UNIVERSIDAD AUTÓNOMA AGRARIA ANTONIO NARRO

SUBDIRECCIÓN DE POSTGRADO

PATRONES ESPACIO-TEMPORALES DE DIVERSIDAD Y ABUNDANCIA DE MAMÍFEROS TERRESTRES EN UN PAISAJE SEMIÁRIDO DEL SURESTE DE COAHUILA, MÉXICO

Tesis

Que presenta ERIKA JASMIN CRUZ BAZAN

como requisito parcial para obtener el Grado de
DOCTOR EN CIENCIAS EN PRODUCCIÓN AGROPECUARIA

Torreón, Coahuila   Noviembre 2025

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Torreón, Coahuila

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Elaborada por ERIKA JASMIN CRUZ BAZAN como requisito parcial para obtener el grado de Doctor en Ciencias en Producción Agropecuaria con la supervisión y aprobación del Comité de Asesoría

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RESUMEN

Patrones espacio-temporales de diversidad y abundancia de mamíferos terrestres en un paisaje semiárido del sureste de Coahuila, México

Erika Jasmin Cruz Bazan
Para obtener el grado de
Doctor en Ciencias en Producción Agropecuaria
Universidad Autónoma Agraria Antonio Narro

Dr. Juan Antonio Encina Domínguez
Director de Tesis

Los mamíferos terrestres desempeñan un papel fundamental en la estabilidad ecológica de los ecosistemas semiáridos, donde la escasez de recursos y la marcada estacionalidad definen su distribución y abundancia. En el sureste de Coahuila, México, se evaluó la diversidad de especies en tres tipos de vegetación: matorral desértico chihuahuense, zacatal semidesértico y bosque de montaña mediante técnicas complementarias que incluyeron fototrampeo, rastreo y captura por medio de trampas Sherman. El esfuerzo de muestreo alcanzó 2,799 días-cámara, registrándose 571 eventos fotográficos independientes, en total se registraron 16 especies de mamíferos medianos y grandes. Los índices de diversidad de Shannon oscilaron entre 1.36 y 1.82, no se registraron diferencias significativas entre temporadas ($p > 0.05$), aunque la composición estuvo influenciada por el tipo de vegetación. El zacatal semidesértico y el bosque de montaña mostraron mayor diversidad durante la temporada seca, mientras que el matorral desértico chihuahuense mantuvo una comunidad más estable a lo largo del año. En el caso de los pequeños mamíferos, se registraron cinco especies de roedores pertenecientes a tres géneros, destacando *Peromyscus zamorae* y *Onychomys arenicola* por su abundancia relativa. El matorral xerófilo presentó la mayor diversidad, mientras que el zacatal semidesértico mostró mayor abundancia, con bajo recambio entre comunidades. Estos patrones reflejan la influencia de la estructura vegetal sobre la riqueza y dominancia faunística. En conjunto, los resultados subrayan la relevancia de conservar las comunidades vegetales dentro de los paisajes ganaderos semiáridos, ya que su mantenimiento favorece la conectividad ecológica y la resiliencia de las especies de mamíferos terrestres.

Palabras claves: Biodiversidad, Monitoreo, Comunidades.

Abstract

Spatial and temporal patterns of diversity and abundance of terrestrial mammals in a semi-arid landscape of southeastern Coahuila, Mexico

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To obtain the Degree of Doctor of Sciences in Agricultural Production
Antonio Narro Autonomous Agrarian University

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Thesis Director

Terrestrial mammals play a fundamental role in maintaining the ecological stability of semi-arid ecosystems, where resource scarcity and pronounced seasonality shape their distribution and abundance. In southeastern Coahuila, Mexico, species diversity was evaluated across three vegetation types—Chihuahuan desert scrub, semi-desert grassland, and montane forest—using complementary techniques including camera trapping, track surveys, and live trapping with Sherman traps. The sampling effort reached 2,799 camera-trap days, yielding 571 independent photographic records and a total of 16 medium- and large-sized mammal species. Shannon diversity indices ranged from 1.36 to 1.82, with no significant differences between seasons ($p > 0.05$), although composition varied according to vegetation type. The semi-desert grassland and montane forest exhibited higher diversity during the dry season, while the Chihuahuan desert scrub maintained a more stable community throughout the year. For small mammals, five rodent species belonging to three genera were recorded, with Peromyscus zamorae and Onychomys arenicola being the most abundant. The xerophilous scrub showed the highest diversity, whereas the semi-desert grassland presented the greatest abundance, with low turnover among communities. These patterns reflect the strong influence of vegetation structure on species richness and faunal dominance. Overall, the results highlight the importance of conserving plant communities within semi-arid ranching landscapes, as their maintenance enhances ecological connectivity and the resilience of terrestrial mammal species.

Keywords: Biodiversity, Monitoring, Communities.

I. INTRODUCCIÓN

Los ecosistemas áridos y semiáridos que se distribuyen en el norte y centro de México cubren aproximadamente una cuarta parte del territorio nacional y representan ambientes de alta singularidad ecológica. Estos sistemas naturales albergan alta diversidad biológica que ha evolucionado bajo condiciones climáticas extremas, caracterizadas por escasas precipitaciones, altas temperaturas y marcados contrastes estacionales. Pese a su relevancia, la presión antropogénica (principalmente derivada de la ganadería extensiva, la agricultura y la urbanización) ha generado un deterioro progresivo en la cobertura vegetal, provocando fragmentación, pérdida de conectividad ecológica y una disminución de los servicios ecosistémicos esenciales (Ramírez-Pulido et al., 2018; Ezcurra, 2004).

México alberga alrededor de 544 especies de mamíferos (Ceballos 2014), mientras que en el estado de Coahuila se ha documentado cerca del 15% (126 spp) de la mastofauna registrada a nivel nacional, con diversas especies endémicas y bajo alguna categoría de riesgo (Ramírez-Pulido et al., 2018). No obstante, los estudios sobre su ecología, abundancia y patrones espacio-temporales aún son escasos, particularmente en el sureste del estado, donde predominan los paisajes semiáridos con influencia en actividades agropecuarias. La escasez de información sobre la dinámica y composición de sus comunidades limita la toma de decisiones orientadas a la conservación de los hábitats y de la fauna nativa (Magioli et al., 2016;).

Los mamíferos terrestres desempeñan funciones ecológicas importantes como la dispersión de semillas, en la regulación de poblaciones de invertebrados y pequeños vertebrados, y contribuyen al reciclaje de materia orgánica. Estas interacciones los convierten en indicadores clave de la calidad del hábitat. De manera particular, la diversidad y abundancia de mamíferos se asocian con la estructura y heterogeneidad del hábitat, así como la estacionalidad y la disponibilidad de recursos (Lacher et al., 2019).

En tal sentido, el estudio se centra en la relación entre la heterogeneidad ambiental y la estructura de las comunidades de mamíferos, integrando la información de mastofauna terrestre de talla pequeña, mediana y grande, mediante métodos complementarios como la captura por medio de trampas Sherman, fototrampeo y rastreo. La investigación tiene como finalidad el aporte de bases científicas sobre la influencia de los gradientes ecológicos sobre la composición de los mamíferos terrestres, contribuyendo al conocimiento de los ecosistemas semiáridos.

II. REVISIÓN DE LITERATURA

2.1 Aspectos ecológicos de los mamíferos

Las comunidades biológicas que habitan en regiones áridas han desarrollado adaptaciones que les permiten sobrevivir bajo condiciones de escasa disponibilidad hídrica y alta variabilidad térmica (Gedir et al., 2020; Blumstein & MacManes 2023). En estos ambientes, los mamíferos desempeñan funciones ecológicas esenciales como dispersores semillas, controladores de poblaciones de invertebrados y contribuyen a los flujos de energía (Hernández et al., 2010; Aragón et al., 2012). Diversos estudios demuestran que los mamíferos constituyen indicadores del cambio ambiental, siendo particularmente útiles para evaluar la integridad ecológica en sistemas áridos (Avenant 2011; Ayodele 2025).

Algunas especies clave como *Ursus americanus* y *Cynomys mexicanus* reflejan el papel de los mamíferos terrestres como especies indicadoras, ya que son capaces de alterar la estructura del hábitat y los procesos asociados a la productividad y regeneración vegetal (González-Saucedo et al., 2020; Rodríguez-Barrera et al., 2022). La declinación de estas especies en hábitats semiáridos resalta la importancia de conservar los remanentes de vegetación natural y mantener la conectividad entre parches de vegetación (Zimbres et al., 2017). Así, la conservación de la actividad faunística en estos paisajes depende cada vez más de la integración de la gestión productiva con el diseño de corredores ecológicos y áreas de reserva funcional (Mattos et al., 2021).

Los roedores, por su alta tasa de reproducción, su sensibilidad ambiental y su papel importante en la dispersión de semillas y en los ciclos de humedad del suelo, constituyen un grupo crítico para la ecología de sistemas áridos. Su riqueza y abundancia están asociadas a la complejidad de la vegetación, a la cobertura del sustrato y a la disponibilidad de refugios (Dong et al., 2024). En un estudio reciente en el Altiplano mexicano, se documentó que la diversidad de roedores disminuye en zonas con menor heterogeneidad de vegetación, lo que sugiere que la estructura del hábitat promueve la coexistencia de especies (Dong et al., 2024). Asimismo, se ha documentado que la combinación de pastizal y matorral favorece una mayor riqueza de roedores frente a hábitats homogéneos (Thibault et al., 2010).

El conocimiento de las especies de mamíferos de talla pequeña de un área es importante debido a la alta riqueza de especies con la que cuenta este orden mastofaunístico, y la función que cumplen en el ecosistema como parte de la cadena trófica (Aragón *et al.*, 2012; MacSwiney *et al.*, 2012), por otra parte, algunas especies silvestres e introducidas son reservorio de enfermedades como la Leishmaniasis, Hantavirus, entre otras (Hernández *et al.,* 2010).

2.2 Métodos para el estudio de la mastofauna terrestre

La diferenciación de tallas y hábitos de los mamíferos terrestres exige el uso de métodos complementarios de muestreo para estimar con precisión su riqueza, diversidad y abundancia. Para mamíferos medianos y grandes, el uso de trampas cámara y rastreo ha demostrado ser altamente eficiente al permitir la detección de especies esquivas o de baja densidad (Mandujano). La técnica del fototrampeo, consiste en la instalación de cámaras que se activan por medio de sensores de movimiento y capturan una imagen cuando un individuo atraviesa su campo de visión; el fototrampeo tiene diferentes aplicaciones como el inventario de fauna, estimaciones de abundancia, desarrollo de modelos de ocupación, uso de hábitat, hábitos de alimentación y patrones de actividad (López-Tello y Mandujano 2017). Mientras el rastreo consiste en la búsqueda de cualquier indicio que la fauna deja a su paso (huellas, excretas, restos óseos) (Aranda, 2012).

Por su parte, la captura con trampas Sherman se mantiene como una técnica estándar para la cuantificación de comunidades de pequeños mamíferos (Krebs, 1985), Esta técnica consiste en la instalación de trampas metálicas livianas provistas de un mecanismo de compuerta que se activa al ingresar el individuo, permitiendo su captura sin causarle daño. Su diseño y facilidad de transporte la convierten en un método eficiente para estimar abundancia, riqueza y estructura poblacional en especies de talla pequeña (Gallina y López-González 2011). Se ha documentado que la combinación de métodos incrementa la exhaustividad del muestreo y reduce el sesgo hacia determinados tamaños o gremios tróficos (Steenweg et al., 2018). La aplicación de estas metodologías permite abordar el estudio de los mamíferos terrestres desde una perspectiva a diferentes escalas, lo cual resulta fundamental para generar estimaciones estadísticas robustas con aportes relevantes para la investigación y a la gestión de la conservación de las especies y de sus hábitats (Mason et al., 2022).

2.3 Vegetación y estacionalidad en la conservación de mamíferos

Los tipos de vegetación que se distribuyen en los pastizales, como el zacatal semidesértico, el bosque de montaña y el matorral desértico chihuahuense actúan como ejes que estructuran la diversidad y abundancia de los mamíferos terrestres, al ofrecer distintos niveles de cobertura, refugio y alimento. En regiones áridas, se ha observado que el tipo de vegetación influye más en la composición de las comunidades que la propia estacionalidad, aunque esta última también modula la disponibilidad de recursos (Klenner & Sullivan 2025). Desde una perspectiva de conservación, la conectividad y la heterogeneidad de vegetación se consideran esenciales para mantener la funcionalidad del ecosistema y su resiliencia ante el cambio climático (Misher & Vanak 2022).

La integración de la producción ganadera con la conservación de la mastofauna en paisajes semiáridos exige que se reconozcan estos gradientes como ejes de planificación y monitoreo (Chillo et al., 2015). Este enfoque permite establecer prioridades de conservación que no se limiten a parches aislados, sino que contemplen la matriz productiva y su interacción con la fauna silvestre (Tyrrell & Western 2017).

III. ARTÍCULOS

Articulo 1

AGRO PRODUCTIVIDAD

Colegio de Postgraduados

Rodents in Xerophilous Shrubland and Semi-Desert Grassland Communities of Southeastern Coahuila, Mexico

Cruz-Bazán, Erika J.[1]; **Encina-Domínguez, Juan A.**[1*]; **Ramírez-Albores, Jorge E.**[2]; **Chávez-Lugo Eber G.**[1]

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ABSTRACT
Objective: To assess the diversity of rodent communities in semi-desert grasslands and xerophilous shrubland at the "Los Ángeles" Ranch in southeastern Coahuila.
Design/methodology/approach: Monthly samplings were carried out from May to November 2020 using Sherman traps. The capture-recapture method was used to estimate species richness and abundance. Non-parametric estimators, species rarefaction curves, and rank abundance plots were utilized to measure species diversity. The Whittaker index was employed to assess species turnover between sampled communities.
Results: A total of 205 individuals from three families and eight species of rodents were recorded, with the Cricetidae family being the best represented. The species rarefaction curve showed that the shrubland exhibited greater diversity compared to the grassland. The dominant species were *Onychomys arenicola* in the semi-desert grassland and *Peromyscus zamorae* in the xerophilous shrubland.
Limitations/implications: There remains a need to extend long-term monitoring efforts to detect how anthropogenic activities influence species composition.
Findings/conclusions: The study highlights the importance of grasslands for the conservation of rodents in the state. Semi-desert grasslands and shrublands provide natural resources that should be preserved to maintain biodiversity in semi-arid ecosystems.

Keywords: Rodentia, habitat, grassland, semi desertic ecosystem, diversity.

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INTRODUCTION

Coahuila is an important part of the arid and semi-arid ecosystems of northern Mexico, as the majority of its surface is immersed in the Chihuahuan Desert (Villarreal-Quintanilla and Encina-Domínguez, 2005). However, some areas within this region experience notable anthropogenic impact due to livestock activities, which generate

modifications in the structure and vegetation cover, thus affecting the availability of habitats for various wildlife species (Hernández-Betancourt *et al*., 2012). Therefore, it is essential to have information about the composition of the different faunistic groups that these ecosystems harbor. Among these, rodents are particularly interesting for understanding the functioning of ecosystems, as they are vulnerable to habitat disturbances and require specific physical and climatic conditions for establishment (Aragón *et al*., 2012). Additionally, this faunistic group plays an important role as seed dispersers and consumers (Godó *et al*., 2022) and constitutes a significant part of the biomass for predators (Hernández *et al*., 2011). Although various studies on mammals have been conducted in Coahuila, most of them have focused on the central and northern regions of the state (Sierra Mojada and San Buenaventura), primarily addressing aspects of population dynamics and faunistic inventories (González-Uribe *et al*., 2023; Valdés-Alarcón *et al*., 2023). Meanwhile, in other areas of the state, studies have been conducted on distribution patterns (Ramírez-Pulido *et al*., 2018; Pineda *et al*., 2024). Therefore, it is essential to increase knowledge in other regions to understand the diversity and composition of mammal communities, such as rodents in the state (Ramírez-Pulido *et al*., 2016). In this context, the objective of this study was to evaluate the diversity of rodent communities in semi-desert ecosystems, such as semi-desert grasslands and xerophilous shrubland at the "Los Ángeles" Experimental Ranch in southeastern Coahuila. This was done to generate basic information about the species that inhabit this region and to fill gaps in the knowledge of species richness and population abundance, there by contributing to the conservation of local biodiversity in the arid and semi-arid ecosystems of Coahuila.

