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Diversity of medium and large mammals in a submontane scrubland

Melissa Ponce-Marroquin[1], Santiago Niño-Maldonado[1]*, Vannia del Carmen Gómez-Moreno[2], Juana María Coronado-Blanco[1], and Andrey Ivanovich Khalaim[1]

[1] Facultad de Ingeniería y Ciencias, Universidad Autónoma de Tamaulipas. Centro Universitario Victoria, Adolfo López Mateos, CP. 87149, Ciudad Victoria. Tamaulipas, México. Email: melissapm27.pm@gmail.com (MP-M); coliopteranino@hotmail.com (SN-M); jmcoronado@docentes.uat.edu.mx (JMC-B); kandrey@docentes.uat.edu.mx (AIK).

[2] Tecnológico Nacional de México/Instituto Tecnológico de Ciudad Victoria. Boulevard Emilio Portes Gil #1301, CP. 87010, Ciudad Victoria. Tamaulipas, México. Email: mantiz@outlook.com (VCG-M).

*Corresponding author: https://orcid.org/0000-0002-7494-6531.

Studies on mammals are essential due to the rapid changes in land use, habitat fragmentation, and poaching that threaten their survival. Significant changes in the composition of mammal communities due to the elimination or displacement of species have been documented. In the face of accelerated environmental degradation, mammal inventories are vital for understanding the structure and composition of communities and facilitating conservation strategies. In Tamaulipas, mammal studies have focused on protected areas, overlooking ecosystems such as submontane scrublands, which, despite being impacted by human activities, can serve as refuges and biological corridors. Studying these ecosystems is crucial for describing ecological aspects and developing effective conservation and management strategies. Therefore, the objective of this study was to investigate the diversity and richness of medium and large mammals in a submontane scrubland. The study area is located southwest of Casas, Tamaulipas. Ten single camera trap stations were set and remained active from July 2020 to June 2021. Species richness was estimated with Chao 1 and Jacknife 1. Diversity values of orders one and two were estimated, and the species composition and abundance were compared between dry and rainy seasons using PERMANOVA and SIMPER analyses. A total of 457 records of 12 species were obtained, the most abundant being *Odocoileus virginianus*, *Dicotyles tajacu*, and *Leopardus pardalis*. Significant differences in species composition between seasons were detected, with *Dicotyles tajacu*, *Odocoileus virginianus*, *Nasua narica,* and *Leopardus pardalis* accounting for 85.32 % of the differences in species composition between seasons. Although the area is impacted by the introduction of free-grazing cattle, *Leopardus pardalis* is the third-most recorded species and is protected by NOM-059-SEMARNAT-2010. In addition, during the sampling, five of the six Mexican felids were reported and the family Felidae is listed in Appendix II of CITES, so the area should be considered for permanent monitoring to establish conservation strategies.

Los estudios sobre mamíferos son esenciales debido al rápido cambio en el uso del suelo, la fragmentación del hábitat y la caza furtiva que amenazan su supervivencia. Se han documentado cambios significativos en la composición de comunidades de mamíferos debido a la eliminación o desplazamiento de especies. Ante el deterioro ambiental acelerado, los inventarios de mamíferos son vitales para entender la estructura y composición de las comunidades y facilitar estrategias de conservación. En Tamaulipas, los estudios de mamíferos se han centrado en áreas protegidas, dejando de lado ecosistemas como el matorral submontano, que, aunque impactado por actividades humanas, puede servir como refugio y corredor biológico. Estudiar estos ecosistemas es crucial para describir aspectos ecológicos y desarrollar estrategias efectivas de conservación y manejo. Por ello, el objetivo de este estudio fue conocer la diversidad y riqueza de mamíferos medianos y grandes en un matorral submontano. El área de estudio se ubicó al suroeste de Casas, Tamaulipas. Se colocaron 10 estaciones sencillas de cámaras trampa, que permanecieron activas de julio de 2020 a junio de 2021. La riqueza se estimó con Chao 1 y Jacknife 1. Se determinaron los valores de diversidad de orden uno y dos, así mismo, se comparó la composición y abundancias de las especies entre las temporadas de secas y lluvia empleando los análisis de PERMANOVA y SIMPER. Se obtuvieron 457 registros independientes de 12 especies, siendo las más abundantes *Odocoileus virginianus*, *Dicotyles tajacu* y *Leopardus pardalis*. Se detectaron diferencias significativas en la composición de especies entre temporadas abundancias siendo *Dicotyles tajacu*, *Odocoileus virginianus*, *Nasua narica* y *Leopardus pardalis* aportan el 85.32 % de las diferencias en la composición entre temporadas. Aunque el área presenta impacto por la introducción de ganado bovino de libre pastoreo se obtuvo a *Leopardus pardalis* como la tercera especie con más registros y es protegida por la NOM-059-SEMARNAT-2010, además durante el muestreo se reportaron cinco de los seis felinos mexicanos y la familia Felidae se encuentra en el apéndice II del CITES, por lo que el área debería ser tomada en cuenta para monitoreo constante, y establecer estrategias de conservación.

Keywords: Abundance; diversity; dry season; mammals; rainy season; species richness.

Introduction

Biodiversity is an essential component for the balance and health of ecosystems. Mammals play central roles, acting as predators, herbivores, and seed dispersers, to mention a few. In Mexico — one of the most diverse countries worldwide (Ceballos and Oliva 2005) —, the study of mammals is essential given the rapid change in land use and habitat fragmentation that, together with poaching, threaten their survival (Aguilar *et al.* 2000). Significant changes in the composition of mammal communities have been documented around the world, due to the elimination or displacement of species (Laurance and Yensen 1991; Krikpatrick and Jarne 2000; Janecka *et al.* 2014).

