 10 % formol, and transported to the Animal Ecology and Biodiversity Laboratory (LEBA, for its acronym is Spanish) at Universidad Autónoma de Ciudad Juárez (UACJ). The skulls of the collected specimens were deposited in the Scientific Collection of Vertebrates at UACJ (CHI-VER 189-08-06) registered with SEMARNAT.

Vegetation sampling. Seven 25 m^2 quadrants separated by 200 m were established along the trapping transect. The plant species comprising the vegetation cover were recorded in each season following the methodology by Mostacedo and Fredericksen (2000). As reference material, we used plant samples from the PJ018 CONABIO Project deposited in the UACJ Herbarium (HERB-UACJ) and samples available in the Animal Ecology and Biodiversity Laboratory (LEBA, for its acronym in Spanish) at UACJ. Additionally, some plant samples were collected in the field following the methodology by Ricker (2019) and deposited in the LEBA reference collection as a botanical catalog (Appendix 1).

Plant material processing. Pressed plant specimens were dried at room temperature for two weeks. Once dry, the family, genus, and species were determined using the SEINet database (2020) with the assistance of the UACJ Herbarium staff. Subsequently, we performed the histological technique described by Gallina-Tessaro (2011).

We built a catalog of reference plant material with diagnostic characteristics that comprised a total of 32 species, 21 collected in the dry season, 29 in the wet season, and 9 in the post-wet season.

Processing of the digestive tracts of Geomys arenarius. The stomach contents of 40 desert pocket gophers were recovered. This material was dehydrated at 80 °C for 4 hours, grounded with a porcelain mortar with pestle, and sieved through a 1 mm-diameter mesh. Histological slides were prepared from the sieved material following the methodology by Castellaro *et al.* (2004). Five slides were prepared from each sample and examined under a light microscope at 40' including 10 fields of view. The frequency was calculated using the formula: Fr = (ai/A)*100, where ai = number of observations of a particular food element and A = number of total observations.

Levin's Niche Breadth Index. This index represents the specialization of an organism by measuring the elements that make up its diet. The standardized form has values ranging from 0 to 1, where 0 corresponds to a specialist and 1 to a generalist (Alarcón-Nieto and Palacios 2009). The Levin's niche index is expressed as $B = 1/\Sigma Pj^2$, where Σ = sum, Pj = ratio of individuals using resource j, and the standardized index as $B_a = B - 1/n+1$, where B = Levin's index and n = number of resources used by organisms, where values lower than 0.6 correspond to a specialist diet and those higher than 0.6, to a generalist diet (Krebs 1989).

Statistical analysis. The mean and standard deviation of morphometric measurements, weight, and IK of 23 specimens were obtained and sorted by season and sex. Due to the number of samples for each season, nonparametric statistics were used to determine significant differences in male IK by season using the Mood test. The Kruskal-Wallis test was used for females, and significant differences were analyzed with the Conover test. The degree of association between plant cover and IK was estimated using Spearman's correlation coefficient. Statistical analyses were performed in Excel using the SPSS Statistics Base 22.0 statistical package.

Results

A total of 40 adult specimens of *Geomys arenarius* were collected as follows: 11 females and 3 males in the dry season, 13 females and 8 males in the wet season, and 5 females in the post-wet season.

Males (n = 5) had the following mean measurements: total length (TL) 267.40 ± 9.60 mm, tail length (T) 77.6 ± 3.78 mm, hind foot (HF) 33.60 ± 3.71 mm, ear length (E) 5.0 ± 1.0 mm, and weight (w) 194.80 ± 43.75 g. Females (n = 18) had the following mean measurements: TL = 234.94 ± 19.24 mm, T = 68.05 ± 11.04 mm, HF = 32.05 ± 3.05, E = 4.05 ± 0.87, and w = 120.83 ± 26.03 g in all three seasons. The measurements and weights by season corresponded to 10 specimens (3 males and 7 females) in the dry season, 8 (2 males and 6 females) in the wet season, and 5 females in the post-wet season (See Table 1).

Table 1. Means ± standard deviation of morphometric measurements and weight of *G. arenarius* by seasons and sex.