MATERIALS AND METHODS

The study was conducted at the "Los Ángeles" Ranch located in the municipality of Saltillo, Coahuila (25° 04' 12" to 25° 08' 51" N, 100° 58' 07" to 101° 03' 12" W) (Figure 1), at an average altitude of 2,150 m (Heredia-Pineda *et al*., 2017). This area covers 7,000 hectares and features elevated zones and valleys. The climate is dry, arid-semi-warm, with a cool winter, and the average annual temperature varies between 18 and 22 °C (García, 2004). The average annual precipitation ranges from 450 to 550 mm, with rainfall primarily occurring during summer and winter (López-Santos *et al*., 2008). The main activity in the area is extensive beef cattle production through rotational grazing.

The dominant types of vegetation are xerophilous shrubland and semi-desert grassland (Encina-Domínguez *et al*., 2018).

Fieldwork: Sampling was conducted monthly from May to November 2020, where four sampling sites were established (two sites in semi-desert grassland and two in xerophilous shrubland). At each site, a quadrant of 4,000 m^2 was established with 40 trapping stations distributed at equal distances of 10 m. At each station, a Sherman trap was placed (González-Romero, 2011). Capturing was conducted over three consecutive nights at each site. The capture and recapture method was used (Krebs, 1985), where each individual was marked by ectomizing phalanges (Pacheco *et al*., 2000; Romero-Almaraz *et al*., 2007). For species identification, the somatic measurements of the

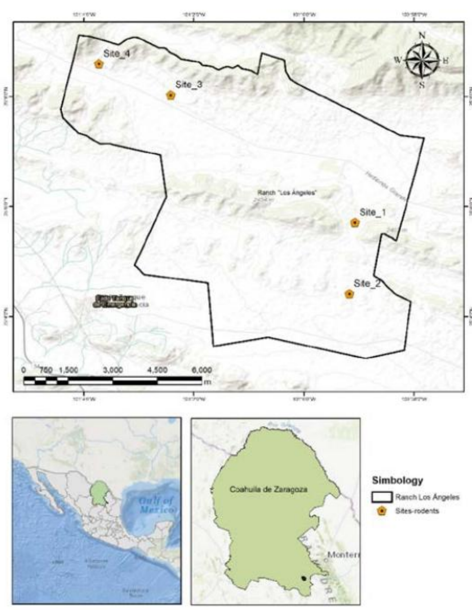

Figure 1. Location of the Los Ángeles Ranch in southeastern Coahuila.

captured individuals were recorded. Subsequently, guides with specialized taxonomic keys were utilized (Ceballos, 2014; Álvarez-Castañeda *et al.*, 2015). Once identified, the individuals were released *in situ*.

Statistical analysis: To estimate species richness, non-parametric estimators ICE and Jackknife 1 were employed (Gotelli & Colwell, 2011), calculated using the EstimateS 9.10 program (Colwell, R. K. 2013). For the analyses, true diversity was used at three levels, where q=0 corresponds to species richness, q=1 is the exponential of Shannon, and q=2 is the inverse of Simpson's index (Jost, 2006). The rarefaction curve was calculated using RStudio 4.3.0 (RStudio Team, 2023) with the iNEXT package (Hsieh *et al.*, 2016), with 95% confidence intervals (Moreno, 2001; Jiménez-Valverde and Hortal *et al.*, 2003). True diversity at each site was measured using the exponential of the first-order Shannon index (1D) (Jost, 2006; García-Morales *et al.*, 2011; Moreno *et al.*, 2011). Rank-abundance graphs were generated to observe the structure of species within the different sites. Finally, to evaluate species turnover among the sampled plant communities, the Whittaker index (Beta diversity) was used, which is defined as the ratio between gamma diversity (at the regional level) and alpha diversity (at the local level), expressed as gamma divided by alpha ($\beta=\gamma/\alpha$). This index measures the degree of differentiation among biological communities (Baselga and Gómez-Rodríguez, 2019).

RESULTS AND DISCUSSION

The recorded rodent species in the study area constitute 15.4% of what has been reported for Coahuila, 9.7% for the Chihuahuan Desert (Ramírez-Pulido *et al.*, 2018), and 3.3% at the national level (Ceballos, 2014; Ramírez-Pulido *et al.*, 2014). A total of 205 individuals were recorded, belonging to three families (Cricetidae, Heteromyidae, and Sciuridae) and eight species (Table 1). The dominance of the Cricetidae family was observed in the "Los Ángeles" Ranch, reflecting their fundamental role in the ecosystem; they have developed physiological and behavioral adaptations, such as fat and water storage in their bodies, allowing them to thrive in environments with limited resources (Harris & Pritchard, 2012) (Table 1).

The Mexican prairie dog (*Cynomys mexicanus*), the spotted ground squirrel (*Xerospermophilus spilosoma*), and the yellow harvest mouse (*Reithrodontomys fulvescens*) were recorded outside the sampling period; however, they were included in the species richness list (Figure 2).

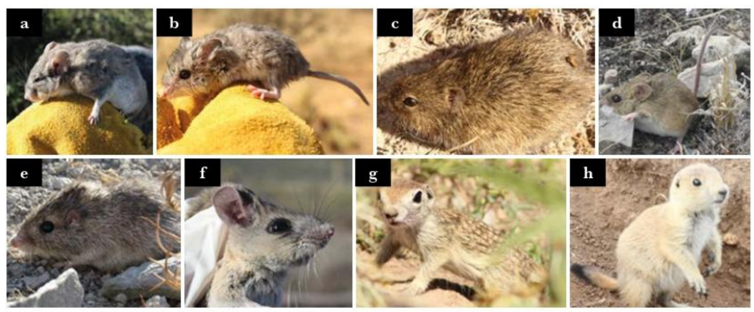

Figure 2. Rodents recorded at the "Los Ángeles" Ranch: a=*Neotoma leucodon*; b=*Onychomys arenicola*; c=*Sigmodon hispidus*; d=*Reithrodontomys fulvescens*; e=*Chaetodipus nelsoni*; f=*Peromyscus zamorae*; g=*Xerospermophilus spilosoma*; h=*Cynomys mexicanus*.

Table 1. Recorded species in each studied plant community.

Species	Name	Distribution	UICN/NOM-59-SEMARNAT-2010	Types of vegetation	
				Grassland	Scrub
Neotoma leucodon	White-toothed woodrat				✓
Onychomys arenicola	Chihuahuan grasshopper mouse			✓	✓
Peromyscus zamorae	Zamora deer mouse	Endemic		✓	✓
Sigmodon hispidus	Hispid cotton rat				✓
Chaetodipus nelsoni	Nelson's pocket mouse			✓	✓
*Reithrodontomys fulvescens**	Fulvous harvest mouse				✓
*Cynomys mexicanus**	Mexican prairie dog	Endemic	EN, EN	✓	
*Xerospermophilus spilosoma**	Spotted ground squirrel			✓	

* Species recorded outside the sampling period; IUCN=International Union for Conservation of Nature (species included in the Red List of Threatened Species); NOM-059-SEMARNAT-2010=Species with some risk category under the Official Mexican Standard-059; Types of vegetation: ZAC=Semidesert Grassland (Species recorded in grassland); MAT=Xerophytic Shrubland (Species recorded in shrubland).

In relation to the species classified as at risk under the Official Mexican Standard 059-2010 (NOM-059-SEMARNAT-2010), the Mexican prairie dog was recorded in the endangered category (P) and also holds the same status (EN) within the International Union for Conservation of Nature (IUCN) Red List of Threatened Species. This species plays a fundamental role in the structure of grassland communities as an umbrella species, as it modifies the landscape by creating habitats for other species through its burrowing activities. The decline in population, attributed to habitat fragmentation, can have negative repercussions on the structure and functionality of the ecosystem, affecting species that depend on the habitats created by this rodent (Castellanos-Morales *et al.*, 2016; O'Brien & Kinnaird, 2016). The species rarefaction curve showed the highest richness for the xerophilous scrub community with five species, while the semidesertic grassland recorded the highest number of individuals (93). Although the rarefaction curve reached the asymptote, there is a probability of recording greater species richness if sampling continues. Regarding the number of effective species, differences in species richness (q=0) were observed: five species in the xerophilous scrub and three in the semidesertic grassland. The exponential of the Shannon index (q=1) indicated that the xerophilous scrub vegetation exhibited the highest diversity (2.62) compared to the semidesertic grassland (1.74). For the inverse Simpson value (q=2), it was higher in the semidesertic grassland (0.69) compared to the scrub (0.54). The wider confidence intervals for Shannon and Simpson diversity in the scrub indicate greater variability in species evenness compared to the grassland (Figure 3).

Regarding the abundance-rank curve in the two plant communities (Figure 4), the semidesert grassland was dominated by the sandy chapuliner mouse (*Onychomys arenicola*), as it is a carnivorous species with fossorial habits that requires open areas for its burrows.

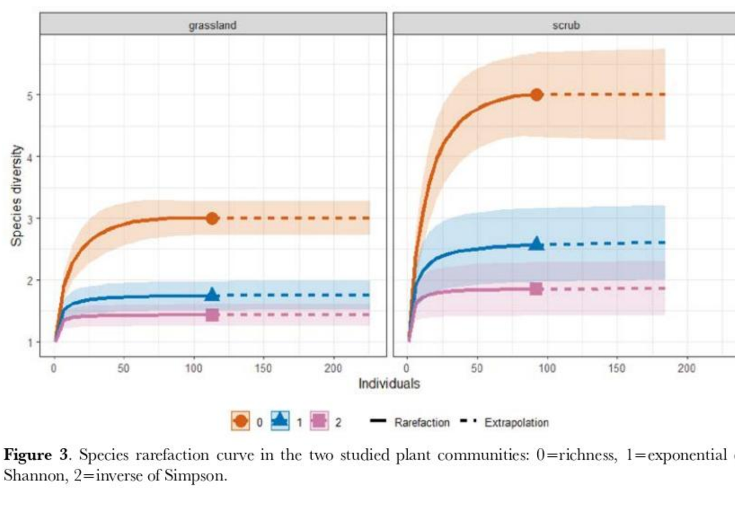

Figure 3. Species rarefaction curve in the two studied plant communities: 0=richness, 1=exponential of Shannon, 2=inverse of Simpson.

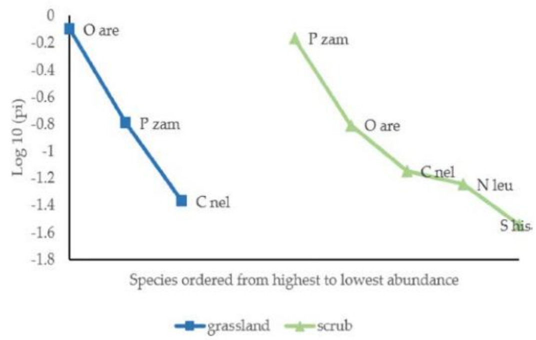

Figure 4. Species abundance rank curve recorded in each type of vegetation. O are=*Onychomys arenicola*; P zam=*Peromyscus zamorae*; C nel=*Chaetodipus nelsoni*; N leu=*Neotoma leucodon*; S his=*Sigmodon hispidus*.

This allows for soil aeration and visibility of potential predators, as well as foraging opportunities (Martín-Regalado *et al.*, 2019; Langley, 2021). In the xerophytic scrub, the dominant species was the Zamora deer mouse (*Peromyscus zamorae*), which is due to its populations being associated with the productivity of resources provided by the plant community (vegetation cover that serves as refuge and raw material for food) (Whitford & Steinberger, 2010, Ceballos, 2014). Among the species with low dominance in the grassland, the Nelson's pocket mouse (*Chaetodipus nelsoni*) was recorded, possibly due to the type of habitat where it is distributed, which is associated with areas featuring rocky slopes and grasslands with shrubs such as governadora and hojasén, which serve as protection against predators and as food sources (Neiswenter *et al.*, 2019; Martínez-Calderas *et al.*, 2023). The record of the cotton rat (*Sigmodon hispidus*) may be attributed to its ability to adapt to conditions with anthropogenic impact, as its populations establish themselves in agricultural areas and regions with livestock activities (Wright & Russell, 2010; Tomé *et al.*, 2020). Regarding species turnover (Beta Diversity), it resulted in 1.25, indicating low differentiation between the vegetation communities, as they share most of their species with low turnover values.

CONCLUSIONS

The information generated in this research provided a baseline on knowledge about the richness and abundance of rodents in the "Los Ángeles" Ranch, highlighting the importance of grasslands as key areas for the protection and maintenance of rodent populations, as well as the conservation potential that both vegetation communities offer for protection in southeastern Coahuila. It is recommended that future studies evaluate other environmental variables such as soil (texture, nutrient content, porosity, and permeability), altitude, diversity of grasses and shrub species, as well as the establishment of a greater number of sampling sites to broaden conservation efforts, particularly for species with conservation status, thereby ensuring the continuity of natural resources.

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REFERENCES

Villarreal-Quintanilla, J. Á., y Encina-Domínguez, J. A. (2005). Plantas vasculares endémicas de Coahuila y algunas áreas adyacentes, México. *Acta Botanica Mexicana*, 70, 1-46.

Hernández-Betancourt, S., Medina Peralta, S., Chablé-Santos, J., Sélem-Salas, C. I., González-Pérez, M. P., Canseco-Balam, L., & Góngora-Salinas, J. (2012). Riqueza y abundancia de pequeños roedores en dos agroecosistemas y un acahual presentes en la Reserva Cuxtal, Mérida Yucatán. *Tropical and Subtropical Agroecosystems*, 15, 329-336.

Aragón, P. E. E., Muñiz, M. R. & Garza, H. A. (2012). Roedores de Durango, México. En A. Cervantes y B. C. Ballesteros (Eds.), Estudios sobre la biología de roedores silvestres mexicanos, (pp. 165-183)

Godó, L., Valkó, O., Borza, & S., Deák, B. (2022). A global review on the role of small rodents and lagomorphs (clade Glires) in seed dispersal and plant establishment. *Global Ecology and Conservation*, 33. doi: 10.1016/j.gecco.2021.e01982

Hernández, L., Laundré, J. W., González, R. A., López, P. J. & Grajales, K. M. (2011). Tale of two metrics: density and biomass in a desert rodent community. *Journal of Mammalogy, 92*(4). 840-851. doi: 10.1644/10-MAMM-A-175.1

González-Uribe, DU, García-Aranda, MA, Heredia-Pineda, F., & Uvalle-Sauceda, JI (2024). Distribución geográfica de *Cynomys mexicanus*. *Ecosistemas y recursos agropecuarios, 11*(1). doi: 10.19136/era.a11n1.3766

Valdés-Alarcón, M., Pacheco, J., Betancourt, A., & Ceballos, G. (2023). Registro de Puercoespín (*Erethizon dorsatum*) en Valle Colombia Coahuila, México. *Revista Mexicana de Mastozoología (Nueva Época),13*(2), 73-80.

Ramírez-Pulido, J., González-Ruíz. N., & Contreras-Balderas A. J. (2018). Mamíferos. La biodiversidad en Coahuila estudio de Estado. (Vol. 2, pp. 411-418). Comisión Nacional para el Conocimiento y Uso de la Biodiversidad./Gobierno del Estado de Coahuila de Zaragoza, México.

Pineda, F. H., Figueroa, GR, Aranda, MAG, & Uribe, DUG (2024). Nuevos registros de comadreja cola larga en áreas de influencia de colonias de perrito llanero mexicano al sureste de Coahuila. *Investigación y Ciencia: de la Universidad Autónoma de Aguascalientes 32*(91), e4335. doi:10.33064/iycuaa2024914335

Ramírez-Pulido, J., González-Ruiz, N., Ameneyro, G., Castro-Campillo, A., & Salame-Méndez, A. (2016). Panorama del conocimiento de los mamíferos de México: con énfasis a nivel estatal. En Miguel Briones-Salas, Y. Hortelano-Moncada, G. Magaña-Cota, G. Sánchez-Rojas, J. E. Sosa-Escalante (Eds.), Riqueza y conservación de los mamíferos en México a nivel estatal (Vol. 1, pp. 39-60).