Consequently, inventories of mammals should be elaborated because they are essential to acquire comprehensive knowledge, essential for carrying out ecological, conservation, and management studies (Pacheco *et al.* 2004). Its importance has grown considerably in the face of the increasing environmental deterioration driven by human population growth and the associated urban, industrial, agricultural, and livestock-raising activities, all of which generate adverse impacts on natural environments (Chávez and Ceballos 1998). In this context, strategies for the management and conservation of natural resources, particularly flora and fauna, largely depend on the availability of information on biological diversity (Chávez and Ceballos 1998; Romero and Ceballos 2006). Inventories provide a crucial starting point for understanding changes in the structure and composition of mammal communities in different areas, conserved and disturbed, as well as at different times, facilitating the implementation of conservation and management strategies (López-Ramírez *et al.* 2020; Mezhua-Velázquez *et al.* 2022).

In Tamaulipas, studies on mammals are scarce, and most focus on protected natural areas (Vargas-Contreras and Hernández-Huerta 2001; Carvajal-Villareal *et al.* 2012; Carrera-Treviño *et al.* 2018; Branney *et al.* 2023; Ochoa-Espinoza *et al.* 2023), leaving aside other forest areas that, despite being affected by anthropogenic activities, function as refuges and biological corridors for biodiversity (López-Ramírez *et al.* 2020). Such is the case of the submontane scrubland, characteristic of northeastern Mexico, including Tamaulipas. This vegetation type is characterized by a mixture of thorny shrubs, small trees, and perennial herbs (Rzedowski 2005). It covers 8.3 % of the surface area of Tamaulipas (INEGI 2017) and undergoes constant changes due to the human activities already mentioned (Estrada-Castillón *et al.* 2012), which affect wild mammal populations.

Therefore, studying this ecosystem is essential to describe its ecological aspects, determine the factors that influence their populations, and generate better conservation, management, and use strategies (Buenrostro-Silva *et al.* 2017; Salazar-Ortiz *et al.* 2020). The objective of this study was to evaluate the diversity, structure, and composition of medium and large mammals in a submontane scrubland.

Materials and methods

Study Area. The study area is located southwest of the municipality of Casas, Tamaulipas, Mexico, between coordinates 23° 24′ and 23° 21′ N, -98° 44′ and -98° 38′ O, at an altitude of 240 to 420 meters above sea level. (INEGI 2010). The area is located outside the limits of the western slope of the Sierra de Tamaulipas Biosphere Reserve (Figure 1). The regional climate is semi-warm and semi-dry, with minimum temperatures of 16 °C to 19 °C and maximum temperatures of 34 °C to 36 °C (INEGI 2021), and a mean annual precipitation of 600 mm to 800 mm. The dominant vegetation type is submontane scrubland (INEGI 2021).

Sampling design. Ten simple stations (camera traps) were placed with a minimum separation of 3 km and a maximum of 3.5 km from each other. The stations were set on nature trails or close to trails and roads with traces of mammals, such as footprints and feces. Camera traps were installed at 30 cm to 50 cm above the ground and set to capture three photographs at five-second intervals, operating 24 hours a day. They were checked each month to change memory cards and batteries (Chávez *et al.* 2013; Maffei *et al.* 2002; Mattey *et al.* 2022). The sampling campaign covered 12 months, from July 2020 to June 2021; months were grouped according to climatic seasons (dry and rainy). To determine the dry and rainy seasons, the mean historical precipitation was calculated for the period between 1982 and 2013 based on climatological statistical information available from the national meteorological service of the National Water Commission (CONAGUA 2010). As a result, the dry season included January, February, March, April, November, and December, while the rainy season spanned from May to October.

Analysis of photographic and taxonomic identification and nomenclature. To determine the independence of the records, the following criteria were considered: a) consecutive photographs of the same species should be separated by 24 h and b) in photographs of gregarious species, each was considered as a separate record (Monroy-Vilchis *et al.* 2011; Chávez *et al.* 2013; Ávila-Nájera *et al.* 2015; Pozo-Montuy *et al.* 2019). Individuals were identified based on Ceballos and Oliva (2005) using the nomenclature according to Ramírez-Pulido *et al.* (2014).

Data analysis. The potential number of species was calculated according to Moreno (2001) and Magurran (2004) by using the non-parametric estimators Chao 1, which uses abundance data, and Jacknife 1, based on species incidence. Estimators were calculated using 100 randomizations with no replacement in the program EstimateS 9.1.0 (Colwell 2013).

Diversity numbers were calculated using the Hill series of first (*q1)* and second (*q2)* orders. These were obtained from the exponential of the Shannon-Wiener index: $q1 = e^{h'}$ (where: $q1$ = first-order Hill number, and $e^{h'}$ = Shannon index) and Simpson's reciprocal: $q2 = 1/D$ (where: $q2$ = second-order Hill number and D = Simpson's dominance