Season	Sex	TL	T	HF	E	w
Dry	Machos (*n*=3)	269.66 ± 6.65	76.66 ± 3.05	33.66 ± 5.03	5.66 ± 0.57	223.66 ± 1.52
	Hembras (*n*=7)	229.85 ± 14.87	70.57 ± 4.46	31.00 ± 1.82	4.71 ± 0.75	134.85 ± 29.70
Wet	Machos (*n*=2)	264.00 ± 15.55	79.00 ± 5.65	33.50 ± 2.12	4.00 ± 0.0	151.50 ± 37.47
	Hembra (*n*=6)	244.83 ± 25.39	73.16 ± 8.65	34.50 ± 3.93	4.00 ± 0.63	114.00 ± 25.88
Post-wet	Hembras (*n*=5)	230.20 ± 14.68	58.4 ± 15.09	30.60 ± 1.34	3.2 ± 0.44	109.40 ± 11.90

Fitness Index (IK). The average IK of males was 2.82 ± 0.47, with 3.12 ± 0.30 in the dry season and 2.38 ± 0.22 in the wet season. For females, the average IK was 2.64 ± 0.61, with 3.28 ± 0.12 in the dry season, 2.29 ± 0.54 in the wet season, and 2.15 ± 0.13 in the post-wet season.

The Mood median test showed no statistically significant differences (α = 0.05; d.f = 1; p = 0.13) in the fitness index (IK) between dry-season and wet-season males.

The Kruskal-Wallis test for the seasonal effect on the IK of females was statistically significant (α = 0.05, d.f. = 2; p = 0.005). The Conover test (α = 0.05) showed statistically significant differences between the dry season versus the wet (p = 0.012) and post-wet (p = 0.0005) seasons. On the other hand, there were no significant differences in the IK between the wet and post-wet seasons (p = 0.57).

A reduction in plant cover associated with the crop was observed throughout the study, mainly due to trimming and plot cleaning. A 72.88 % cover was reported for the dry season, 16.12 % for the wet season, and 4.14 % for the post-wet season. Spearman's correlation coefficient for males (R = 0.86) and females (R = 0.74) showed a strong correlation between the fitness index (IK) and plant cover (Figure 2).

Diet of Geomys arenarius. In all seasons, the diet of the 40 desert pocket gophers consisted mainly of the ivyleaf groundcherry (*Physalis hederifolia*) with 29.26 % of the consumed items, followed by the spectacle pod (*Dimorphocarpa wislizeni*; 16.29%) and the common sandbur (*Cenchrus incertus*; 14.40 %; Table 2).

In the dry season, the diet consisted of 11 species, 11 genera, and 9 families. The common sandbur (*Cenchrus incertus*) was the most abundant food item (27.97 %), followed by the spectacle pod (*Dimorphocarpa wislizeni*; 21.14 %) and the ivyleaf groundcherry (*Physalis hederifolia*; 15.78 %; Table 2).

In the wet season, 11 species, 10 genera, and 7 families were recorded in the diet. The ivyleaf groundcherry (*Physalis hederifolia*) was the dominant food item (31.24 %), followed