Heredia-Pineda, FJ, Lozano-Cavazos, EA, Romero-Figueroa, G., Alanís-Rodríguez, E., Tarango-Arámbula, LA, & Ugalde-Lezama, S. (2017). Relaciones interespecíficas de alimentación del gorrión de Worthen (*Spizella Wortheni*) durante la época no reproductiva en Coahuila, México. *Revista Chapingo Serie Zonas Áridas, 16*(2), 23-36. doi: 10.5154/r.rchsza.2017.11.009

García, E. (2004). Modificaciones al sistema de clasificación climática de Köeppen. Serie Libros México.

López-Santos, A., Zermeño González A., Cadena Zapata M. Gil Marín J. A., Cornejo Oviedo E. & Ríos Camey M. (2008). Impacto de la labranza en el flujo energético de un suelo arcilloso. *Terra Latinoamericana, 26*(3), 203-213.

Encina-Domínguez, J.A., Valdés, R. J., & Villarreal, Q. J. A. (2018). Tipos de vegetación y comunidades vegetales. La biodiversidad en Coahuila estudio de Estado. (Vol. 2, pp. 89-110). Comisión Nacional para el Conocimiento y Uso de la Biodiversidad./Gobierno del Estado de Coahuila de Zaragoza, México.

González-Romero, A. (2011). Métodos de estimación, captura y contención de mamíferos. En. S. Gallina y G.C. López (Eds.). Manual de técnicas para el estudio de la fauna (pp. 124-132).

Krebs, C. J. (1985). Ecología: estudio de la distribución y la abundancia. 2ª. En Harper y Row (Eds.). Latinoamericana (pp. 495-536).

Pacheco, J., Ceballos, G., & List, R. (2000). Los mamíferos de la región de Janos-Casas Grandes, Chihuahua, México. *Revista Mexicana de Mastozoología*, 4, 71-85. doi: 10.22201/ie.20074484e.1999.4.1.82

Romero-Almaraz, MdL., Sánchez Hernández, C., García Estrada, C., & Owen, R. D. (2007). Mamíferos pequeños. Manual de técnicas de captura, preparación, preservación y estudio. Las Prensas de Ciencias.
Ceballos, G. (2014). Mammals of Mexico. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad.
Álvarez-Castañeda, S. T., Ríos, E., Gutiérrez R. A. & Méndez L. (2015). Guía para la identificación de los mamíferos de México en campo y laboratorio. Centro de Investigaciones Biológicas del Noroeste, SC. y Asociación Mexicana de Mastozoología, AC.
Gotelli, N. J., & Colwell, R. K. (2011). Estimating species richness. En A. E. Magurran & B. J. McGill (Eds.), Biological Diversity: Frontiers in Measurement and Assessment (pp. 39-54). Oxford University Press.
Colwell, R. K. (2013). EstimateS: Statistical estimation of species richness and shared species from samples (Version 9.10). URL: http://purl.oclc.org/estimates
Jost, L. (2006). Entropy and diversity. *Oikos, 113*(2), 363-375.
RStudio Team. (2023). RStudio: Integrated development environment for R (Version 2023.09.1). RStudio, PBC, MA URL https://www.rstudio.com/
Hsieh, T.C., Ma, K.H. & Chao, A. (2016) iNEXT: An R package for interpolation and extrapolation of species diversity (Hill numbers). *Methods in Ecology and Evolution*, 7, 1451-1456.
Moreno, C. E. (2001). Métodos para medir la biodiversidad. MyT- Manuales y Tesis SEA. Zaragoza. (1 ra ed., Vol. 1). Programa Iberoamericano de Ciencia y Tecnología para el Desarrollo/Oficina Regional de Ciencia y Tecnología para América Latina y el Caribe/ Sociedad Entomológica Aragonesa.
Jiménez-Valverde, A., & Hortal, J. (2003). Las curvas de acumulación de especie y la necesidad de evaluar la calidad de los inventarios biológicos. *Revista Ibérica de Aracnología*. 8, 151-161.
García-Morales, R., Moreno, C. E., Bello-Gutiérrez, J. (2011). Renovando las medidas para evaluar la diversidad en comunidades ecológicas: el número de especies efectivas de murciélagos en el sureste de Tabasco, México. *Therya, 2*(3), 205-215. doi: 10.12933/therya-11-47
Moreno, C. E., Barragán, F., Pineda, E., & Pavón, N. P. (2011). Reanálisis de la diversidad alfa: alternativas para interpretar y comparar información sobre comunidades ecológicas. *Revista Mexicana de Biodiversidad, 82*(4), 1249-1261. doi: 10.22201/ib.20078706e.2011.4.745
Baselga, A., & Rodríguez, C. G. (2019). Diversidad alfa, beta y gamma: ¿cómo medimos diferencias entre comunidades biológicas?. *Nova acta científica compostelana (Bioloxía)*, 26, 39-45.
Ramírez-Pulido, J., González-Ruíz. N., Gardner, A. L., & Arroyo-Cabrales. J. (2014). List of recent land mammals of Mexico, 2014. En R. J. Baker (Ed.) Special Publications Museum of Texas Tech University. (pp. 1-76).
Harris, J. M., & Pritchard, R. (2012). Physiological and behavioral strategies for survival. *Journal of Desert Ecology, 15*(4), 223-235. doi: 10.1111/j.1749-4877.2009.00176.x.
Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT). (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-Lista de especies en riesgo. Diario Oficial de la Federación. https://www.dof.gob.mx
Unión Internacional para la Conservación de la Naturaleza (UICN). (02 de septiembre de 2024). Lista Roja de Especies Amenazadas de la UICN. https://www.iucnredlist.org
Castellanos-Morales, G., Hernández-Gómez, J. E., García-Moreno, J., & León-Paniagua, L. (2016). Peripatric speciation of an endemic species driven by Pleistocene climate change: The case of the Mexican prairie dog (*Cynomys mexicanus*). *Molecular Phylogenetics and Evolution*, 94, 171–181. doi: 10.1016/j.ympev.2015.08.010
O'Brien, T. G., & Kinnaird, M. F. (2016). Ecology and Conservation of the Mexican Prairie Dog: A Keystone Species in the Chihuahuan Desert. *Journal of Mammalogy, 97*(3), 623-632. doi:10.1093/jmammal/gyw043
Martín-Regalado, C. N., Briones, M., & Moreno, C. (2019). Oaxaca, medalla de oro en diversidad de pequeños roedores. *Temas de Ciencia y Tecnología*, 23: 41-46.
Langley, W. M. (2021). Evolutionary changes in the predatory attack of carnivorous rodents: A comparative analysis emphasizing grasshopper mice (*Onychomys* spp.). *Journal of Comparative Psychology* 135:114-126. doi: 10.1037/com0000257
Whitford, WG & Steinberger, Y. (2010). Pack rats (*Neotoma* spp.): Keystone ecological engineers? *Revista de ambientes áridos, 74*(11), 1450-1455.
Neiswenter, S. A., Hafner, D. J., Light, J. E., Cepeda, G. D., Kinzer, K. C., Alexander, L. F. & Riddle, B. R. (2019). Phylogeography and taxonomic revision of Nelson's pocket mouse (*Chaetodipus nelsoni*). *Journal of Mammalogy, 100*(6), 1847-1864.
Martínez-Calderas, J. M., Palacio-Núñez, J., Clemente-Sánchez, F., Martínez-Montoya, J. F., Sánchez-Rojas, G., Olmos-Oropeza, G. (2015). Distribución potencial de la rata magueyera (*Neotoma leucodon*) y

densidad de madrigueras en el sur del desierto chihuahuense. *Therya, 6*(2), 421-433. doi: 10.12933/therya-15-223
Wright, G. D., Geluso, K., & Benedict, RA (2010). Rata algodonera híspida (*Sigmodon hispidus*) en Nebraska: distribución, reproducción y actividad estacional. *Western North American Naturalist, 70*(3), 400-406. doi: 10.2307/41718076
Tomé, C. P., Elliott Smith, E. A., Lyons, S. K., Newsome, S. D., & Smith, F. A. (2020). Changes in the diet and body size of a small herbivorous mammal hispid cotton rat (*Sigmodon hispidus*) following the late Pleistocene megafauna extinction. *Ecography, 43*(4), 604-619. doi: 10.1111/ecog.04596

Articulo 2

diversity

MDPI

Article

Spatial–temporal patterns of mammal diversity and abundance in three vegetation types in a semi-arid landscape in southeastern Coahuila, Mexico

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Abstract: The grasslands and shrublands of northern and central Mexico cover nearly 25% of the country and harbor high biodiversity. However, they are increasingly degraded by agriculture, urbanization, infrastructure development, and water overexploitation. To assess the status of medium- and large-sized mammals in these threatened ecosystems, we quantified species richness, relative abundance, and naïve occupancy across vegetation types and seasons. From April 2023 to February 2024, monthly track surveys and camera trapping were performed, and the data were analyzed in R. We documented 16 species representing four orders and nine families, with Carnivora being the most diverse (eight species). The species richness varied by habitat, ranging from 11 in montane forest to 13 in semi-desert grassland, the latter habitat having the highest Shannon and Simpson indices, particularly in the dry season. *Odocoileus virginianus* and *Sylvilagus audubonii* were consistently the most abundant species in montane forest and desert scrub, whereas *Cynomys mexicanus* predominated in semi-desert grasslands, accounting for > 90% of detections during the rainy season. Rare species included *Lynx rufus*, *Taxidea taxus*, and *Ursus americanus*, each with isolated detections. Rarefaction and sample coverage curves approached asymptotes (> 99%), indicating sufficient sampling effort. Naïve occupancy and encounter rates were highest for *O. virginianus* (0.82) and *S. audubonii* (0.68), with a strong positive correlation between both metrics ($r^2 = 0.92$). These findings provide robust baseline information on mammalian diversity, abundance, and habitat associations in semi-arid anthropogenic landscapes, supporting future monitoring and conservation strategies.

Keywords: camera trap; conservation; mammal richness; Sierra Madre Oriental; semi-arid ecosystems; tracking surveys.

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1. Introduction

The grasslands and shrublands of the arid and semi-arid regions of central and northern Mexico cover nearly 25% of the national territory and support high levels of biodiversity [1,2]. Despite their ecological importance, these ecosystems exhibit increasing degradation driven by population growth and unsustainable resource use, which accelerate biodiversity loss and compromise ecosystem integrity [2]. In semi-arid environments, anthropogenic pressures represent one of the main threats to medium- and large-sized mammals by altering habitat availability, behavioral patterns, and long-term population viability [3,4]. Agricultural expansion, urban development, and transportation infrastructure fragment the landscape, reduce ecological connectivity, and diminish native vegetation cover, thereby restricting access to essential resources such as food, water, and shelter [5,6]. Habitat fragmentation, in turn, promotes population isolation, decreases gene flow, and increases susceptibility to stochastic events [7]. Additional pressures include the overexploitation of water resources, which intensifies physiological stress during critical periods of the year, and illegal hunting and human–wildlife conflicts associated with livestock production, which reduce populations of key species (e.g., *Puma concolor*, *Canis latrans*, *Ursus americanus*) and disrupt trophic interactions [8,9]. Moreover, anthropogenic disturbances frequently facilitate the expansion of generalist or invasive species, displacing specialists and contributing to biotic homogenization [10]. These cumulative impacts, coupled with the high climatic variability characteristic of semi-arid ecosystems, are expected to elevate the risk of local extinctions. In Coahuila, semi-arid grasslands have undergone alterations over the past several decades that have led to a substantial decline in the spatial distribution of biodiversity [2].

The northern Mexican state of Coahuila is notable for its faunal diversity, particularly of mammals. Among the 544 mammal species reported nationwide [11,12], approximately 126 species are found in the state, and nearly 15% of these are endemic to Mexico [13]. According to Mexican legislation, 20 of these species are classified under risk categories [11,13]. Terrestrial mammals are key to ecological stability, functioning as primary dispersers of seeds and organic matter and as regulators of prey and plant populations. Through these dispersal and trophic interactions, they shape population dynamics, stabilize community structure, and sustain the functional integrity and resilience of ecosystems across landscapes [14]. However, intensifying pressures such as overgrazing, extensive agriculture, and land-use change, continue to degrade habitat quality and reduce functional connectivity across the landscape [15,16]. Specifically, mammal communities in the arid and semi-arid ecosystems of northern Mexico have remained functionally and genetically isolated from contiguous vegetation for decades, increasing their vulnerability to diversity loss, genetic drift, and local extinction [17-19]. This historical fragmentation reduces connectivity, alters population dynamics, and complicates recovery from anthropogenic and climatic disturbances [17,19]. For example, endangered species within the grasslands of southern Coahuila, such as the American black bear (*Ursus americanus*) [11], depend on biological corridors to move between suitable vegetation patches, avoid being road-killed, and maintain genetic exchange [20,21]. Similarly, the Mexican prairie dog (*Cynomys mexicanus*), which is endemic to northeastern Mexico, plays a keystone ecological role. Through its burrowing activities, it increases biodiversity by modifying the landscape, altering soil composition, enhancing water infiltration, facilitating plant regeneration, and providing refuge for numerous other species [22,23]. Both species are severely threatened by habitat loss and fragmentation, largely driven by agricultural expansion and land-use change, which have drastically reduced landscape connectivity, restricted movement, and compromised population viability [24-26].

The distribution of mammals is influenced by seasonal dynamics and habitat types, with each species occupying a range shaped by the interaction between current ecological conditions and its evolutionary history [27,28]. Although some species exhibit similar distributional patterns, these are rarely identical. At the local scale, home ranges, territories, and microhabitat use reflect individual-level distribution within accessible environments

[29,30]. Medium- and large-sized mammals are particularly sensitive to habitat alterations, making them effective bioindicators of ecosystem integrity [31,32]. Ecosystems with greater structural complexity generally provide more niches and greater diversity of strategies for resource use, which, in turn, promotes greater mammalian diversity [33,34]. In semi-arid systems, the spatial and temporal distribution of mammals has a strong seasonal pattern. During the dry season, limited water and food availability restricts movement and activity, leading to a concentration of individuals in microhabitats that provide water sources or dense vegetation cover [35,36]. Conversely, during the rainy season, increased primary productivity expands the availability of food and refuge, facilitating wider ranging behavior [37]. Such seasonal shifts modify competition, predation, and reproductive patterns, ultimately shaping population dynamics and community structure. Understanding these ecological processes is essential for the development of effective conservation and management strategies in semi-arid regions, particularly under climate change scenarios that are altering seasonality and resource availability.

Monitoring mammal communities relies on complementary methods, including camera trapping and tracking. Camera traps enhance the detection of cryptic and nocturnal species, while also providing robust data on species richness, capture rates, and site occupancy [38-40]. Meanwhile, tracking techniques, based on the identification of footprints, feces, burrows, feeding remains, or other activity signs, provide indirect but reliable evidence of species presence and spatial distribution across large areas [41-43]. These approaches are non-invasive and cost-effective, making them particularly valuable in large or remote landscapes where extensive sampling is required. When combined, camera traps and track surveys provide complementary insights, strengthening assessments of mammalian diversity, distribution, and habitat use, thereby supporting more informed conservation planning.

In Coahuila, mammalian inventories have been less frequently documented than in other regions of Mexico [13,44,45]. This scarcity of information is particularly critical in semi-arid ecosystems, where anthropogenic pressure and habitat transformation can significantly affect the composition and structure of mammal communities. In contrast to tropical forests, where high mammal densities facilitate detection, arid and semi-arid ecosystems pose significant challenges due to sparse vegetation and low encounter rates. The complementary use of camera trapping and track surveys enhances species detectability and ecological inference, providing crucial insights for mammal conservation under increasing anthropogenic pressures [43,46,47]. In semi-arid ecosystems with a high degree of anthropization, effective mammal monitoring requires methods that maximize detection and minimize disturbance. The combination of indirect techniques, such as camera trapping and track surveying is essential for obtaining robust data on the presence, activity, and habitat use of medium- and large-sized species. In this context, it is essential to generate reference data that allows for the evaluation of species diversity, relative abundance, and occupancy patterns to design conservation and management strategies. Therefore, this study aimed to estimate the alpha diversity of medium- and large-sized mammals, evaluate the photographic rate and naïve occupancy of these species, and compare diversity, photographic rate, and naïve occupancy between the rainy and dry seasons in different vegetation types in an anthropized landscape in southeastern Coahuila, Mexico, to provide a baseline for understanding spatial and seasonal variation in mammal communities, which is critical for ecosystem monitoring and management.