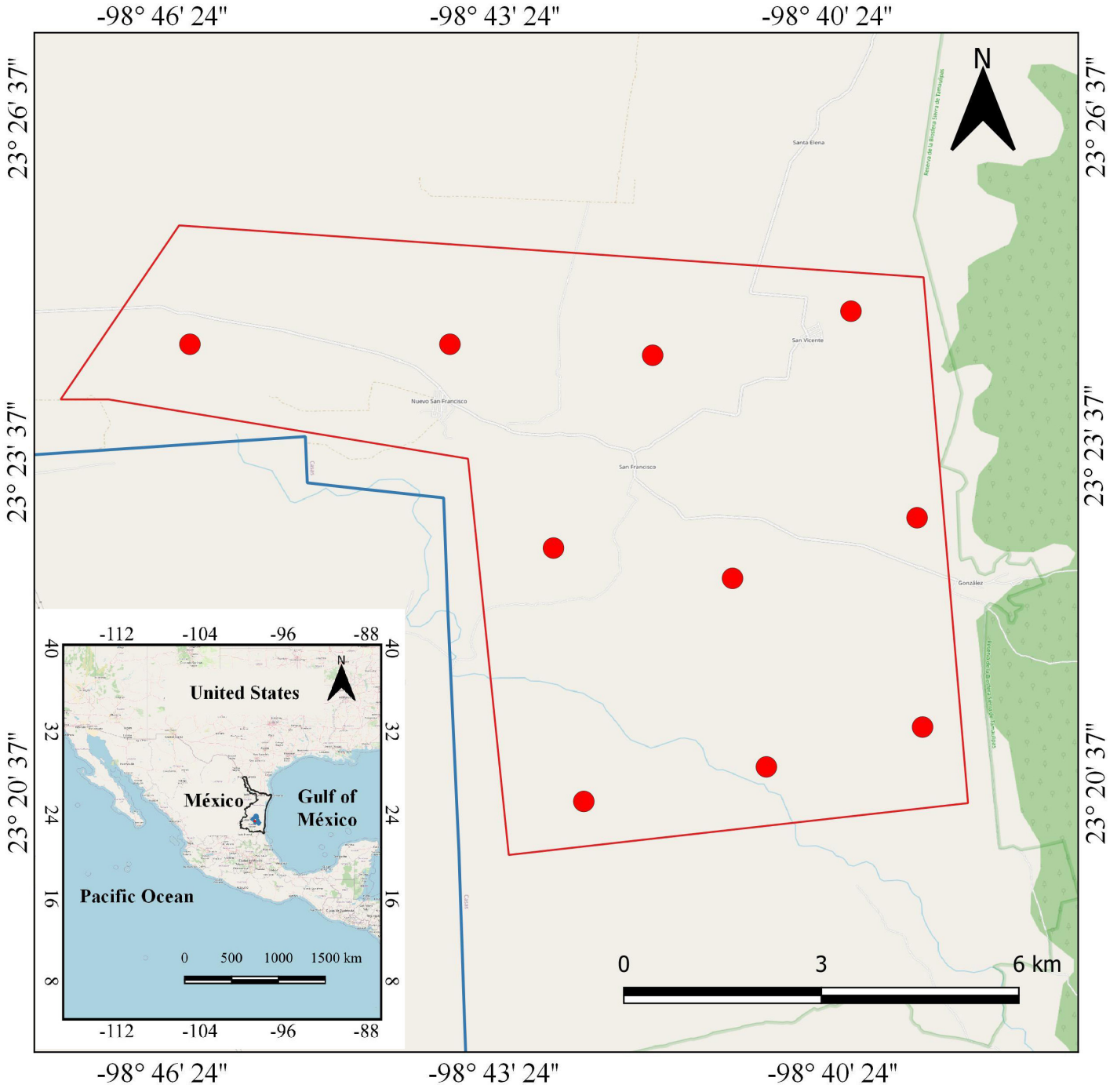

Figure 1. Location of the study area, Casas, Tamaulipas, México.

index); these indicate the number of effective species (Moreno 2001; Magurran 2004; Magurran 2021).

The species composition of mammal communities and their abundances between seasons were compared with a permutation-based analysis of variance (PERMANOVA); this results in the sum of squares within groups (*SS)* and the sum of squares within groups (*Ss*), using the Bray-Curtis index as a measure of distance, with 9999 random permutations (Anderson 2001). A percentage similarity analysis (SIMPER) was also used to determine which species contributed most to the differences between the seasons (Clarke 1993).

Results

Species richness. A total of 457 independent records were obtained with a sampling effort of 3,650 trap-days; the mammals recorded belong to three orders, seven families, and 12 species. The order Carnivora presented the highest richness with four families: Canidae, Felidae, Mephitidae, and Procyonidae; of these, Felidae was the best-represented family, with five species (Table 1). The highest species richness was recorded during the rainy season (12 species) *vs.* the dry season (nine species), while the potential richness for each season was in rainfall from 13.99 (Chao 1) to 16.17

Table 1. Taxonomic list of the records of medium and large mammals in the study area and dry and rainy season, in the municipality of Casas, Tamaulipas.

Order, Family, and Species	Records			NOM-059
	Dry	Rainy	Area	
DIDELPHIMORPHIA				
DIDELPHIDAE				
Didelphis marsupialis	5	1	6	-
CARNIVORA				
FELIDAE				
Herpailurus yagouaroundi	-	1	1	A
Leopardus pardalis	40	18	58	P
Lynx rufus	6	4	10	-
Puma concolor	1	2	3	-
Panthera onca	-	1	1	P
CANIDAE				
Canis latrans	17	10	27	-
MEPHITIDAE				
Conepatus leuconotus	2	3	5	-
PROCYONIDAE				
Nasua narica	25	12	37	-
Procyon lotor	-	1	1	-
ARTIODACTYLA				
TAYASSUIDAE				
Dicotyles tajacu	17	86	103	-
CERVIDAE				
Odocoileus virginianus	118	87	205	-

(Jacknife 1) and for the dry season from 10.06 to 11.50. Thus, the observed richness relative to the potential richness ranged from 74.21 % to 97.95 % in the rainy season and from 78.26 % to 89.46 % in the dry season (Figure 2).

Records and diversity. The mammal species with the highest number of records were *Odocoileus virginianus* (white-tailed deer) with 205 records (44.86 %), followed by *Dicotyles tajacu* (collared peccary) with 103 (22.5 %) and *Leopardus pardalis* (ocelot) with 58 (12.7 %) (Figure 3). On the other hand, the species with a single record were *Herpailurus yagouaroundi*, *Panthera onca*, and *Procyon lotor* (Table 1).

For the study area, we estimated $q1$ = 4.908 abundant species and $q2$ = 3.584 dominant species that contribute to diversity. The highest number of effective species was observed in the dry season, with 4.468 (Table 2).