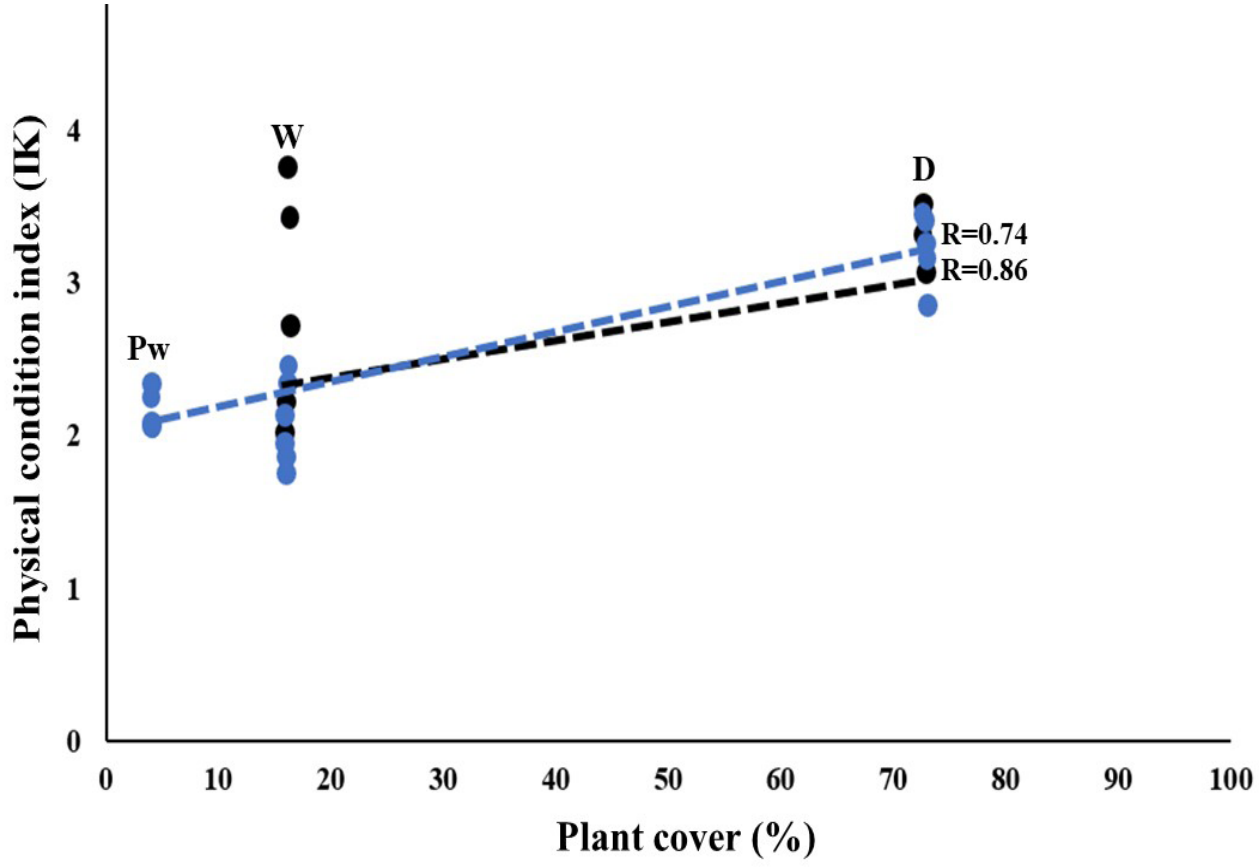

Figure 2. Correlation between plant cover and physical condition index (IK) by season and sex (males marked in black, females marked in blue).

Table 2. Overall and seasonal diet of *Geomys arenarius*

Family	Genus/species	General	Season		
			Dry	Wet	Post-wet
Solanaceae	*Physalis hederifolia*	29.26	15.78	31.24	58.2
Brassicaceae	*Dimorphocarpa wislizeni*	16.29	21.14	17.88	
Poaceae	*Cenchrus incertus*	14.40	27.97	5.63	2.46
Nyctaginaceae	*Tripterocalyx carneus*	10.20	6.51	17.88	
Boraginaceae	*Heliotropium curassavicum*	9.73	15.44	4.19	9.42
Poaceae	*Panicum hallii*	6.42		15.3	
Poaceae	*Setaria macrostachya*	4.94		1.61	25.82
Poaceae	*Setaria leucopila*	2.90	5.04	1.93	
Asteraceae	*Palafoxia sphacelata*	1.82	0.49	3.86	
Amaranthaceae	*Salsola kali*	1.42	3.09		0.82
Poaceae	*Sporobolus airoides*	1.01	2.43		
Onagraceae	*Oenothera pallida*	0.40	0.97		
Juglandaceae	*Carya illinoinensis*	0.54			3.28
Malvaceae	*Sphaeralcea incana*	0.54	1.14	0.16	
Poaceae	*Sporobolus contractus*	0.13		0.32	

. *All values correspond to the percentage (%) in the diet.

by the spectacle pod (*Dimorphocarpa wislizeni*; 17.88 %), and Hall's panicgrass (*Panicum hallii*; 15.29 %; Table 2).

Finally, six species, six genera, and five families were recorded in the post-wet season. The ivyleaf groundcherry (*Physalis hederifolia*) was the most abundant food item (58.05 %), followed by the plains bristle grass (*Setaria macrostachya*; 25.84 %), and the salt heliotrope (*Heliotropium curassavicum*; 13.20 %; Table 2).

Levin's Niche Breadth Index: Levin's index for *G. arenarius* was $B = 5.27$, with a standardized value of $B_a = 0.37$, indicating that the desert pocket gopher is a specialist herbivorous. Levin's values by season suggest that the gopher has a narrow trophic niche (Table 3).

Discussion

Anderson (1972) reported the morphometric measurements of male and female gopher specimens collected in the surroundings of Samalayuca; however, he did not report weight values. The present study reports the measurements of a larger number of specimens of *G. arenarius*. Males showed a larger body size than females, consistent with several studies (Hendricksen 1972; Daly and Patton 1986; Mauk *et al.* 1999; Connior 2011; Calede and Brown 2021).