2. Materials and Methods

2.1. Study area

Coahuila is located in northeastern Mexico, between 24°32′-29°53′ north latitude and 99°51′-103°58′ west longitude (Figure 1). It shares borders with the United States of America to the north, Zacatecas and San Luis Potosí to the south, Nuevo León to the east, and Chihuahua and Durango to the west. The state lies within the Chihuahuan Desert, an ecoregion that covers approximately 7.9% of the Mexican territory [48]. Its complex topography and wide altitudinal range (130–3,470 m) create marked climatic heterogeneity supporting a mosaic of arid and semi-arid ecosystems [48]. Arid and semi-arid ecosystems in northern Mexico, particularly in southwestern Coahuila, are increasingly threatened by livestock overgrazing, habitat fragmentation, groundwater depletion, and land-use change driven by agriculture and energy development. These anthropogenic pressures alter vegetation structure, reduce habitat connectivity, and compromise mammal community integrity and ecosystem functioning [49,50].

The study was conducted at the Los Ángeles Cattle Ranch (RGLA), a property of the Universidad Autónoma Agraria Antonio Narro (UAAAN). The ranch encompasses ~7,000 hectares and is primarily dedicated to extensive cattle ranching [24,51,52]. It is situated in the municipality of Saltillo, southeastern Coahuila (25°04′12″–25°08′51″ N, 100°58′07″–101°03′12″ W; Figure 1), at elevations ranging from 1,600 to 2,150 m. The regional climate is predominantly dry, with the most arid zones concentrated in the east, while sub-humid conditions occur in the Sierra de Arteaga and the north-central portion of the state [53]. Mean annual temperatures range from 18 to 22 °C, and average precipitation varies between 500 and 600 mm [51,53]. Vegetation cover at RGLA is dominated by Chihuahuan desert scrub and semi-desert grassland, which together occupy more than 70% of the surface. *Larrea tridentata* and *Neltuma glandulosa*, characterize the scrubland, while the grasslands are dominated by native grasses such as *Bouteloua gracilis* and *B. curtipendula*, interspersed with scattered shrubs. Additionally, patches of montane forest dominated by *Pinus cembroides* occur on some hillsides, reflecting the environmental heterogeneity of the area [54].

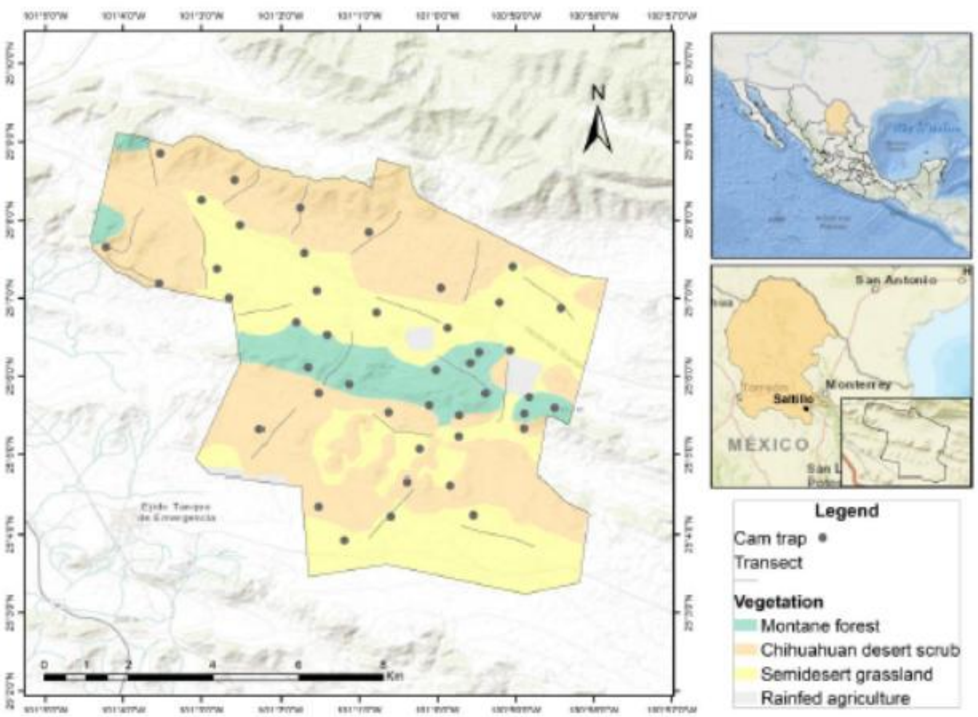

Figure 1. Map showing the location of the study site in southeastern Coahuila, Mexico.

2.2. *Field work*

The study was conducted between April 2023 and February 2024 using two complementary sampling methods: track surveys (using transect lines) and camera trapping. Transect surveys were implemented monthly to estimate species diversity and habitat associations of medium- and large-sized mammals. Transects were stratified by vegetation type and randomly allocated in proportion to the area of each habitat [55,56]. A total of 18 transect lines, each 1.5 km long and 0.2 km wide, were established at intervals of 1–2 km to minimize duplicate counts and systematically distributed at intervals of ~2 km across the study area. Along each transect, wherever evidence of mammal presence was recorded (e.g., tracks, droppings, burrows, and remains), it was documented photographically using a Canon® Rebel 3 camera. The total sampling effort was calculated as the combined length of all transect walks. Surveys were conducted twice daily for three consecutive days each month, during both the dry season (October–May) and the rainy season (June–September), from 06:00 to 11:00 h and from 15:00 to 19:00 h, coinciding with periods of peak activity and visibility. Species identification was carried out using Aranda's methodology [41], field guides, and local ecological knowledge. To reduce duplicate records, feeding and resting areas were monitored simultaneously, particularly in rugged terrain. The habitat type, season, and number of individuals were recorded for each sighting. Nine active camera traps were deployed for periods of 27–31 days and rotated across sites to maximize coverage of all vegetation types. Sampling stations were placed at 2 km intervals in locations with evidence of mammal activity (e.g., tracks, burrows, latrines) or along wildlife trails [57,58]. No attractants were used. Equipment included six Reconyx® Hyperfire Semi-Coverage IR HC500 units, two Wildgame® Innovations Terra Extremes, and one Bushnell® 24MP Core camera. Cameras were mounted 40–60 cm above the ground on Yucca (*Yucca carnerosana*) or pine (*Pinus cembroides*) trunks in scrub and forest habitats or on wooden posts in open grasslands. Each station was georeferenced using a Garmin® eTrex 10 unit. Photographed mammals were identified based on the specialized literature [11,12,59].

2.3. *Data analysis*

The data were compiled into a structured database and analyzed using R version 4.3.1 [60]. Mammalian diversity was evaluated through alpha diversity metrics calculated using the vegan package [61]. To compare diversity between the dry and rainy seasons, we generated rarefaction and extrapolation curves based on Hill numbers using the iNEXT package [62-65]. These curves provide standardized estimates of species richness and allow robust comparisons of diversity across unequal sampling efforts [66]. Differences in Shannon diversity (H') between seasons were evaluated using Hutcheson's *t*-test, which statistically compares index values while accounting for their estimated variance [67,68]. The analysis was conducted in R [60] using the ecolTest package [69]. H' values corresponded to estimates obtained for each vegetation type—Chihuahuan Desert scrub, montane forest, and semi-desert grassland—during the rainy and dry seasons. A significance threshold of $\alpha = 0.05$ was used to identify statistically significant differences.

Camera-trap photographs were processed and annotated using Digikam software (available at https://apps.kde.org/es/digikam/). A photographic-event database was then constructed in R [60] with the camtrapR package [70], which is specifically designed for camera-trapping data management [39]. Independent detection events were defined as consecutive records of the same species separated by at least 24 h or by the presence of different individuals within shorter intervals, thus avoiding pseudo replication [58, 71-73]. Sampling effort was quantified as the total number of trap nights, calculated as the sum of days in which each camera was active and functioning properly [74]. To assess variation in the composition of terrestrial mammal assemblages recorded in both tracking and camera trapping, a multivariate ordination approach was applied using canonical correspondence analysis (CCA). The response matrix comprised species detection data, while explanatory variables included season (dry vs. rainy), vegetation type (Chihuahuan desert scrub, semi-desert grassland, montane forest), and sampling method (tracking vs. camera trapping). The significance of the model and the predictor variables was evaluated using permutation tests with 999 permutations [61], which allowed us to determine the statistical contribution of each environmental factor to the observed variation in community composition, ensuring a robust inference free of parametric assumptions. The analysis was performed using the vegan package [61] in R [60], and graphical representations of ordination results were generated with the ggplot2 package [75]. To assess species composition similarity among vegetation types and between seasons (rainy and dry), the Jaccard similarity index was calculated, based on the proportion of shared species between pairs of sites relative to the total number of species recorded in both. Analyses were conducted in R [60] using the vegan package [61]. The resulting similarity matrix was converted into long format using the reshape2 package [76] to generate a heatmap visualization with ggplot2 [75]. For records obtained using camera traps, the photographic rate (or encounter rate) was used as a relative measure of abundance, and was calculated using the following expression:

$$Encounter\ rate = \frac{Total\ number\ of\ independent\ records}{Total\ number\ of\ sampling\ days}\ X\ 100$$

This estimate relates the average number of detections to the sampling effort [77,78]. Any event of the same species separated by a minimum interval of 24 hours was considered an independent record, to minimize pseudo replication and ensure that each detection represented a distinct biological event. The photographic rate of each species was estimated using the beta version of the RAIeR package [77,78]. Naïve occupancy (OccNaïve)—defined as the proportion of camera-trap stations where a species was recorded— was calculated as the proportion of stations where a species was recorded relative to the total number of active stations [79]. To evaluate the potential relationship of spatial distribution of species, we calculated correlations between naïve occupancy and photographic encounter rates [77,78].

Finally, each species was assigned a conservation status based on two criteria: (1) the International Union for Conservation of Nature (IUCN) Red List of Threatened Species [Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD), or Not Evaluated (NE)] [80], and (2) the legislation established in Mexican Official Standard (NOM-059-SEMARNAT-2010) [81].

3. Results

3.1 Species composition and richness

We recorded 16 mammal species, belonging to four orders and nine families (Table 1, Figure 2). The order Carnivora was the most diverse, comprising five families and eight species (Table 1). Track surveys, with a cumulative effort of 297 km, detected 14 species. Camera trapping resulted in 2,799 trap nights and 571 independent photographic records, corresponding to 14 species (Figure 2). Regarding conservation status, one species, *Cynomys mexicanus*, is listed as Endangered by the IUCN Red List. Under Mexican law (NOM-059-SEMARNAT-2010), *Taxidea taxus* is classified as Threatened, while *Ursus americanus* and *C. mexicanus* are classified as Endangered (Table 1).

Table 1. Mammal species recorded using camera trapping and tracking at the Los Ángeles Cattle Ranch, Coahuila, Mexico. NOM-059 (NOM-059-SEMARNAT-2010) [69]: E: Endangered; T: Threatened; IUCN [68]: LC: Least Concern; EN: Endangered.

Order	Family	Species	Common name	Method	Conservation status (NOM-059/UICN)
Artiodactyla	Cervidae	*Odocoileus virginianus*	White-tailed deer	Camera trap/track surveys	LC
		Dicotyles tajacu	Collared peccary	Camera trap/track surveys	LC
Carnivora	Canidae	*Canis latrans*	Coyote	Camera trap/track surveys	LC
		Urocyon cinereoargenteus	Gray fox	Camera trap/track surveys	LC
	Mephitidae	*Conepatus leuconotus*	Northern hog-nosed skunk	Camera trap/track surveys	LC
		Mephitis macroura	Southern spotted skunk	Camera trap	LC
		Spilogale gracilis	Western spotted skunk	Camera trap	LC

	Felidae	*Lynx rufus*	Bobcat	Camera trap/track surveys	LC
	Ursidae	*Ursus americanus*	American black bear	Camera trap/track surveys	EN
	Mustelidae	*Taxidea taxus*	American badger	Camera trap	T
		Neogale frenata	Long-tailed weasel	Track surveys	LC
Lagomorpha	Leporidae	*Sylvilagus audubonii*	Desert cottontail rabbits	Camera trap/track surveys	LC
		Lepus californicus	Black-tailed jackrabbit	Camera trap/track surveys	LC
Rodentia	Sciuridae	*Cynomys mexicanus*	Mexican prairie dog	Camera trap/track surveys	E/EN
		Xerospermophilus spilosoma	Spotted ground squirrel	Camera trap/track surveys	LC
	Geomyidae	*Cratogeomys castanops*	Yellow-faced pocket gopher	Track surveys	LC

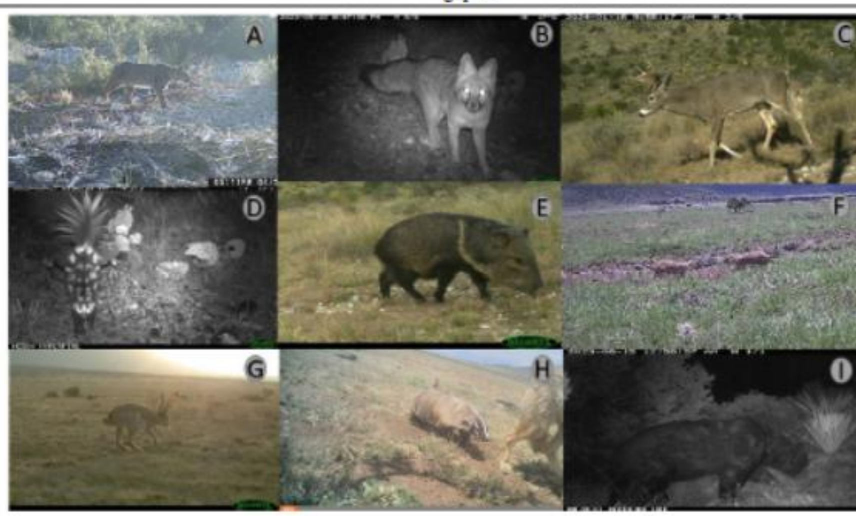

Figure 2. Some mammal species recorded using camera trapping at the Los Ángeles Cattle Ranch, Coahuila, Mexico: A) *Lynx rufus*, B) *Urocyon cinereoargenteus*, C) *Odocoileus virginianus*, D) *Spilogale gracilis*, E) *Dicotyles tajacu*, F) *Cynomys mexicanus*, G) *Lepus californicus*, H) *Taxidea taxus* and *Canis latrans*, I) *Ursus americanus*.

During the dry season, *Odocoileus virginianus* showed the highest relative abundance in the Chihuahuan desert scrub (0.59) and montane forest (0.51), followed by *Sylvilagus audubonii* (0.09–0.19). In the semi-desert grassland, *C. mexicanus* was dominant (0.34), together with *Lepus californicus* (0.23; Figure 3). During the rainy season, *O. virginianus* (0.53–0.55) and *S. audubonii* (0.20–0.23) maintained their predominance in scrub and forest, while *C. mexicanus* increased its abundance (0.60) in grasslands. In all habitats, carnivores had the lowest relative abundances (< 0.012; Figure 3).

Using the track surveys, we recorded a total of 604 terrestrial mammal signs, representing four orders, eight families, and 14 species. The order Rodentia was the most represented, with four species and 379 records, followed by Artiodactyla with two species and 111 records. The order Carnivora had the highest number of species (six) but the lowest number of records (43). The most abundant species was *C. mexicanus* (279 records), while *Lynx rufus*, *Conepatus leuconotus*, *Neogale frenata*, and *U. americanus* were the least abundant, with only one record each (Figure 3). Seasonal and habitat-specific patterns were also evident: *C. mexicanus* was particularly abundant in the semi-desert grassland during the rainy season (208 records), while *L. rufus* (montane forest, rainy season), *C. leuconotus* (Chihuahuan desert scrub, rainy season), *N. frenata* (semi-desert grassland, dry season), and *U. americanus* (semi-desert grassland, rainy season) were detected only once (in isolation).