The PERMANOVA determined significant differences between the seasons [SS = 1.331; Ss = 0.9798; F = 3.586; p < 0.019] (Table 3). The SIMPER analysis indicated that the species that determine the main differences between seasons are *D. tajacu* (34.87 %), *O. virginianus* (28.36 %), *N. narica* (11.26 %), and *L. pardalis* (10.84 %), accounting for 85.32 % of the differences between the seasons. Specifically, *O. virginianus* and *D. tajacu* showed the highest mean abundance per season, with 14.5 and 14.3 in the rainy seasons, while *O. virginianus* (19.7), *L. pardalis* (6.67), and *N. narica* (4.17) showed the highest mean abundance in the dry season; Table 4).

Discussion

The present study reports approximately 8 % of the wild mammal species known for the state of Tamaulipas (152 species) and 24.5 % of the medium and large species (49 species.; Ceballos and Oliva 2005; Moreno 2024). Compared with the study by Branney *et al.* (2023), which recorded 15 species of the Order Carnivora in the Sierra de Tamaulipas Biosphere Reserve (RBST), an adjacent area, the present study reports nine species of this order despite the impact of livestock ranching. This variation can be attributed to the number of sampling stations, as more camera traps were used in the RBST and a larger area was covered. The pres-

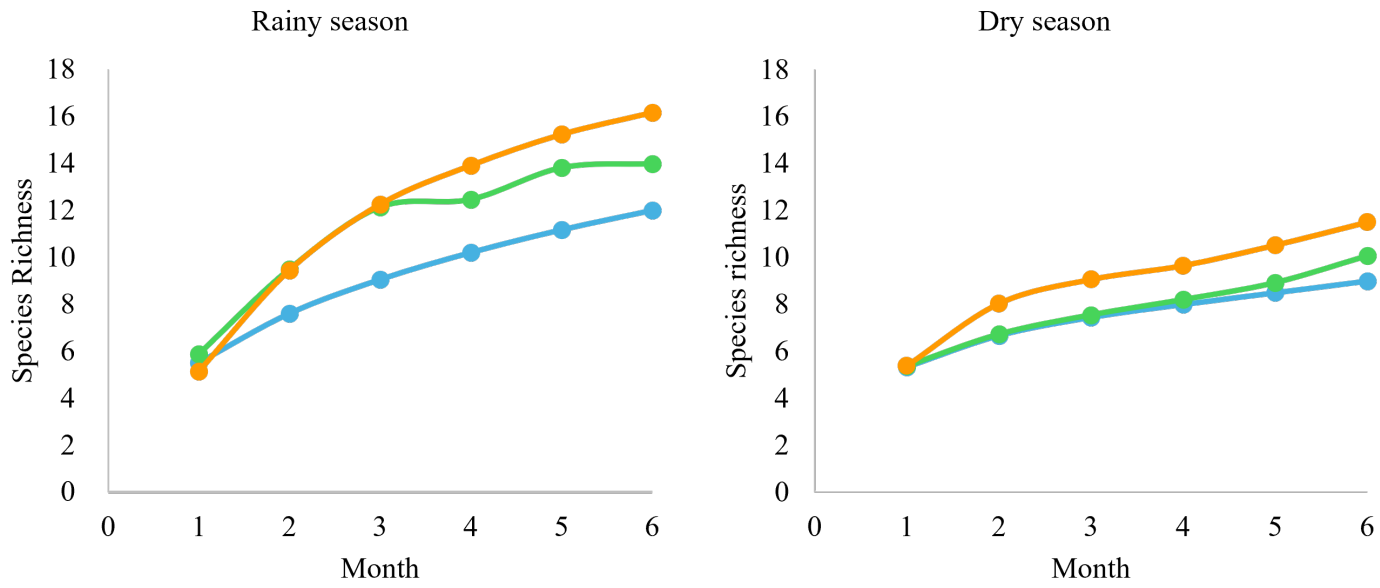

Figure 2. Species accumulation curves during seasons. Light blue = observed species; Green = Chao 1; Orange = Jack 1.

Table 2. Diversity indices by dry and rainy season, in the municipality. Houses, Tamaulipas.

Diversity			
	Dry	**Rainy**	**Study Area**
Richness	9	12	12
Abundance	231	226	457
Effective species			
$e^{H'}$ ($q1$)	4.544	4.468	4.908
$1/D$ ($q2$)	3.177	3.280	3.584

Hill Series *q1 = abundant species; q2* dominant species.

ence of *Sylvilagus* sp. Is worth noting, detected by direct observation, although it was not included in the study because it was not recorded in the sampling stations. The high species richness in the study area may be associated with the vegetation type and food availability (SEMARNAT 2018; Pozo-Montuy *et al.* 2019). Diverse habitats, such as submontane scrubland, provide a wide range of resources and microhabitats that offer shelter and suitable feeding areas (Alanís-Rodríguez *et al.* 2015).

This study reports five of the six Mexican felines. This finding could indicate that the ecosystem has fragments of vegetation with a good degree of conservation (Aranda *et al.* 2012; Hernández-Pérez *et al.* 2024). According to Ceballos and Olivia (2005), Aranda *et al.* (2012), Velazco and Macías and Peña-Mondragón (2015), the feline species identified in the area thrive preferentially in arid, xeric (submontane), and subtropical scrublands. These areas, covered by dense vegetation, provide an ideal habitat for these taxa (Buenrostro-Silva *et al.* 2015), as they provide them with shelter and camouflage, contributing to their successful hunting.