Fitness Index (IK). The male IK showed no statistically significant differences between seasons (dry versus wet), probably due to the low capture rate and the lack of male specimens collected in the post-wet season. For females, the fitness index was significantly higher in the dry season, although this season had the greatest plant cover. A strong correlation between IK and plant cover was evidenced in both cases. These results are consistent with Romañach *et al.* (2007) for *G. attwateri*, *G. bursarius*, and *Thomomys bottae*, where the variation in body mass was related to changes in plant cover, with larger body size at sites with higher plant biomass. This information confirms that the physical condition of small mammals is associated with the variation in the distribution of food resources (Schulte-Hostedde *et al.* 2001). In the Arantxa Ranch, where agriculture is performed, the vegetation is influenced by anthropogenic factors such as weeding and irrigation, which has led to the reduction or expansion of plant cover, density, and species richness. These changes impact the gopher diet and are reflected in the seasonal variation of IK values.

Diet of Geomys arenarius. Of the 32 plant species recorded in the Arantxa Ranch, *G. arenarius* only consumed 15 (46.87 %) during the three seasons. Herbaceous plants were the main type, which is consistent with reports for other gopher species such as *Thomomys mazama*, *T. talpoides*, and *G. bursarius* (Tietjen *et al.* 1967; Vaughan 1967; Burton and Black 1978; Luce *et al.* 1980) where herbaceous plants make up most of the annual diet. The low density or absence of herbaceous plants is associated with a low gopher abundance. Thus, it is evident that the diet of gophers is composed of certain plant species that grow in the areas where they live, so gophers depend on the availability of these plant species. Other studies on the diet of gophers in alfalfa fields have reported that crops account for more than 90 % of the stomach contents (Ward 1960; Luce and Case 1977). Our results showed that *G. arenarius* did not actively consume walnut trees, which accounted for less than 1 % of the diet in the three seasons. This resource was only consumed during the post-wet season, reflecting the consumption of plants associated with crops.

It has been reported that gophers are associated with significant damage to agricultural crops, causing production losses (Witmer *et al.* 1999; Lacher *et al.* 2019). This is consistent with what has been mentioned by producers, who reported that gophers constantly gnaw on irrigation lines. In addition, it has been documented that gopher mounds can have other impacts on crop areas, burying plants, damaging irrigation lines, and serving as weed

Table 3. Overall and seasonal Levin's trophic niche breadth index values.

Family	Species	General	Dry	Wet	Post-wet
Solanaceae	*Physalis hederifolia*	0.085	0.024	0.097	0.338
Brassicaceae	*Dimorphocarpa wislizeni*	0.026	0.044	0.031	
Poaceae	*Cenchrus incertus*	0.020	0.078	0.003	0
Nyctaginaceae	*Tripterocalyx carneus*	0.010	0.004	0.031	
Boraginaceae	*Heliotropium curassavicum*	0.009	0.023	0.001	0.008
Poaceae	*Panicum hallii*	0.004		0.023	
Poaceae	*Setaria macrostachya*	0.002		0	0.066
Poaceae	*Setaria leucopila*	0	0.002	0	
Asteraceae	*Palafoxia sphacelata*	0	0	0.001	
Amaranthaceae	*Salsola kali*	0	0		0
Poaceae	*Sporobolus airoides*	0	0		
Onagraceae	*Oenothera pallida*	0	0		
Juglandaceae	*Carya illinoinensis*	0			0.001
Malvaceae	*Sphaeralcea incana*	0	0	0	
Poaceae	*Sporobolus contractus*	0		0	
	B=	5.21	4.54	4.20	1.40
	B_a=	0.37	0.45	0.42	0.28

seedbeds (Baldwin 2011). Likewise, tunnels can divert water, causing losses of surface irrigation water; besides, tree roots are frequently damaged from gopher tunneling (Knight 2000). Although *G. arenarius* does not actively feed on walnut trees, the presence of these rodents has adverse effects on walnut crops. The constant damage to irrigation systems restrains the establishment of new crop areas and reduces the vigor of previously established ones due to the limited water availability. This has been reported for *Thomomys* sp., where damage includes loss of vigor or mortality of crop plants due to damage in the underground drip lines and loss of water irrigation caused by the burrow system (Baldwin *et al.* 2011). This is likely the main conflict between producers and gophers in pecan production areas, as these act as artificial habitats for *G. arenarius*, which damages crops when excavating their burrows.