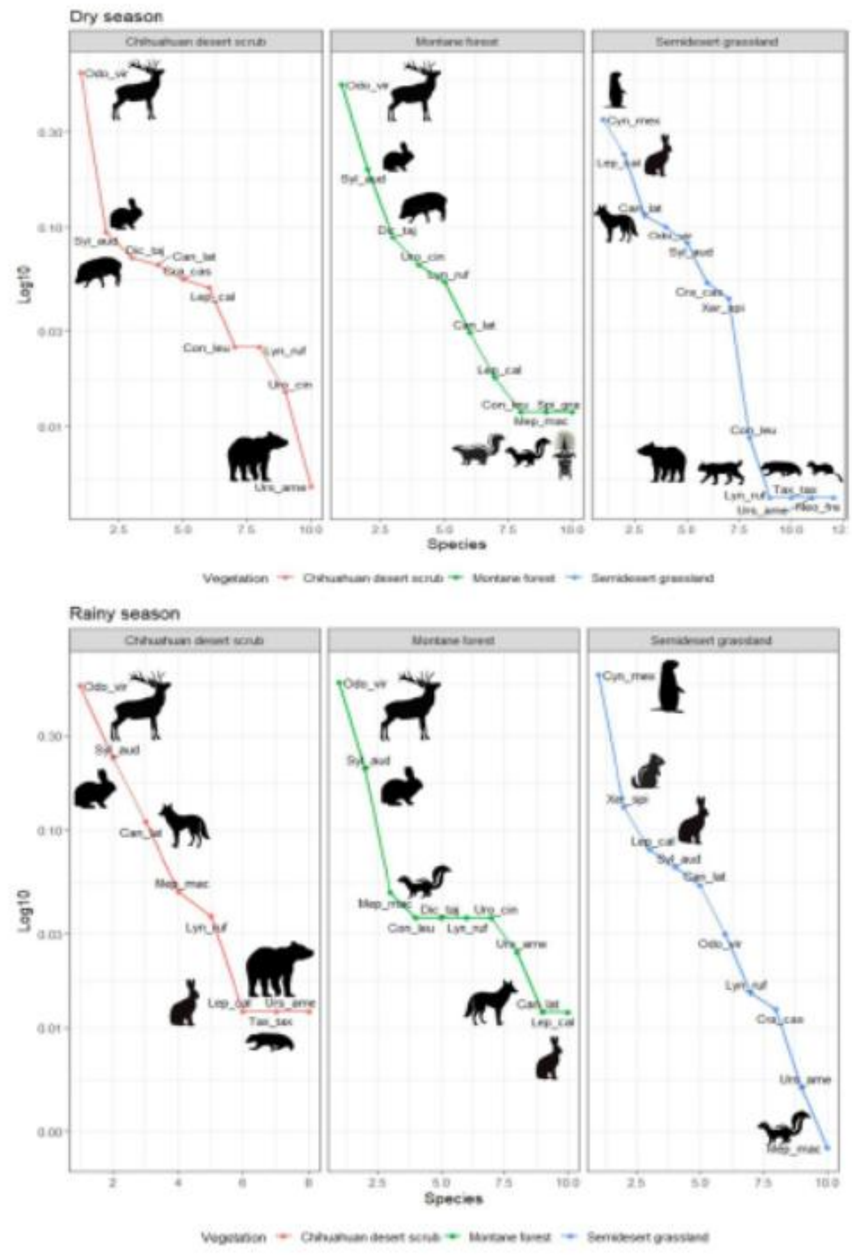

Figure 3. Rank abundance graphs of mammals recorded during the dry and rainy seasons in the study area. Odo_vir: *Odocoileus virginianus*; Syl_aud: *Sylvilagus audubonii*; Dic_taj: *Dicotyles tajacu*; Can_lat: *Canis latrans*; Uro_cin: *Urocyon cinereoargenteus*; Con_leu: *Conepatus leuconotus*; Mep_mac: *Mephitis macroura*; Spi_gra: *Spilogale gracilis*; Lyn_ruf: *Lynx rufus*; Urs_ame: *Ursus americanus*; Tax_tax: *Taxidea taxus*; Neo_fre: *Neogale frenata*; Lep_cal: *Lepus californicus*; Cyn_Mex: *Cynomys mexicanus*; Xer_spi: *Xerospermophilus spilosoma*; Cra_cas: *Cratogeomys castanops*.

In terms of species richness, 11 species were recorded in the montane forest, 12 in the Chihuahuan desert scrub, and 13 in the semi-desert grassland, yielding a mean species richness of 12 (Table 2). Diversity indices showed spatial and seasonal variation (Table 2); for example, during the rainy season, the montane forest, Chihuahuan desert scrub, and semi-desert grassland had Shannon diversity indices of 1.36, 1.43, and 1.37, and Simpson indices of 0.64, 0.63, and 0.60, respectively. Similarly, the semi-desert grassland showed the highest Simpson index (0.79), followed by the montane forest (0.73) and the Chihuahuan desert scrub (0.53) (Table 2). Hutcheson's *t*-test revealed no significant differences in diversity between the wet and dry seasons ($t = 0.18$, $df = 5.01$, $p = 0.86$), suggesting that terrestrial mammal diversity remained relatively stable across seasons. No significant differences in Shannon diversity (H') were observed among vegetation types ($p > 0.05$), indicating comparable levels of species diversity across habitats. The H' values varied slightly between 1.52 and 1.61, with overlapping variances among communities, suggesting a relatively homogeneous distribution of species and evenness across the evaluated vegetation types.

Table 2. Diversity indices recorded in the different types of vegetation during the dry and rainy seasons in the study area.

	Rainy			Dry		
Vegetation type	**Richness**	**Shannon**	**Simpson**	**Richness**	**Shannon**	**Simpson**
Chihuahuan desert scrub	9	1.43	0.63	10	1.23	0.53
Montane forest	8	1.36	0.64	11	1.76	0.73
Semi-desert grassland	10	1.37	0.60	12	1.82	0.79

3.2 Species rarefaction curves

Rarefaction curves for both seasons tended to stabilize, suggesting sufficient sampling completeness. Although the rarefaction curve suggested higher species diversity in the dry season, the overlap of the 95% confidence intervals revealed no significant differences between seasons (Figure 4). Sample coverage curves also reached an asymptote, with values close to 99% for both seasons, confirming a high level of representativeness and that most species present were recorded. Hill numbers provided complementary insights into diversity patterns. The species richness (q0) was 16 species in the dry season and 14 in the rainy season. The highest values for q1 (Shannon) and q2 (inverse Simpson exponential) also occurred in the dry season, indicating greater diversity and greater evenness compared to the rainy season (Figure 5).

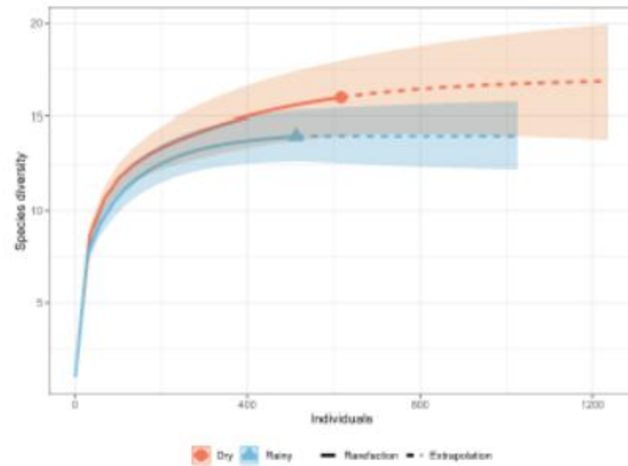

Figure 4. Rarefaction curve of medium and large mammal species during the dry and rainy seasons in the study area.

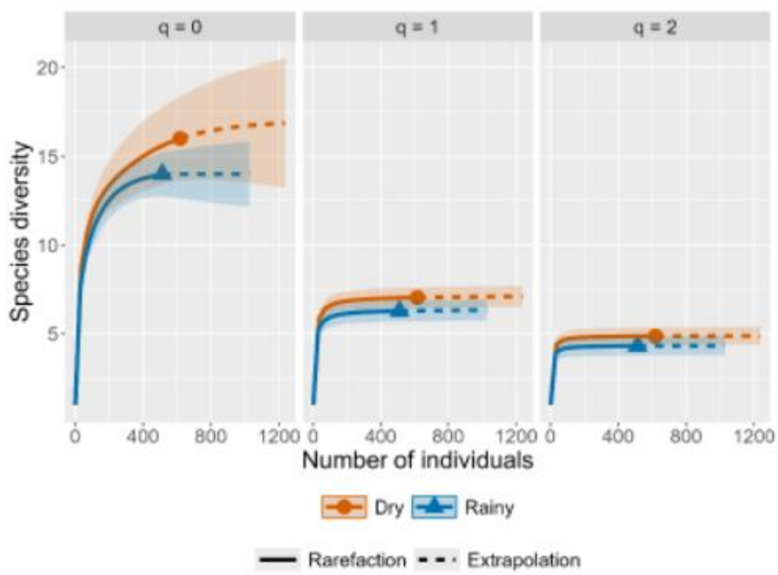

Figure 5. Species diversity curves according to Hill numbers (q=0, richness; q=1, Shannon exponential; and q=2, the inverse Simpson).

3.3 Effects of method, season, and habitat at community level

The heatmap shows a continuous color gradient representing Jaccard similarity values, where darker tones indicated higher similarity in species composition among vegetation types and seasons (Figure 6). The similarity values ranged from 0.38 to 0.82, indicating moderate to high variation across communities (Figure 6). The highest similarity (0.82) was recorded between the montane forest in the rainy season and the Chihuahuan desert scrub in the dry season, while the lowest (0.38) occurred between the semi-desert grassland and the montane forest, both in the dry season. Intermediate similarity values (0.54–0.57) were observed between the montane forest and the Chihuahuan desert scrub, denoting a moderate degree of species overlap across vegetation types and seasons (Figure 6).

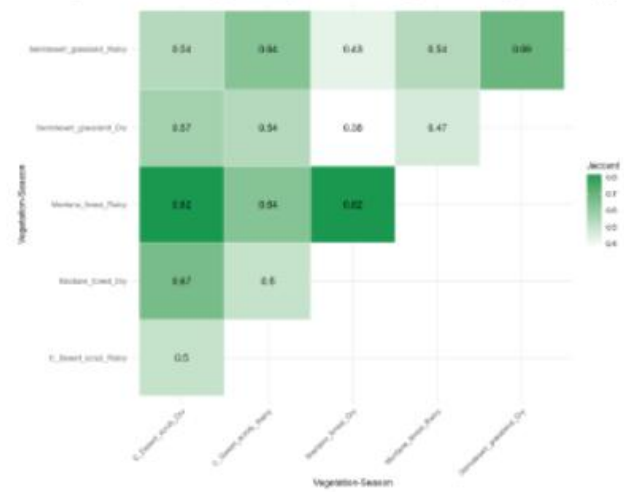

Figure 6. Heatmap between medium and large mammal community composition and vegetation types during the dry and rainy seasons in the study area.

The canonical correspondence analysis (CCA) explained 21.7% of the total variation in mammal community composition. The first two canonical axes, CCA1 and CCA2, accounted for 16.1% and 2.9% of the total variation, respectively, summing to 19.0% (Figure 7). Permutation tests confirmed that the overall model was statistically significant ($F_{4,94}$ = 6.51, p = 0.001), indicating a strong association between species abundance and the analyzed environmental gradients. Among the explanatory variables, vegetation type exerted the strongest and most significant influence on species distribution ($F_{2,94}$ = 8.14, p = 0.001), followed by season ($F_{1,94}$ = 5.60, p = 0.003) and sampling method ($F_{1,94}$ = 4.15, p = 0.017). CCA showed that environmental variables explained 21.7% of the total variation in terrestrial mammal composition, demonstrating a structured community response to environmental gradients. The first two axes (CCA1 and CCA2) together explained 19.0% of the total variance and were significant ($p < 0.05$), indicating that environmental conditions determine the distribution and composition of species across sites. The CCA1 axis was primarily associated with the vegetation type gradient, distinguishing communities of the Chihuahuan desert scrub toward negative values, whereas semi-desert grasslands were distributed across both canonical axes, indicating broader variability (Figure 7). The CCA2 axis reflected seasonal variation in community composition. Montane forest assemblages exhibited a more compact clustering pattern, suggesting greater structural homogeneity, while semi-desert grassland communities showed a wider dispersion, consistent with higher compositional heterogeneity (Figure 7). Seasonality affected the spatial dispersion of the sampled sites, with greater heterogeneity during the rainy season, whereas the sampling method did not produce a clear separation among groups. In the CCA ordination plot (Figure 7), confidence ellipses differentiated by vegetation type illustrate distinct species–habitat associations, while the seasonal dispersion of points reflects temporal shifts in community composition. In the semi-desert grassland, species such as C. *mexicanus*, *Xerospermophilus spilosoma*, *N. frenata*, *L. californicus*, and *Canis latrans* exhibited a broad distribution across canonical axes, indicating ecological tolerance and plasticity in response to environmental variation.

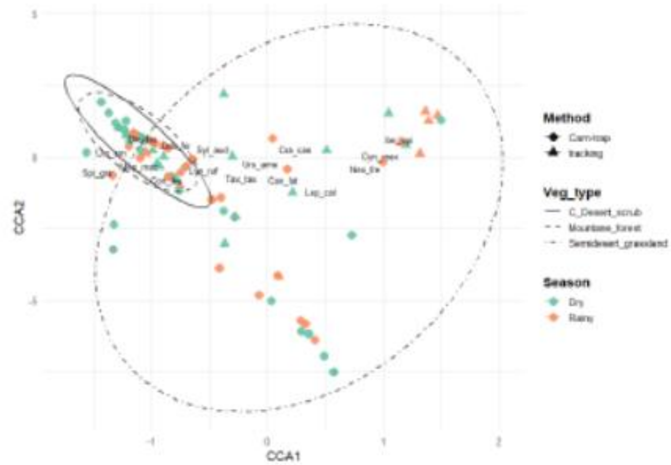

Figure 7. Canonical correspondence analysis (CCA) of the variation in medium and large mammal community composition during the dry and rainy seasons in the study area. Odo_vir: *Odocoileus virginianus*; Syl_aud: *Sylvilagus audubonii*; Dic_taj: *Dicotyles tajacu*; Can_lat: *Canis latrans*; Uro_cin: *Urocyon cinereoargenteus*; Con_leu: *Conepatus leuconotus*; Mep_mac: *Mephitis macroura*; Spi_gra: *Spilogale gracilis*; Lyn_ruf: *Lynx rufus*; Urs_ame: *Ursus americanus*; Tax_tax: *Taxidea taxus*; Neo_fre: *Neogale frenata*; Lep_cal: *Lepus californicus*; Cyn_Mex: *Cynomys mexicanus*; Xer_spi: *Xerospermophilus spilosoma*; Cra_cas: *Cratogeomys castanops*.

3.4 Photographic rates

Photographic rates from camera trapping reflected similar patterns to track surveys. During the dry season, *O. virginianus* and *S. audubonii* exhibited the highest photographic rates (RAIeR = 4.10 ± 9.3). *Lepus californicus* showed an intermediate rate (4.0), while *C. latrans*, *C. leuconotus*, *C. mexicanus*, *Dicotyles tajacu*, *L. rufus*, *Mephitis macroura*, *Spilogale gracilis*, *T. taxus*, *Urocyon cinereoargenteus*, *U. americanus*, and *X. spilosoma* all presented low values (0.1 ± 1.3). In the rainy season, *S. audubonii* and *O. virginianus* again dominated (3 ± 10), while *L. californicus*, *C. latrans*, and *L. rufus* exhibited intermediate values (1 ± 4) with moderate dispersion. The remaining species showed consistently low photographic rates (0.1 ± 1.1) with reduced variability compared to the dry season (Figure 8).