The submontane scrubland is of great importance because it is home to medium and large mammal species with a high cultural and ecosystem value (Cortes-Marcial and Briones-Salas 2014). Among these species, there are six with declining populations (*H. yagouaroundi*, *L. pardalis*, *P. concolor*, *P. onca*, *C. leuconotus*, *N. narica*), four with stable populations (*D. marsupialis*, *L. rufus*, *D. tajacu*, and *O. virginianus*), and two with growing populations (*C. latrans* and *P. lotor;* IUCN 2023). In addition, 11 of these species are classified as Least Concern (LC) and only *P. onca* is listed as Near Threatened (NT) by the IUCN (2023); three of these species are protected by NOM-059-SEMARNAT-2010 (SEMARNAT 2010). Likewise, *H. yagouaroundi*, *L. pardalis*, and *P. onca* are included in Appendix I of CITES, while *L. rufus* and *P. concolor* are in Appendix II (CITES 2023).

In both seasons, a similar diversity (orders 1 and 2) was recorded in the mammal communities, with uniform values in terms of the abundant and dominant species in the site. This is consistent with the study conducted by Ríos-Solís *et al.* (2021) in El Gavilán, Oaxaca, an area covered by tropical dry forest with dense vegetation in some period of the year, similar to some elements of the submontane scrubland. These ecosystems are suitable for the diversity of medium and large mammals.

On the other hand, the mountain cloud forest (BMM, in Spanish) of Tamaulipas shows a higher diversity during the dry season, similar to the submontane scrubland. In the submontane scrubland, diversity values also show a greater presence of abundant and dominant species during the dry season, with a minimal variation between seasons.

It is important to note that the BMM is located in the El Cielo Biosphere Reserve, which could be stabilizing the diversity levels, i.e., it fosters a stable structure and composition of mammals over time, since, being a protected natural area, activities such as hunting are prohibited. In contrast, the submontane scrubland, which lacks this type of protection, shows a constant diversity between the rainy and dry seasons. This suggests an ecosystem that maintains a greater resilience in the face of temporal variations (De Mazancourt *et al.* 2013; Loreau and De Mazancourt 2013).

The distribution of mammal abundance varies between seasons. During the dry season, the species with the highest number of records were *O. virginianus*, *L. pardalis*, and *N. narica*; during the rainy season, the abundant species were *O. virginianus*, *D. tajacu*, and *L. pardalis*. To note, *O. virginianus*, *D. tajacu*, and *L. pardalis* maintain reproductive populations, since they were recorded with offspring.

Of the recorded species, *O. virginianus* was very abundant obtained in both seasons, likely due to its high plasticity to different environments. These generalist herbivores thrive in various types of vegetation and, according to several authors (Ceballos and Oliva 2005; Weber 2014; Gallina and López 2016; Jiménez-Sánchez *et al.* 2024), are common in arid and scrub areas. In addition, their diet usually includes plants from the families Fabaceae and Asteraceae (Navarro-Cardona *et al.* 2018), which are abundant in submontane scrubland areas (Rzedowski 2005). However, a trend of declining abundance of *O. virginianus* was observed during the rainy season, while the abundance of *D. tajacu* increased. This suggests a more intense competition for food in the rainy season, forcing *O. virginianus* to travel greater distances in search of food (Sánchez-Pinzón and Arias 2022).

Like *O. virginianus*, *D. tajacu* is adapted to a wide variety of ecosystems (Zaldivar *et al.* 2022). In the present study, its abundance was higher during the rainy season. This finding is consistent with the observations reported by Reyna-Hurtado *et al.* (2014) and Sánchez-Pinzón *et al.* (2020), who highlighted that water availability is essential for the presence of this species and also influences the rolling behavior for grooming, to regulate temperature, or to eliminate ecto-

Table 3. PERMANOVA, comparisons of the structure of medium and large mammal communities between seasons in the municipality of Casas, Tamaulipas.

Season	**Rainy**	**Dry**
Rainy	-	0.0116*
Dry	3.586	-

Upper diagonal = *p*-values, lower diagonal = *F*-values. * = significant values.

Figure 3. Mammals recorded in the southwest of the municipality of Casas, Tamaulipas, México.

parasites (García-Marmolejo *et al.* 2015; Sánchez-Pinzón *et al.* 2020).

The fact that *L. pardalis* was the feline with the highest number of records may indicate that it is the top predator in the study area, and its presence may lead to the "pardalis effect". In other words, the presence of the ocelot influences the dynamics of the populations of its prey and other predators, affecting the structure and composition of the ecological community (Silva-Magaña and Santos-Moreno 2020). This may explain the low number of records of *P. onca*, *P. concolor*, *Lynx rufus*, and *H. yagouaroundi*, so they may be occasional visitors. Likewise, *H. yagouaroundi* is a cryptic and rare species, so it is difficult to detect it (Giordano 2015), and its presence is influenced by the pardalis effect (De Olivera *et al.* 2010; Caso *et al.* 2015).

Compared to other studies, ocelot records were more frequent in the present study. For example, in the El Cielo Biosphere Reserve in Tamaulipas, 40 records were documented over a 24-month period (Ochoa-Espinoza *et al.* 2023); in the northeastern Sierra de Puebla, 33 records were captured over 21 months (Ordoñez-Pardo et al. 2023); in Tequila, Veracruz, a single record was recorded in eight months (Salazar-Ortiz *et al.* 2020); and in the Lagunas de Chacahua National Park, Oaxaca, four records were captured during 12 months (Buenrostro-Silva *et al.* 2015). These differences can be attributed to variables such as the vegetation type, degree of human activities, or presence of big cats, in contrast with the area studied in the present

Table 4. Analysis SIMPER: determines the percentage of contribution of mammal species between seasons (rainy and dry) in the municipality of Casas, Tamaulipas.