Levin's Niche Breadth Index. Gophers are considered general herbivores that feed on different parts (leaves, roots, and fruits) of a wide variety of plant species (Howard and Childs 1959; Williams and Cameron 1986; Hunt 1992). In the present study, Levin's index showed that *G. arenarius* is a specialist species, a finding that rejects the above hypothesis. However, Briones-Salas *et al.* (2013) described that classifying an organism as a specialist depends not only on the Levin's index value but also on a set of conditions particular to the species and the area where it lives. In the pecan orchard, the permanent change in irrigation and weeding by walnut producers forces gophers to depend on a limited range of resources in the area. Consequently, *G. arenarius* may be adopting an optimal foraging strategy that provides the greatest benefit at the lowest cost, thus maximizing the energy obtained. As Pyke (1984) reported, the dependence of organisms on a particular food type is related to abundance, search time, and energy value, which leads to selection. It has been described that in gophers, the search for food shows a relatively intense selection, balancing the energy costs and gains of food search (Vleck 1981; Andersen 1988; Reichman 1988; Jenkins and Bollinger 1989). In the case of *G. arenarius*, the narrow food niche is probably determined by the availability and energy supply of plants, as well as continued agricultural management (trimming, fertilization, irrigation, and weeding) that limits or removes food sources throughout the year. Sexual dimorphism was evident as the average morphometric and weight measurements were higher in males than in females. The fitness index (IK) of males and females is influenced by the availability of plants resulting from agronomic management in pecan orchards.

The diet of the desert pocket gopher (*Geomys arenarius*) in the Arantxa Ranch (pecan orchard) comprised 15 plant species associated with crops, mainly *Physalis hederifolia* (Solanaceae), *Dimorphocarpa wislizeni* (Brassicaceae), and *Cenchrus incertus* (Poaceae). We demonstrated that *G. arenarius* is a specialist species. The Walnut tree (*Carya illinoinensis*) was not a major food item in the gopher diet during the three seasons studied (2020).

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Appendix 1

Plant species recorded in the study area in the Arantxa Ranch in the dry (D), wet (W), and post-wet (Pw) seasons and source of the botanical reference material: PJ018 CONABIO Project (HERB-UACJ), Animal Ecology and Biodiversity Laboratory (LEBA) and material collected in the field and included in the reference collection of LEBA (collected/LEBA).

Family	Genus/species	D	W	Pw	Source
Amaranthaceae	*Amaranthus hybridus*		*		Collected/LEBA
Amaranthaceae	*Chenopodium album*		*		Collected/LEBA
Amaranthaceae	*Salsola kali*	*	*	*	LEBA
Asparagaceae	*Yucca elata*	*	*		HERB-UACJ 1992
Asteraceae	*Ambrosia acanthicarpa*		*		Collected/LEBA
Asteraceae	*Picradeniopsis absinthifolia*		*		HERB-UACJ 2233
Asteraceae	*Brickellia coulteri*		*		HERB-UACJ 2238
Asteraceae	*Dieteria canescens*		*	*	HERB-UACJ 2267
Asteraceae	*Lactuca serriola*	*	*	*	Collected/LEBA
Asteraceae	*Palafoxia sphacelata*	*			HERB-UACJ 2250
Asteraceae	*Verbesina encelioides*		*		HERB-UACJ 2236
Boraginaceae	*Heliotropium curassavicum*	*	*	*	HERB-UACJ 2307
Boraginaceae	*Euploca convolvulacea*		*		HERB-UACJ 1995
Brassicaceae	*Dimorphocarpa wislizeni*	*	*		LEBA
Convolvulaceae	*Cuscuta umbellata*	*	*		HERB-UACJ 1760
Juglandaceae	*Carya illinoinensis*	*	*	*	Collected/LEBA
Malvaceae	*Sphaeralcea incana*	*	*		Collected/LEBA
Martyniaceae	*Proboscidea louisianica*	*	*		HERB-UACJ 1904
Nyctaginaceae	*Boerhavia spicata*		*		HERB-UACJ 1987
Nyctaginaceae	*Tripterocalyx carneus*	*	*		HERB-UACJ 1938
Onagraceae	*Oenothera pallida*	*	*	*	HERB-UACJ 1771
Plantaginaceae	*Epixiphium wislizeni*	*			HERB-UACJ 2005
Poaceae	*Cenchrus incertus*	*	*	*	LEBA
Poaceae	*Chloris virgata*		*		HERB-UACJ 2046
Poaceae	*Eragrostis cilianensis*	*			HERB-UACJ 2120
Poaceae	*Panicum hallii*	*	*		LEBA
Poaceae	*Setaria leucopila*	*	*		HERB-UACJ 2080
Poaceae	*Setaria macrostachya*	*	*	*	HERB-UACJ 2184
Poaceae	*Sporobolus airoides*	*	*		HERB-UACJ 2166
Poaceae	*Sporobolus contractus*		*		HERB-UACJ 2156
Solanaceae	*Physalis hederifolia*	*	*	*	HERB-UACJ 2333
Zygophyllaceae	*Tribulus terrestris*	*	*		Collected/LEBA