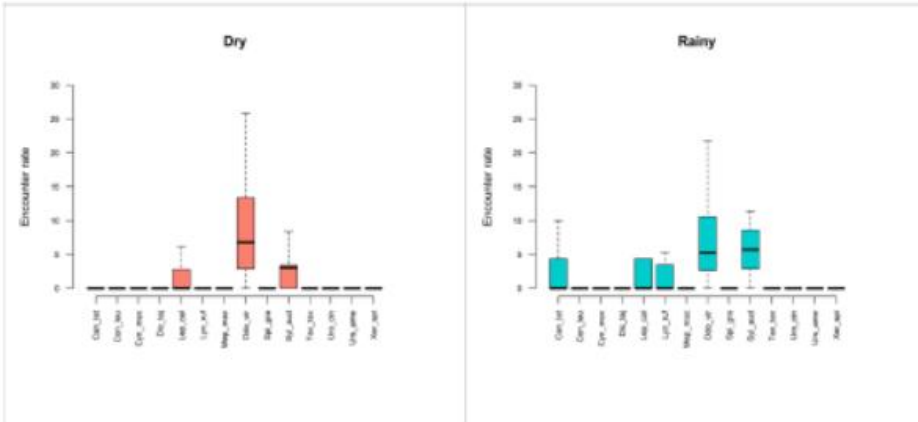

Figure 8. Boxplots of the encounter rate of terrestrial mammal species recorded by camera trapping in the study area. Odo_vir: *Odocoileus virginianus*; Syl_aud: *Sylvilagus audubonii*; Dic_taj: *Dicotyles tajacu*; Can_lat: *Canis latrans*; Uro_cin: *Urocyon cinereoargenteus*; Con_leu: *Conepatus leuconotus*; Mep_mac: *Mephitis macroura*; Spi_gra: *Spilogale gracilis*; Lyn_ruf: *Lynx rufus*; Urs_ame: *Ursus americanus*; Tax_tax: *Taxidea taxus*; Neo_fre: *Neogale frenata*; Lep_cal: *Lepus californicus*; Cyn_Mex: *Cynomys mexicanus*; Xer_spi: *Xerospermophilus spilosoma*; Cra_cas: *Cratogeomys castanops*.

Photographic rates varied notably among vegetation types. In the montane forest, the highest photographic rates corresponded to *O. virginianus* (2.6 ± 44.8) and *S. audubonii* (2.6 ± 21.7), while *S. gracilis* and *U. americanus* also exhibited relatively elevated values (2.9 ± 3.4). In the Chihuahuan desert scrub, *O. virginianus* had the highest detection rate (2.7 ± 57.1). However, despite being represented by a single record, *T. taxus* reached the maximum photographic rates (RAIeR = 4.3). In the semi-desert grassland, *C. mexicanus* had the highest photographic rate (> 90% of detections), whereas *C. leuconotus* had the lowest (2.9; Figure 9).

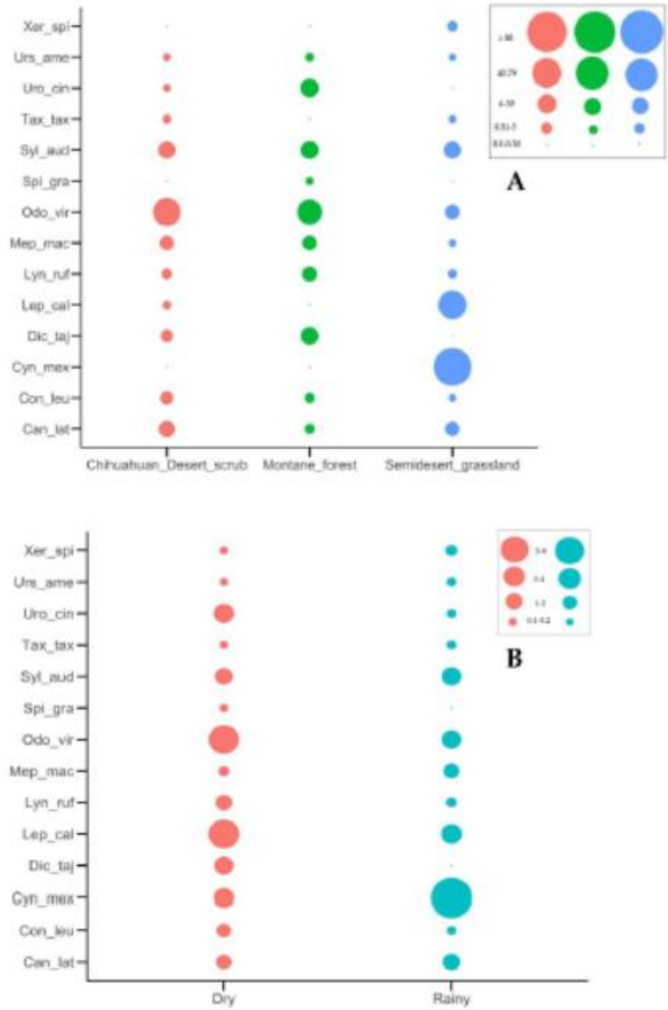

Figure 9. Photographic rates of mammals recorded in the different types of vegetation (A) and in the dry and rainy seasons (B) in the study area. Odo_vir: *Odocoileus virginianus*; Syl_aud: *Sylvilagus audubonii*; Dic_taj: *Dicotyles tajacu*; Can_lat: *Canis latrans*; Uro_cin: *Urocyon cinereoargenteus*; Con_leu: *Conepatus leuconotus*; Mep_mac: *Mephitis macroura*; Spi_gra: *Spilogale gracilis*; Lyn_ruf: *Lynx rufus*; Urs_ame: *Ursus americanus*; Tax_tax: *Taxidea taxus*; Neo_fre: *Neogale frenata*; Lep_cal: *Lepus californicus*; Cyn_Mex: *Cynomys mexicanus*; Xer_spi: *Xerospermophilus spilosoma*; Cra_cas: *Cratogeomys castanops*.

During the dry season, *O. virginianus* was the most frequently recorded species, suggesting high activity during this period. In contrast, during the rainy season, *C. mexicanus* dominated detections, suggesting increased visibility and activity in grassland habitats. Other species with relatively high photographic rates in both seasons included *S. audubonii*, *L. californicus*, and *U. cinereoargenteus* (Figure 9).

A significant and positive correlation was observed between the photographic rate (RAIeR) and naïve occupancy (OccNaïve, $r^2 = 0.92$; $p < 0.001$), indicating a strong relationship between detection frequency and spatial occurrence across species (Fig. 10). Among the recorded taxa, *O. virginianus* exhibited the highest detection metrics, with a photographic rate of 9.35, a naïve occupancy of 0.82, and 234 independent photographic events. Following this species, *S. audubonii* (RAIeR = 4.9; OccNaïve = 0.68; events = 88), *L. californicus* (RAIeR = 3.89; OccNaïve = 0.35; events = 67), *C. latrans* (RAIeR = 1.59; OccNaïve = 0.30; events = 48), and *C. mexicanus* (RAIeR = 2.95; OccNaïve = 0.10; events = 43) also displayed relatively high detection rates and broad spatial distributions within the study area. In contrast, several species clustered in the lower-left quadrant of the correlation plot, including *D. tajacu*, *C. leuconotus*, *M. macroura*, *U. cinereoargenteus*, *U. americanus*, *X. spilosoma*, *T. taxus*, and *S. gracilis* (Figure 10). These species exhibited fewer than 25 photographic events and low encounter rates (mean RAIeR = 0.1 ± 2.9), reflecting limited spatial occupancy and reduced detectability.

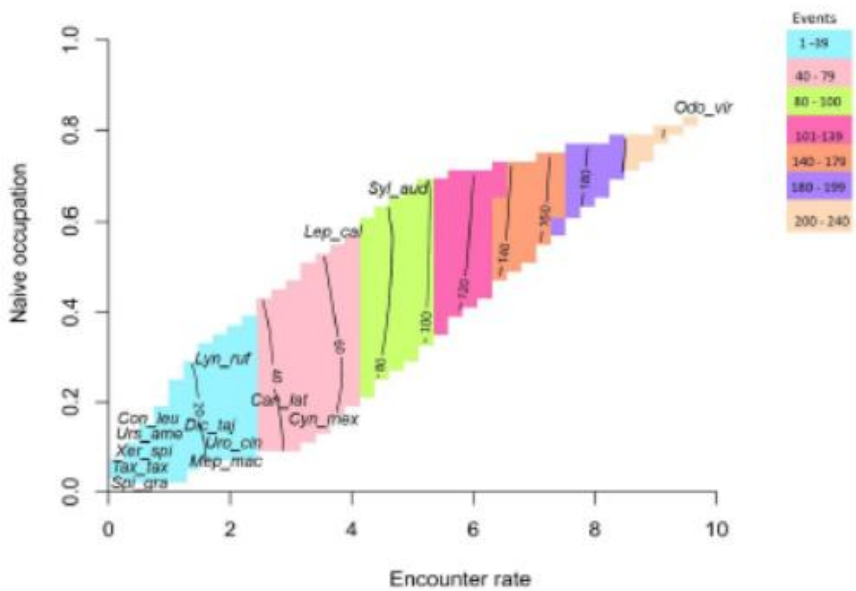

Figure 10. Correlation between photographic rate and naive occupancy (OccNaive) for the mammal community in the study area. Odo_vir: *Odocoileus virginianus*; Syl_aud: *Sylvilagus audubonii*; Dic_taj: *Dicotyles tajacu*; Can_lat: *Canis latrans*; Uro_cin: *Urocyon cinereoargenteus*; Con_leu: *Conepatus leuconotus*; Mep_mac: *Mephitis macroura*; Spi_gra: *Spilogale gracilis*; Lyn_ruf: *Lynx rufus*; Urs_ame: *Ursus americanus*; Tax_tax: *Taxidea taxus*; Neo_fre: *Neogale frenata*; Lep_cal: *Lepus californicus*; Cyn_Mex: *Cynomys mexicanus*; Xer_spi: *Xerospermophilus spilosoma*; Cra_cas: *Cratogeomys castanops*.

4. Discussion

A total of 16 medium- and large-sized mammal species, belonging to four orders and nine families, were recorded through the combined use of track surveys and camera trapping, a complementary approach that enhances detection probability and provides a more comprehensive assessment of species richness and functional diversity [46,82]. This integrative methodology is particularly valuable in arid and semi-arid ecosystems, where low population densities, cryptic behavior, and harsh environmental conditions often hinder direct observations [43,83]. The integration of these complementary methodologies improved detection efficiency, as it facilitated the recording of species with cryptic behavior and low visual detectability while also capturing records of more abundant and wide-ranging taxa. This approach aligns with previous studies that highlight the importance of combining direct and indirect monitoring methods to generate robust and reliable estimates of mammal community structure [84,85]. Among the recorded species, *C. mexicanus* is listed as Endangered by the IUCN [80], *T. taxus* is classified as Threatened, and both *U. americanus* and *C. mexicanus* are considered Endangered under Mexican Official Standards [81]. The presence of protected and regionally threatened species highlights the importance of conservation in the study area, acting as a critical refuge that supports populations of taxa facing elevated extinction risk. This pattern is consistent with broader conservation trends across arid and semiarid regions of Mexico and the Americas, where escalating anthropogenic pressures—particularly habitat loss, fragmentation, and climate variability—are eroding ecosystem integrity and driving a disproportionate increase in the number of threatened and endangered species [86].

Compared to other studies in arid and semiarid ecosystems [87,88], the species richness observed here is moderate. Nevertheless, camera trapping has proven to be an essential tool in northern Mexico for documenting mammal richness, distribution, and activity patterns, particularly for species adapted to conditions of water scarcity and marked temperature fluctuations [89,90]. For instance, in the Janos Biosphere Reserve, the presence of *Cynomys ludovicianus* has been well documented. This species acts as an ecosystem engineer, enhancing habitat heterogeneity, promoting water infiltration, and providing shelter for a variety of taxa [49]. At the same time, the reintroduction of *Bison bison* into the same reserve has improved grassland health, strengthened ecosystem services, and contributed to the preservation of indigenous cultural values. In other portions of the Chihuahuan Desert, camera trapping has recorded more than 30 mammal species, including rodents (*Dipodomys merriami*), lagomorphs (*L. californicus*), and carnivores (*Puma concolor*), thus enriching the faunal inventory of this region [91].

Indirect evidence, including tracks, scat, and burrows, provides an important complement to camera-trapping data, particularly for elusive species with low detectability [38]. In anthropogenically transformed regions of northern Mexico, the integration of both methods has proven effective for identifying movement corridors, transit zones, and areas of conflict with human infrastructure [87,91]. However, there remains a notable gap in the Mexican literature, as few published studies have explicitly combined these approaches within a unified framework. On a broader scale, integrated monitoring has also shown considerable potential. For example, in hyper-arid regions of the Middle East, camera trapping documented 59 vertebrate species—including 12 IUCN-listed threatened species—and highlighted the dependence of desert fauna on scarce water sources. The study also evaluated reintroduction success by detecting offspring and predators of reintroduced populations, such as the desert gazelle (*Gazella dorcas*) [92]. Similarly, in Khaudum National Park, Namibia, camera trapping has been instrumental in identifying individuals of *Panthera pardus*, revealing habitat-use patterns and home-range sizes of large carnivores in arid ecosystems, with direct implications for their conservation [93]. Although track surveys and sign surveys remain methodologically useful in arid ecosystems, particularly for detecting species with low camera-trap detectability, the systematic integration of both approaches is still limited in the scientific literature. Strengthening this combined methodology will provide more comprehensive insights into mammal communities, particularly in regions facing intense anthropogenic pressures and climatic variability.

In tropical ecosystems, camera trapping has proven particularly effective for detecting complex community patterns. A standardized global survey in tropical forests, including sites in Costa Rica and Brazil, documented 105 mammal species and demonstrated how habitat fragmentation reduces both species richness and functional diversity [94]. Similarly, in cloud forests of the Sierra Madre Oriental, Hidalgo, camera placement along riparian and non-riparian areas enabled the estimation of relative abundance indices and activity patterns, revealing marked differences in habitat use [95]. These examples underscore that tropical ecosystems, although richer in species diversity, are also more sensitive to fragmentation: studies show that terrestrial mammal communities in fragmented tropical forest landscapes exhibit lower species richness, altered functional composition and elevated extinction risk [18,94]. In contrast to more mesic systems, semi-arid ecosystems in northern Mexico are characterized by lower overall species richness; nonetheless, camera-trap surveys have proven indispensable for detecting key mammalian taxa and elucidating spatial usage patterns across landscapes increasingly dominated by anthropogenic activity (e.g., detection of carnivores and prey in the Mapimí Biosphere Reserve, Chihuahuan Desert) [95-97]. Meanwhile, although less commonly applied in arid settings, indirect track- or footprint-based surveys hold considerable potential for documenting elusive or visually inconspicuous taxa, identifying movement corridors and critical human–wildlife crossing zones (methods reviewed in sign-based surveys of desert mammals) [96,97]. Despite these methodological advantages, integrative studies combining camera trapping with track surveys in arid and semi-arid northern Mexican landscapes remain scarce.

In the present study area, the mammal assemblage recorded during both wet and dry seasons reflected moderate richness and was dominated by generalist herbivores (*O. virginianus*, *S. audubonii* and *C. mexicanus*) and a key colonial rodent of arid zones as *C. mexicanus*. Greater diversity and evenness were observed in the dry season, particularly in semi-desert grassland. The overlap in the 95% confidence intervals of the seasonal rarefaction curves, both reaching asymptotes, indicates that sampling effort was sufficient to capture most of the species present in each season. Ecologically, this suggests comparable community richness and a stable assemblage structure across seasons, reflecting limited temporal turnover in species composition. This result suggests that seasonal differences were not significant. This pattern is consistent with arid ecosystems, where reduced vegetation cover and water availability increase animal movements toward predictable resources, enhancing detectability. Comparable results from the Chihuahuan and Sonoran deserts indicate that colonial rodents and lagomorphs drive relative abundance, while carnivores occur at low densities and with highly localized detections. This aligns with the low occupancy rates of mustelids, skunks, and ursids observed in this study. In contrast, tropical ecosystems typically exhibit higher local richness, a greater representation of medium- to large-sized carnivores and frugivores, and more complex trophic structures, where dominance rarely depends on a few diurnal herbivores [94,98]. Moreover, tropical systems often show seasonal peaks in detectability linked to fruiting or dry-season resource concentration, but higher baseline productivity buffers these fluctuations and sustains high diversity year-round. At a global scale, tropical forests are generally characterized by higher Shannon diversity values and greater evenness, whereas deserts and arid shrublands exhibit lower alpha diversity and assemblages that are strongly shaped by primary productivity and climatic variability [99]. The results presented here—species richness of ≈12 and pronounced dominance of *O. virginianus* and *S. audubonii*—are consistent with expectations for arid systems, where community structure is tightly constrained by environmental unpredictability.