Species	% Contrib.	% Accum.	Prom. A. Rainy	Prom. A. Dry
Dicotyles tajacu	34.870	34.87	14.300	2.830
Odocoileus virginianus	28.360	63.23	14.500	19.700
Nasua narica	11.260	74.49	2	4.170
Leopardus pardalis	10.840	85.32	3	6.670
Canis latrans	5.770	91.09	1.670	2.830
Didelphis marsupialis	2.575	93.67	0.167	0.833
Lynx rufus	2.177	95.85	0.667	1
Conepatus leuconotus	1.779	97.62	0.5	0.333
Puma concolor	1.03	98.65	0.333	0.167
Procyon lotor	0.566	99.22	0.167	0
Herpailurus yagouaroundi	0.408	99.63	0.167	0
Panthera onca	0.370	100	0.167	0

It indicates % Contrib. = percentage of total contribution per species; % Acum. = cumulative percentage of species; Prom. A. rainfall and dry = Average abundance of species in the seasons.

work, which is covered by a dense submontane scrubland vegetation (Rzedowski 2005), which favors the presence of *L. pardalis* (Ceballos and Oliva 2005; Aranda *et al.* 2012; Galindo-Aguilar et al. 2019). In addition, the study was carried out during the COVID-19 pandemic during which human activities were limited, a circumstance that may have also favored the presence of this feline.

Ramírez-Bravo *et al.* (2010) and Galindo-Aguilar et al. (2019) point out that the ocelot tolerates fragmented environments that are usually close to mountainous areas within protected areas. Such is the case of this study, which was carried out in an area adjacent to the Sierra de Tamaulipas Biosphere Reserve. In addition, habitat modification and fragmentation are detrimental to feline populations, with ocelots being most affected by the decline in vegetation cover (Hernández-Pérez *et al.* 2024).

It should be mentioned that the study area is being affected by the introduction of free-range cattle. The abundance of *Leopardus pardalis* in this area indicates that there are still vegetation remnants or fragments that are suitable for the subsistence of species with a high ecosystem value. Therefore, the area should be considered for monitoring, and federal and state authorities should establish conservation strategies.

The record of a raccoon was interesting because this species thrives in a wide variety of environments associated with permanent water bodies (Guerrero *et al.* 2000; Timm *et al.* 2016). One of the reasons of this distribution is that, as racoons lack salivary glands, they need to moisten the food to ingest it (Ceballos and Oliva 2005). In the study area, water bodies are temporary from April to September, so this habitat is not suitable for the species.

Additional research and inventories on mammals should be conducted, especially in unprotected areas, to gain a more complete understanding of mammal diversity and their conservation status. This may contribute to identify priority areas and develop effective strategies for species conservation.

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Literature cited

Alanís-Rodríguez, E. *et al.* 2015. Composición y diversidad del matorral desértico rosetófilo en dos tipos de suelo en el noreste de México. Acta Botánica Mexicana 110:105–117.

Anderson, M. J. 2001. A new method non-parametric multivariate analyses of variance. Austral Ecology 26:32–46.

Aguilar, C.E, *et al.* 2000. Deforestación y fragmentación de ecosistemas: qué tan grave es el problema en México. CONABIO. Biodiversitas 30: 7-11.

Aranda, M., F. Botello, and L. López-deBuen. 2012. Diversidad y datos reproductivos de mamíferos medianos y grandes en el bosque mesófilo de montaña de la Reserva de la Biosfera Sierra de Manantlán, Jalisco-Colima, México. Revista Mexicana de Biodiversidad 83:778–784.

Ávila-Nájera, D. *et al.* 2015. Estimación Poblacional y conservación de felinos (Carnivora: Felidae) en el norte de Quintana Roo, México. Revista de Biología Tropical 63:799–813.

Branney, A. B., *et al.* 2023. Jaguars, ocelots, coatimundis... ah my: Species composition and temporal overlap of a diverse carnivore guild in the Sierra of Tamaulipas, México. Global Ecology and Conservation 44: 1-12.

Buenrostro-Silva A., B. Pinacho-López, and J. García-Grajales. 2017. Diversidad de mamíferos en una reserva privada de la sierra

sur de Oaxaca, México. Ecosistemas y Recursos Agropecuarios 4:111–122.

Buenrostro-Silva, A. D., P. Sigüenza, and J. García-Grajales. 2015. Mamíferos carnívoros del parque nacional Lagunas de Chacahua, Oaxaca, México: Riqueza, abundancia y patrones de actividad. Revista Mexicana de Mastozoología Nueva Época 5:39–51.

Canizales-Velázquez, P. A. *et al*. 2009. Caracterización estructural de matorral submontano de la Sierra Madre Oriental, Nuevo León. Revista Chapingo Serie Ciencias 15:115–120.

Carrera-Treviño, R. *et al*. 2018. Interacciones temporales y espaciales de mesocarnívoros simpátricos en una Reserva de la Biosfera: ¿coexistencia o competencia? Revista de Biología Tropical 66:996–1008.

Carvajal-Villareal, S., *et al*. 2012. Spatial patterns of the margay (*Leopardus wiedii,* Felidae, Carnivora) at "El Cielo" Biosphere reserve, Tamaulipas, Mexico. Mammalian 76: 237-244.

Caso, A., T. de Olivera, and S. V. Carvajal. 2015. *Herpailurus yagouaroundi*. The IUCN Red List of Threatened Species 2015:e. T9948A50653167.

Ceballos, G., and G. Oliva. 2005. Los mamíferos silvestres de México. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad y Fondo de Cultura Económica. Distrito Federal, México.

Chávez C., and G. Ceballos. 1998. Diversidad y estado de conservación de los mamíferos del Estado de México. Revista Mexicana de Mastozoología 3:113–134.

Chávez, C. *et al*. 2013. Manual de fototrampeo para estudio de fauna Silvestre. El jaguar en México como estudio de caso. Alianza WWF- Telcel, Universidad Autónoma de México. Ciudad de México, México.

CITES (Convención sobre el comercio internacional de espcies amenazadas de fauna y flora silvestres). 2024. Convención sobre el comercio internacional de especies amenazadas de fauna y flora silvestres. Apéndices I, II y III.

Clarke, K. R. 1993. Non-parametric multivariate analyses of changes in community structure. Australian Journal of Ecology 18:117–143.

Colwell, R. K. 2013. EstimateS Statistical estimation of species richness and shared species from simples. Version 9.1.0. https://www.robertkcolwell.org/pages/1407.

Cortés-Marcial, M., and M. Briones-Salas. 2014. Densidad, abundancia relativa y patrones de actividad de mamíferos medianos y grandes en una selva seca del Istmo de Tehuantepec, Oaxaca, México. Revista de Biología Tropical 62:1433–1448.

CONAGUA (Comisión Nacional del Agua). 2010. Información estadística climatológica de las estaciones climatológicas. Servicio Meteorológico Nacional-CONAGUA. http://smn.gob.mx/información-climatologica. Consultado el 15 de diciembre de 2022.

De Mazancourt, C. *et al*. 2013. Predicting ecosystem stability from community composition and biodiversity. Ecology Letters 16:617–625.

De Olivera, T. G. *et al*. 2010. Ocelot ecology and its effect on the small felid guild in the lowland neotropics. Pp. 559-580 en Biology and Conservation of Wild Felids, New York, United States.

Forman, R. T. 1995. Land Mosaics: the ecology of landscapes and regions. Cambridge: Cambridge University Press.

Estrada-Castillón, E. *et al*. 2012. Clasificación, estructura y diversidad del matorral submontano adyacente a la planicie costera del Golfo Norte en el Noreste de México. Botanical Sciences 90:37–52.

Galindo A., R. E. *et al*. 2019. Cambio de uso de suelo, fragmentación del paisaje y conservación de *Leopardus pardalis* Linnaeus, 1758. Revista Mexicana de Ciencias Forestales 10:149–169.

Gallina, S., and H. Lopez A. 2016. *Odocoileus virginianus*, white-tailed deer. The IUCN Red List of Threatened Species 2016:e. T42394A22162580.

García-Marmolejo, G., *et al*. 2015. Landscape composition influences abundance patterns and habitat use of three ungulate species in fragmented secondary deciduous tropical forest, Mexico. Global Ecology and Conservation 3: 744-755.

Giordano, a. j. 2015. Ecology and status of the jaguarundi *Puma yagouaroundi* a synthesis of existing knowledge. Mammal Review 46: 30-43.

Guerrero, S., M. R. Sandoval, and S. S. Zalapa. 2000. Determinación de la dieta del mapache (*Procyon lotor hernandezii* Wagle, 1831) en la costa sur de Jalisco, México. Acta Zoológica Mexicana 80:211–221.

Hernández-Pérez, E. *et al*. 2024. Land-use change and habitat fragmentation of *Leopardus pardalis* in Highlands of Puebla, Mexico. Therya 15:202–217.

INEGI (Instituto Nacional de Estadística y Geografía). 2010. Compendio de información geográfica municipal 2010. Casas, Tamaulipas.

INEGI. (Instituto Nacional de Estadística y Geografía). 2017. Conjunto de datos vectoriales de uso de suelo y vegetación. Escala 1:250 000. Serie VI. http://www.conabio.gob.mx/informacion/gis/. Accessed on april 12, 2020.

INEGI (Instituto Nacional de Estadística y Geografía). 2021. Uso de suelo y vegetación (vectoriales de usos de suelo y vegetación escala 1:250 000). https://www.inegi.org.mx/temas/usosuelo/. Consultado el 20 de agosto de 2022.

IUCN (The International Union of Conservation of Nature). 2023. The IUCN Red list of threatened species. http://www.iucnredlist.org. Consultado el 30 de enero de 2023.

Janecka, J. E. *et al*. 2014. Loss of genetic diversity among ocelots in the United States during the 20th century linked to human induced population reductions. PLoS ONE 9:1–10.

Jiménez-Sánchez, A. *et al*. 2024. Occupancy, relative abundance, and activity patterns of three sympatric deer associated to ponds. Therya 15:39–49.

Kirkpatrick, M., and P. Jarne. 2000. The effect of bottleneck on inbreeding depression and the genetic load. American Naturalist 155:154–167.

Laurance, W. F. L., and E. Yensen. 1991. Predicting impacts of edge effects in fragmented habitats. Biological Conservation 55:77–92.

López-Ramírez, C., T. Restrepo-Quiroz, and S. Solari. 2020. Diversidad y ecología de Mamíferos no voladores asociados a un Sistema agro-productivo de cacao, Granja Yariguíes, Santander, Colombia. Actualidades Biológicas 42:1–13.

Loreau, M., and De Mazancourt, C. 2013. Biodiversity and ecosystem stability: a synthesis of underlying mechanisms. Ecology Letters 16:106–115.

Maffei, L., E. Cuéllar, and A. J. Noss. 2002. Uso de trampas- cámara para la evaluación de mamíferos en el ecotono Chaco-Chiquitanía. Revista Boliviana de Ecología y Conservación Ambiental 11:55–65.

Magurran, A. E. 2004. Measuring biological diversity. Blackwell Science Ltd. United Kingdom.

Magurran, A. E. 2021. Measuring biological diversity. Current Biology 31:1174–1175.

Mattey T., A. J. *et al*. 2022. Diversity and activity patterns of medium and large terrestrial mammals in the Lapa Verde Wildlife Refuge, Heredia, Costa Rica. Revista de Ciencias Ambientales (Tropical Journal of Environmental Sciences) 56:242–258.

Mezhua-Velázquez, M. J. *et al*. 2022. Diversidad de mamíferos medianos y grandes del Ejido Zamajapa, Zongolica, Veracruz, México; implicaciones de manejo. Ecosistemas y Recursos Agropecuarios 9:1–15.

Monroy-Vilchis, O. *et al*. 2011. Fototrampeo de mamíferos en la Sierra Nanchititla, México: abundancia relativa y patrón de actividad. Revista de Biología Tropical 59:373–383.