Rarefaction stabilization and ≥99% sample coverage indicates near-complete inventory. This is comparable to well-designed tropical surveys, though dense forests typically require greater effort to reach asymptotes due to microenvironmental heterogeneity. The strong correlation between RAIeR and naïve occupancy ($r^2 = 0.92$) suggests that photographic rates effectively captured spatial availability, a common pattern in open landscapes with low vegetation cover. In contrast, in closed tropical forests, the relationship is often weakened by microhabitat complexity, trail-use biases, and species-specific detectability. From a conservation perspective, the co-occurrence of at-risk species (i.e., *C. mexicanus*, *U. americanus*, *T. taxus*, under national legislation) underscores the ecological relevance of arid mosaics with heterogeneous productivity and grassland patches. At a global scale, grassland and desert specialists face steep declines driven by fragmentation, overgrazing, and climate change, while in the humid tropics, deforestation and hunting remain predominant threats [100,101]. The dominance of *C. mexicanus* in semi-desert grassland and its marked seasonal signal are consistent with studies in arid grasslands that document ecological engineering effects and colonial aggregation. In tropical forests, community structuring is also mediated by engineering species (e.g., peccaries), but dominance tends to be distributed across multiple guilds. Collectively, the observed patterns conform with theoretical and empirical expectations for arid systems, which differ from tropical ones in richness, evenness, detectability, and seasonality [99].

The high similarity (0.82) recorded between the mammal community of the montane forest during the rainy season and that of the Chihuahuan desert scrub during the dry season suggests a relatively homogeneous composition between structurally contrasting habitats. This pattern indicates the presence of generalist species, or species with broad ecological plasticity, capable of exploiting resources in different environments and under varying seasonal conditions. Similar results have been reported by Derebe et al. [102], who attribute this affinity to the spatial continuity of the landscape and the existence of natural corridors that facilitate species movement. The desert scrub, characterized by its structural heterogeneity and the temporal availability of resources, favors the coexistence of species with different ecological strategies and contributes to the functional connectivity of the landscape [103]. These conditions could explain its role as a transitional habitat between arid and temperate ecosystems. In contrast, the low similarity between the semi-desert grassland and montane forest communities during the dry season demonstrates a marked differentiation in species composition, likely associated with variations in vegetation structure, ground cover, and refuge availability. Coincidentally, changes in terrestrial mammal composition have been documented to depend more on habitat type than on climatic seasonality [104,105]. Taken together, these results underscore the role of landscape heterogeneity and habitat structure in the spatial organization of mammal communities.

In climates with strong seasonal gradients, the strategic placement of cameras near water sources has proven highly effective for detecting carnivores, and global aridland studies have confirmed that proximity to water increases both species' detectability and recorded richness [106]. Nationally, in more humid regions, camera traps have shown connectivity along riparian corridors in Sonora, where jaguars, black bears, and ocelots use river systems as transit routes, highlighting the importance of conservation of rivers in fragmented landscapes [87]. In the Sierra Nanchititla, studies revealed that ~67% of species are nocturnal, with diurnal and crepuscular activity varying seasonally and by sex or resource availability [107]. These findings demonstrate the utility of camera trapping for assessing temporal patterns and connectivity in both natural and anthropized ecosystems. A key methodological challenge in arid and semi-arid systems is the bias introduced by camera placement. In such areas, cameras positioned on animal trails often inflate detection probabilities for some species while underrepresenting others, potentially leading to biased interpretations. Consequently, mixed sampling designs—combining trail-based placements with off-trail or interior habitats—are recommended to reduce spatial bias.

Overall, evidence indicates that camera trapping provides robust, non-invasive data on faunal composition, richness, and activity in arid and semi-arid systems, while indirect tracking remains a valuable complement for detecting elusive or highly mobile taxa. However, integrative methodological approaches remain underdeveloped in northern Mexico. Strategic camera placement, especially near water sources or anthropogenic access structures, significantly increases sampling efficiency in fragmented landscapes. When combined, camera trapping and track surveys enhance the capacity to characterize habitat use, connectivity, and anthropogenic pressures on mammal populations [38,108]. Advancing integrative approaches in northern Mexico's semi-arid landscapes—where agriculture, livestock, and infrastructure intensify human pressure—is therefore essential for designing conservation and adaptive management strategies. Such efforts will improve understanding of medium- and large-sized mammal dynamics in anthropized arid environments, strengthening the scientific basis for informed policy and effective conservation action.

Our findings emphasize the importance of studying overlooked and unique ecosystems such as semi-arid and arid ecosystems, even within fragmented and human-dominated landscapes. The mammal communities documented in our study are likely to have been isolated for decades from larger, contiguous tracts of natural vegetation, making them both vulnerable and valuable as reservoirs of genetic diversity. Small and isolated populations of medium- and large-sized mammals are disproportionately affected by human-induced mortality, which substantially increases their probability of local extinction [109,110].

5. Conclusions

This study provides baseline information on the composition and abundance of medium- and large-sized terrestrial mammals in southeastern Coahuila, Mexico. The results align with expected patterns for arid ecosystems: dominance of colonial herbivores and rodents, moderate diversity, higher evenness during the dry season, elevated detectability, and efficient sampling. In contrast, tropical ecosystems in Mexico typically exhibit greater species richness, more complex trophic structures, and variable detectability. These contrasts reflect global ecological patterns and reinforce the need for biome-specific conservation strategies.

Our contribution expands current knowledge of mammalian diversity and habitat associations in semi-arid anthropogenic landscapes. Importantly, the integration of complementary approaches—including camera trapping, track surveys, biological collections, and community participation—facilitates a more comprehensive understanding of species distributions, population dynamics, and anthropogenic impacts. Consequently, conservation planning should prioritize the maintenance of native ecosystems—such as mountain forests, Chihuahuan desert scrub, and semi-desert grasslands—while reducing proximity to human infrastructure. Our results are essential for informing adaptive and sustainable conservation strategies in semi-arid regions under increasing human pressure and climate change. Protecting and managing remnant natural habitats, while mitigating infrastructure impacts, will be critical to ensuring the long-term persistence of medium- and large-sized mammals in northern Mexico.

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D., J.E.R-A., J.A.H-H., and E.G.C-L.; visualization, E.J.C-B.; supervision, J.A.E-D. and J.E.R-A.; project administration, E.J.C-B. and J.A.E-D.; funding acquisition, E.J.C-B. and J.A.E-D. All authors have read and agreed to the published version of the manuscript.

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References

1. Challenger, A. *Utilización y conservación de los ecosistemas de México: pasado, presente y futuro*. Instituto de Biología, UNAM, Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, México, **1998**.
2. Jurado-Guerra P.; Velázquez-Martínez M.; Sánchez-Gutiérrez R.A.; Álvarez-Holguín A.; Domínguez-Martínez P.A.; Gutiérrez-Luna R.; Chávez-Ruiz M.G. Los pastizales y matorrales de zonas áridas y semiáridas de México: Estatus actual, retos y perspectivas. *Rev. Mex. Cienc. Pecu.* **2021**, 12, 261-285. https://doi.org/10.22319/rmcp.v12s3.5875
3. Ewart H.E.; Pasqualotto N.; Paolino R.M.; Jensen K.; Chiarello A.G. Effect of anthropogenic disturbance and land cover protection on the behavioral patterns and abundance of Brazilian mammals. *Global Ecol. Conserv.* **2024**, 50, e02839. https://doi.org/10.1016/j.gecco.2024.e02839
4. Uzun G.; Evcin Ö. Determination of Dispersal Corridors Used by Large Mammals Between Close Habitats. *Diversity* **2025**, 17(3), 165. https://doi.org/10.3390/d17030165
5. Tiang D.C.F.; Morris A.; Bell M.; Gibbins C.N.; Azhar B.; Lechner A.M. Ecological connectivity in fragmented agricultural landscapes and the importance of scattered trees and small patches. *Ecol. Process.* **2021**, 10, 20. https://doi.org/10.1186/s13717-021-00284-7
6. Ma S.; Wang L-J.; Jiang J.; Zhao Y-G. Direct and indirect effects of agricultural expansion and landscape fragmentation processes on natural habitats. *Agric. Ecosyst. Environ.* **2023**, 353, 108555. https://doi.org/10.1016/j.agee.2023.108555
7. Cheptou P.O.; Hargreaves A.L.; Bonte D.; Jacquemyn H. Adaptation to fragmentation: evolutionary dynamics driven by human influences. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* **2017**, 372(1712), 20160037. https://doi.org/10.1098/rstb.2016.0037.
8. Cromsigt J.P.G.M.; Kuijper D.P.J.; Adam M.; Beschta R.L.; Churski M.; Eycott A.; Kerley G.I.H.; Mysterud A.; Schmidt K.; West K. Hunting for fear: innovating management of human-wildlife conflicts. *J. Appl. Ecol.* **2013**, 50, 544-549. https://doi.org/10.1111/1365-2664.12076
9. Pérez-Flores J.; Mardero S.; López-Cen A.; Contreras-Moreno F.M. Human-wildlife conflicts and drought in the greater Calakmul Region, Mexico: implications for tapir conservation. *Neotrop. Biol. Conserv.* **2021**, 16(4), 539-563. https://doi.org/10.3897/neotropical.16.e71032
10. Hessen D.O. Biotic Deterioration and Homogenization: Why It Matters. *Int. J. Polit. Cult. Soc.* **2024**, https://doi.org/10.1007/s10767-024-09498-x
11. Ceballos G.; Oliva G. *Los Mamíferos Silvestres de México*. Conabio-Fondo de Cultura Económica. México, **2005**.
12. Ceballos, G. Mammals of Mexico. Johns Hopkins University Press, Baltimore, U.S.A., **2014**.
13. Ramírez-Pulido J.; González-Ruiz N.; Contreras-Balderas A.J. Mamíferos. *La biodiversidad en Coahuila estudio de Estado*. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Gobierno del Estado de Coahuila de Zaragoza, Eds.; México, **2018**, Volumen 2, pp. 411-418.
14. Hernández-Rodríguez E.; Escalera-Vázquez L.; Calderón-Patrón J.M.; Mendoza E. Mamíferos medianos y grandes en sitios de tala de impacto reducido y de conservación en la sierra Juárez, Oaxaca. *Rev. Mex. Biodivers.* **2019**, 90, e902776. https://doi.org/10.22201/ib.20078706e.2019.90.2776
15. Milligan M.C.; McNew L.B. Evaluating the cumulative effects of livestock grazing on wildlife with an integrated population model. *Front. Ecol. Evol.* **2022**, 10, 818050. https://doi.org/10.3389/fevo.2022.818050

16. Ezcurra E. Los corredores biológicos desde las ciencias ambientales. In *Conectividad para la conservación de la biodiversidad en México: estado actual, retos y perspectivas*; Bezaury-Creel J.E., Ed.; Agencia Francesa de Desarrollo, México, **2024**, pp. 22-25.
17. León-Paniagua L.; García-Trejo E.; Arroyo-Cabrales J.; Castañeda-Rico S. Patrones biogeográficos de la mastofauna. *Biodiversidad de la Sierra Madre Oriental*; Luna I., Morrone J.J., Espinosa D., Eds.; Las Prensas de Ciencias, México, **2004**, pp. 469-486.
18. Crooks K.R.; Burdett C.L.; Theobald S.R.B.; Di Marco M.; Rondinini M.; Rondinini C.; Boitani L. Quantification of hábitat fragmentation reveals extinction risk in terrestrial mammals. *Proc. Natl. Acad. Sci. USA* **2017**, 114(29), 7635-7640. https://doi.org/10.1073/pnas.1705769114
19. Pfau R.S.; Kozora A.N.; Gatica-Colima A.B.; Sudman P.S. Population genetic structure of a Chihuahuan Desert endemic mammal, the desert pocket gopher, *Geomys arenarius*. *Ecology and Evolution* **2023**, 13(10), e10576. https://doi.org/10.1002/ece3.10576
20. Balbuena-Serrano Á.; Zarco-González M.M.; Carreón-Arroyo, G.; Carrera-Treviño R.; Amador-Alcalá S.; Monroy-Vilchis O. Connectivity of priority areas for the conservation of large carnivores in northern Mexico. *J. Nat. Conserv.* **2022**, 65, 126116. https://doi.org/10.1016/j.jnc.2021.126116
21. Zarco-González Z.; Carrera-Treviño R.; Monroy-Vilchis O. Conservation of black bear (*Ursus americanus*) in Mexico through GPS tracking: crossing and roadkill sites. *Wildl. Res.* **2023**, 51(1). https://doi.org/10.1071/WR22121
22. Castellanos-Morales G.; Hernández-Gómez J.E.; García-Moreno J.; León-Paniagua L. Peripatric speciation of an endemic species driven by Pleistocene climate change: The case of the Mexican prairie dog (*Cynomys mexicanus*). *Mol. Phylogenet. and Evol.* **2016**, 94, 171–181. https://doi.org/10.1016/j.ympev.2015.08.010
23. Cano A.; Cerna E.; Ceballos G.; Ochoa Y.M. Detección y cuantificación de plaguicidas en heces de *Cynomys mexicanus* en colonias de dos estados del norte de México. *Act. Univ.* **2023**, 33, e3865. https://doi.org/10.15174/au.2023.3865
24. Cruz-Bazan E.J.; Encina-Dominguez J.A.; Ramirez-Albores J.E.; Chávez-Lugo E.G. Rodents in xerophilous shrubland and semi-desert grassland communities of southeastern Coahuila, Mexico. *Agro Productividad* **2024**, 17(12), 25–34. https://doi.org/10.32854/agrop.v17i11.3076
25. Cruz-García F.; Escobar-Flores J.G.; Vázquez-López P.A. Potential distribution models for predicting human-Black bear (*Ursus americanus var. eremicus*) interactions in the Sierra de Zapalinamé Natural Reserve, Saltillo, Coahuila. *Agro Productividad* **2024**, 17(11), 127-136. https://doi.org/10.32854/agrop.v17i11.2856
26. Liu J.; Wilson M.; Hu G.; Liu J.; Wu J.; Yu M. How does habitat fragmentation affect the biodiversity and ecosystem functioning relationship? *Landsc. Ecol.* **2018**, 33, 341-352. https://doi.org/10.1007/s10980-018-0620-5
27. Jones K.E.; Safi K. Ecology and evolution of mammalian biodiversity. *Philos. Trans. R. Soc. Lond. B. Biol. Sci.* **2011**, 366(1577), 2451-61. https://doi.org/10.1098/rstb.2011.0090
28. Udy K.; Fritsch M.; Meyer K.M.; Grass I.; Hanß S.; Hartig F.; Kneib T.; Kreft H.; Kukunda C.B.; Pe'er G.; Reininghaus H.; Tietjen B.; Tscharntke T.; van Waveren C-S.; Wiegard K. Environmental heterogeneity predicts global species richness patterns better than area. *Global Ecol. Biogeogr.* **2021**, 30(4), 842. https://doi.org/10.1111/geb.13261
29. Bene J.K.; Bitty E.A.; Bohoussou K.H.; Abedi M.; Gamys J.; Soribah P.A.J. Current conservation status of large mammals in Sime Darby oil palm concession in Liberia. *Global J. Biol. Agric. Health Sci.* **2013**, 2(3), 93–102.
30. García-Feria L.M.; Pérez-Solano L.A.; Gallina-Tessaro S.; Peña-Peniche A. Microhabitat characterization in the home range of the Mule deer (*Odocoileus hemionus*) in arid zones. *Therya* **2025**, 15, 113-122. https://doi.org/10.12933/therya-24-6000
31. Rabira G.; Tsegaye G.; Tadesse H. The diversity, abundance and habitat association of medium and large-sized mammals of Dati Wolel National Park, Western Ethiopia. *Int. J. Biodivers. Conserv.* **2015**, 7(2), 112–8. https://doi.org/10.5897/ijbc2014.0808
32. Tefera G.G.; Tessema T.H.; Bekere T.A.; Gutema T.M. The diversity and habitat association of medium and large mammals in the Dhidhessa Wildlife Sanctuary, Southwestern Ethiopia. *PLoS One* **2025**, 20(3), e0317441. https://doi.org/10.1371/journal.pone.0317441
33. Smith R.S.; Johnston E.L.; Clark G.F. The role of habitat complexity in community development is mediated by resource availability. *PLoS One* **2014**, 9(7), e102920. https://doi.org/10.1371/journal.pone.0102920.
34. Jardim V.L.; Boyé A.; Le Garrec V.; Maguer M.; Tauran A.; Gauthier O.; Grall J. Habitat complexity promotes species richness and community stability: a case study in a marine biogenic habitat. *Oikos* **2025**, e10675. https://doi.org/10.1111/oik.10675
35. Fynn R.W.S.; Chase M.; Röder A. Functional habitat heterogeneity and large herbivore seasonal habitat selection in northern Botswana. *South African J. Wildl. Res.* **2014**, 44, 1-15. https://doi.org/10.3957/056.044.0103
36. Demosthenous-Bonastre E.; Grau-Andrés R.; Batlle-Benaiges J.; Corbera J.; Preece C.; Torner G.; Viza A.; Fernández-Martínez M. Water sources shape drought effects on mammal activity in mediterranean woodlands. *Mamm. Biol.* **2025**. https://doi.org/10.1007/s42991-025-00507-w