Moreno, C. E. 2001. Métodos para medir la biodiversidad. Manuales y Tesis SEA, volumen 1. CYTED (Programa Iberoamericano de Ciencia y Tecnología para el Desarrollo), ORCYT- UNESCO (Oficina Regional de Ciencia y Tecnología para América Latina y el Caribe) y SEA (Sociedad Entomológica Aragonesa). Zaragoza, España.

Moreno, V. A. 2024. Mamíferos. Pp. 535–545 en La Biodiversidad de Tamaulipas. Volumen 2 Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Ciudad de México, México.

Navarro-Cardona, J.A. *et al*. 2018. Dieta, población y capacidad de carga del venado cola blanca (*Odocoileus virginianus*) en dos condiciones de hábitat en Tlachichila, Zacatecas, México. Agroproductividad 11:15–23.

Naveh, Z., Lieberman, A. S. 1984. Landscape ecology. Theory and application. Springer-Verlag, Nueva York, USA.

Ochoa-Espinoza, J. M. *et al*. 2023. Diversidad y abundancia de mamíferos del mesófilo de montaña del noreste de México. Acta Zoológica Mexicana (nueva serie) 39:1–8.

Ordoñez P., C. *et al*. 2023. Diversidad de mamíferos medianos y grandes del Sitio Experimental Las Margaritas, Sierra, Nororiental de Puebla. Revista Mexicana de Ciencias Forestales 14:87–116.

Pacheco, J. *et al*. 2004. Diversidad, historia natural y conservación de los mamíferos de San Vito de Coto Brus, Costa Rica. Revista de Biología Tropical 54:219–240.

Pozo-Montuy, G. *et al*. 2019. Análisis espacial y temporal de la estructura de la comunidad de mamíferos mediando y grandes de la reserva de la Biosfera Selva El Ocote, en el sureste mexicano. Revista Mexicana de Biodiversidad 90:1–14.

Ramírez-Bravo, E. *et al*. 2010. Ocelot (*Leopardus pardalis*) ditribution in the state of Puebla, Central Mexico. Therya 1: 111–120.

Ramírez-Mejía, D., and E. Mendoza. 2010. El papel funcional de la interacción planta-mamífero en el mantenimiento de la diversidad tropical. Biológicas 12:8–13.

Ramírez-Pulido, J. *et al*. 2014. Listo f recent land mammals of Mexico, 2014. Special Publications Museum of Texas Tech University 63:1–69.

Reyna-Hurtado, R. *et al*. 2014. Pecaríes en México. Wildlife of México. Biblioteca Básica de Agricultura, Colegió de Postgraduados. Ciudad de México, México.

Ríos-Solis, J. A., *et al*. 2021. Diversity and activity patterns of medium and large-sized terrestrial mammals at the Los Tuxtlas Biosphere Reserve, México. Therya 12:237–248.

Romero R., F., and G. Ceballos. 2006. Diversidad, historia natural y conservación de los mamíferos en Encinillas, Polotitlán, Estado de México. Revista Mexicana de Mastozoología 8:21–49.

Rzedowski, J. 2005. Vegetación de México. Edición digital. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, México.

Salazar-Ortiz, J. *et al*. 2020. Diversidad de mamíferos del municipio de Tequila, Veracruz, México. Abanico Veterinario 10:1–18.

Sánchez-Pinzón, K. G., and N. Arias D. 2022. Interference competition between *Pecari tajacu* and *Odocoileus virginianus*. Mammalogy Notes 8:1–5.

Sánchez-Pinzón, K. *et al*. 2020. Peccaries and their relationship with water availability and their predators in Calakmul, México. Therya 11:213–220.

Sanchez-pinzón, k. g., and n. arias d. 2022. Interference competition between *Pecari tajacu* and *Odocoileus virginianus.* Mammalogy Notes 8: 1-5.

SEMARNAT (Secretaría de Media Ambiente y Recursos Naturales). 2010. Norma Oficial Mexicana NOM-059-SEMARNAT-2010, Protección ambiental-especies nativas de México de flora y fauna silvestres-Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio-Listas de especies en riesgo. Diario Oficial de la Federación. 30 de diciembre, 2010.

SEMARNAT (Secretaría de Medio Ambiente y Recursos Naturales). 2018. Programa de acción para la conservación de la especie Pecarí de labios blancos (*Tayassu pecari*). SEMARNAT, CONANP. México.

Silva-Magaña, N., and A. Santos-Moreno. 2020. El efecto pardalis: su variación espacial y temporal. Revista Mexicana de Biodiversidad 91:1–12.

Timm, R. *et al*. 2016. *Procyon lotor*. The IUCN Red List of Threatened Species 2016:1–100.

Vargas-Contreras, J. A., and A. Hernández-Huerta. 2001. Distribución altitudinal en la reserva de la Biosfera "El Cielo", Tamaulipas, México. Acta Zoológica Mexicana 82: 83-109.

Velazco-Macías, C. G., and J. L. Peña-Mondragón. 2015. Nuevo registro de ocelote (*Leopardus pardalis*) en el estado de Nuevo León, México. Acta Zoológica Mexicana 31:470–472.

Villareal, H. *et al*. 2004. Manual de métodos para el desarrollo de inventarios de biodiversidad. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt. Colombia.

Weber, M. 2014. Temazates y vendados cola blanca tropicales. Pp. 421–452 in Ecología y manejo de fauna silvestre en México (Valdez, R. y J.A. Ortega-S., eds.). Colegio de Posgraduados, Universidad Autónoma de Chapingo. Texcoco, México.

Zaldivar, B. *et al*. 2022. Uso de hábitat y patrones de actividad de los pecaríes labiado (*Tayassu pecari*) y de collar (*Pecari tajacu*) en paisajes ganaderos del Chaco Seco, Paraguay. Reportes Científicos de la FACEN 13:20–27.

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