37. Tucker M.A.; Santini L.; Carbone C.; Mueller T. Mammals population densities at a global scale are higher in human-modified areas. *Ecography* **2021**, 44, 1-13. https://doi.org/10.1111/ecog.05126
38. Lyra-Jorge M.C.; Ciocheti G.; Pivello V.R.; Meirelles S.T. Comparing methods for sampling large- and medium-sized mammals: camera traps and track plots. *Eur. J. Wildl. Res.* **2008**, 54, 739–744. https://doi.org/10.1007/s10344-008-0205-8
39. López-Tello E.; Mandujano S. Paquete camtrapR para gestionar datos de foto-trampeo: Aplicación en la Reserva de la Biosfera Tehuacán-Cuicatlán. *Rev. Mex. Mastozool.* **2017**, 7(2), 13-37. https://doi.org/10.22201/es.decir.20074484e.2017.1.2.245
40. Mandujano S. Índice de abundancia relativa y tasa de encuentro con trampas cámara. *Mammal. Notes* **2024**, 10(1), 389-389. https://doi.org/10.47603/mano.v10n1.389
41. Aranda M. Manual para el rastreo de mamíferos silvestres de México. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. México, **2012**.
42. Chávez C.; De La Torre A.; Bárcenas H.; Medellín R.A.; Zarza H.; Ceballos G. *Manual de fototrampeo para estudio de fauna silvestre. El jaguar en México como estudio de caso.* Alianza WWF-Telcel, Universidad Nacional Autónoma de México, México, **2013**.
43. Suárez-Tangil B.D.; Rodriguez A. Uniform performance of mammal detection methods under contrasting environmental conditions in Mediterranean landscapes. *Ecosphere* **2021**, 12(3), e03349. https://doi.org/10.1002/ecs2.3349
44. Espinosa-Martínez D.V.; Ríos-Muñoz C.A.; González-Ruíz N.; Ramírez-Pulido J.; León-Paniagua L.; Arroyo-Cabrales J. Mamíferos de Coahuila. *Rev. Mex. Mastozool.* **2016**, 6(2), 1-28. https://doi.org/10.22201/es.decir.20074484e.2016.6.2.227
45. Ramírez-Pulido J. Panorama del conocimiento de los mamíferos de México: con énfasis a nivel estatal. In *Riqueza y conservación de los mamíferos en México a nivel estatal*, Sosa-Escalante J.E., Sánchez-Rojas G., Briones-Salas M., Hortelano-Moncada Y., Magaña-Cota G., Eds.; Instituto de Biología, Universidad Nacional Autónoma de México, Asociación Mexicana de Mastozoología A.C., Universidad de Guanajuato, México, **2016**, pp. 23-38.
46. Burton A.C.; Neilson E.; Moreira D.; Ladle A.; Steenweg R.; Fisher J.T.; Bayne E.; Boutin S. Wildlife camera trapping: a review and recommendations for linking surveys to ecological processes. *J. Appl. Ecol.* **2015**, 52(3), 675-685. https://doi.org/10.1111/1365-2664.12432
47. Trofino-Falasco C.; Simoy M.V.; Aranguren M.F.; Pizzarello M.G.; Cortelezzi A.; Vera D.G.; Simoy M.I.; Marinelli C.B.; Cepeda R.E.; Di Giacomo A.S.; Berkunsky I. How effective is camera trapping in monitoring grassland species in the southern Pampas ecoregion? *Rev. Mex. Biodivers.* **2023**, 94, e945243. https://doi.org/10.22201/ib.20078706e.2023.94.5243
48. González-Aldaco S.X. Análisis espacial y temporal de la cobertura forestal. In *La Biodiversidad en Coahuila. Estudio de Estado*; Conabio, Gobierno del Estado de Coahuila de Zaragoza, Comps.; México, Vol. 1, **2017**; pp. 113–122.
49. Ceballos G.; Davidson A.; List R.; Pacheco J.; Manzano-Fisher P.; Santo-Barrera G.; Cruzado J. Rapid decline of a grassland system and its ecological and conservation implications. *PLoS One* **2010**, 5(1), e8562. https://doi.org/10.1371/journal.pone.0008562
50. Mendoza E.; Guevara R.; Dirzo R. Impacts of land use and cover change on land mammal distribution ranges across Mexican ecosystems. *Mexican fauna in the Anthropocene.* Jones R.W., Ornelas-García C.P., Pineda-López R., Álvarez F., Eds.; Springer, Cham. **2023**. https://doi.org/10.1007/978-3-031-17277-9_12
51. López-Santos A.; Zermeño-González A.; Cadena-Zapata M.; Gil-Marín J.A.; Cornejo-Oviedo E.; Ríos-Camey M.S. Impacto de la labranza en el flujo energético de un suelo arcilloso. *Terra Latinoamericana* **2018**, 26(3), 203–213.
52. Heredia-Pineda F.J.; Lozano-Cavazos E.A.; Romero-Figueroa G.; Alanís-Rodríguez E.; Tarango-Arámbula L.A.; Ugalde-Lezama S. Relaciones interespecíficas de alimentación del gorrión de Worthen (*Spizella wortheni*) durante la época no reproductiva en Coahuila, México. *Rev. Chapingo Ser. Zonas Áridas* **2017**, 16(2), 23-36. https://doi.org/10.5154/r.rchsza.2017.11.009
53. Mendoza-Hernández J.M.; González-Aldaco S.X. Clima. In *La Biodiversidad en Coahuila. Estudio de Estado*, Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Gobierno del Estado de Coahuila de Zaragoza, Comps., Volumen 1, **2018**, pp. 45–54.
54. Encina-Domínguez J.A.; Valdés J.; Villarreal J.A. Tipos de vegetación y comunidades vegetales. In *La biodiversidad en Coahuila estudio de Estado*; Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Gobierno del Estado de Coahuila de Zaragoza, México, Volumen 2, **2018**. pp. 89-110.
55. Stachowicz I.; Ferrer J.R.; Quiroga-Carmona M.; Moran L.; Lozano C. Baseline for monitoring and habitat use of medium to large non-volant mammals in Gran Sabana, Venezuela. *Therya* **2020**, 11, 169-179. https://doi.org/10.12933/therya-20-891
56. Babyesiza S.W.; Mgode G.; Mpagi J.L.; Sabuni C.; Ssuuna J.; Akoth S.; Katak-Webwa A. Composition in non-volant small mammals inhabiting a degradation gradient in a lowland tropical forest in Uganda. *Wildl. Biol.* **2023**, e01135. https://doi.org/10.1002/elb3.01135

57. Karanth K.U.; Nichols J.D. Estimation of tiger densities in India using photographic captures and recaptures. *Ecology* **1998**, 79, 2852-2862.
58. Maffei L.; Cuellar E.; Noss J. Uso de trampas cámara para la evaluación de mamíferos en el ecotono Chaco-Chiquitanía. *Rev. Bol. Ecol. Conserv. Amb.* **2002**, *11*, 55-65.
59. Álvarez-Castañeda S.T.; Álvarez T.; González-Ruiz N. *Guía para la identificación de los mamíferos de México en campo y laboratorio.* Centro de Investigaciones Biológicas del Noroeste, S.C., Instituto Politécnico Nacional 195. México, **2015**.
60. R Core Team. R: A Language and Environment for Statistical Computing; R Foundation for Statistical Computing: Vienna, Austria, **2023**. Available online: https://www.r-project.org/
61. Oksanen J.; Simpson G.; Blanchet F.G.; Kindt R.; Legendre P.; Minchin P.; Weedon J. Vegan community ecology package version 2.6, The Comprehensive R Archive Network, **2022**. Available online: http://cran. r-project. org (accessed on 15 August 2022).
62. Hill A.M.O. Diversity and evenness: a unifying notation and its consequences. *Ecology* **1973**, 54, 427–432.
63. Moreno C.E. *Métodos para medir la biodiversidad*. MyT- Manuales y Tesis SEA. Zaragoza, España. **2001**.
64. Hsieh T.C.; Ma K.H.; Chao, A. iNEXT: An R package for interpolation and extrapolation of species diversity (Hill numbers). *Methods Ecol. Evol.* **2016**, 7, 1451-1456. https://doi.org/10.1111/2041-210X.12613
65. Chao A.; Kubota Y.; Zelený D.; Chiu C.H.; Li C.F.; Kusumoto B.; Colwell R.K. Quantifying sample completeness and comparing diversities among assemblages. *Ecol. Res.* **2020**, 35: 292-314. https://doi.org/10.1111/1440-1703.12102
66. Hernández-Hernández J.C. Inter/extrapolación de la diversidad: iNEXT. In *Fototrampeo en R: organización y análisis de datos*, Mandujano S., Pérez-Solano L.A., Eds.; Instituto de Ecología A. C., México, Vol. 1, **2019**, pp. 115–127.
67. Hutcheson K. A test for comparing diversities based on the Shannon formula. *J. Theor. Biol.* **1970**, 29(1), 151–154. https://doi.org/10.1016/0022-5193(70)90124-4
68. Magurran A.E. Measuring biological diversity. John Wiley & Sons. **2003**.
69. Ramirez-Delgado D. ecolTest: Community Ecology Tests. R package version 1.0.2. **2021**. Available at https://cran.r-project.org/package=ecolTest
70. Niedballa J.; Sollmann R.; Courtiol A.; Wilting A. camtrapR: an R package for efficient camera trap data management. *Methods Ecol. Evol.* **2016**, 7, 1457-1462. https://doi.org/10.1111/2041-210X.12600
71. Lira-Torres I.; Briones-Salas M.; Sánchez-Rojas G. Abundancia relativa, estructura poblacional, preferencia de hábitat y patrones de actividad del tapir centroamericano *Tapirus bairdii* (Perissodactyla: Tapiridae), en la Selva de Los Chimalapas, Oaxaca, México. *Rev. Biol. Trop.* **2014**, 62(4), 1407-1419.
72. Hernández-Pérez E.; Reyna-Hurtado R.; Castillo-Vela G.; Sanvicente-López M.; Moreira-Ramírez J.F. Fototrampeo de mamíferos terrestres de talla mediana y grande asociados a petenes del noroeste de la península de Yucatán, México. *Therya* **2015**, 6(3), 559-574. https://doi.org/10.12933/therya-15-290
73. Soto-Werschitz A.; Mandujano S.; Passamani M. Influence of forest type on the diversity, abundance, and naive occupancy of the mammal assemblage in the southeastern Brazilian Atlantic Forest. *Therya* **2023**, 14(3), 329-341. https://doi.org/10.12933/therya-23-4991
74. Ochoa-Espinoza J.M.; Soria-Díaz L.; Astudillo-Sánchez C.C.; Treviño-Carreón J.; Barriga-Vallejo C.; Maldonado-Camacho E. Diversidad y abundancia de mamíferos del bosque mesófilo de montaña del noreste de México. *Act. Zool. Mex.* (n.s.) **2023**, 39, 1-18. https://doi.org/10.21829/azm.2023.3912591
75. Wickham H. Remodelación de datos con el paquete reshape. *J. Stat. Soft.* **2007**, 21 (12), 1–20. Available at http://www.jstatsoft.org/v21/i12/
76. Wickham H. ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag, New York. **2016**. https://doi.org/10.1007/978-3-319-24277-4_9
77. Mandujano S. Beta version of the RAI_eR package, GitHub repository, **2023**, Available at https://github.com/SMandujanoR/RAI_eR
78. Mandujano S.; Pérez-Solano L.A. Fototrampeo en R: organización y análisis de datos. Instituto de Ecología A. C. Xalapa, México, **2019**.
79. Kéry M.; Royle, J.A. *Applied hierarchical modeling in ecology: Analysis of distribution, abundance and species richness in R and BUGS.* Academic Press, London, **2015**.
80. International Union for Conservation of Nature (IUCN). Red List of Threatened Species-International Union for Conservation of Nature. **2024**. Available online: https://www.iucnredlist.org/
81. Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT). 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- Lista de especies en riesgo. Diario Oficial de la Federación, **2010**, Available at https://www.dof.gob.mx

82. Steenweg R.; Hebblewhite M.; Whittington J.; Lukacs P.; McKelvey K. Sampling scales define occupancy and underlying occupancy-abundance relationships in animals. *Ecology* **2018**, 99(1), 172-183. https://doi.org/10.1002/ecy.2054
83. Nogues E.; Arends A.; von Keyserlingk M.A.G. Rapid systematic literature review: camera trap sampling in ecological studies: consideration of wildlife welfare. *Animal Welfare* **2025**, 34, e44. https://doi.org/10.1017/awf.2025.10.014
84. Pérez-Irineo G.; Santos-Moreno A. Diversidad de una comunidad de mamíferos carnívoros en una selva mediana del noreste de Oaxaca, México. *Act. Zool. Mex. (n. s.)* **2010**, 26, 721-736.
85. Greco I.; Salvatori M.; Buonafede E.; Pistolesi A.; Corradini A.; Cappai N.; Marconi M.; Seidenari L.; Cagnacci F.; Rovero F. Placement matters: implications of trail-versus random-based camera-trap deployment for monitoring mammal communities. *Ecol. Appl.* **2025**, 35, e70083. https://doi.org/10.1002/eap.70083
86. Sánchez-Cordero V.; Botello F.; Flores-Martínez J.J.; Gómez-Rodríguez R.A.; Guevara L.; Gutiérrez-Granados G. Biodiversidad de Chordata (Mammalia) en México. *Rev. Mex. Biodivers.* **2014**, Supl. 85, S496.
87. Ragan K.; Schipper J.; Bateman H.L.; Hall S.J. Mammal use of riparian corridors in semi-arid Sonora, Mexico. J. *Wildl. Manag.* **2023**, 87, e22322. https://doi.org/10.1002/jwmg.22322
88. Camargo-Sanabria A.A.; Fernández J.A.; Hernández-Quiroz N.S.; Buitrago-Torres D.L.; Álvarez-Córdova F. Ecological interactions of terrestrial mammals in the Chihuahuan Desert: a systematic map. *Mammal Review* **2025**, 55, e70001. https://doi.org/10.1111/mam.70001
89. McCallum J. Changing use of camera traps in mammalian field research: habitats, taxa and study types. *Mammal Review* **2013**, 43, 196-206. https://doi.org/10.1111/j.1365-2907.2012.00216.x
90. Halle S. Ecological Relevance of Daily Activity Patterns. In *Activity patterns in small mammals*, Halle S., Stenseth N.C., Eds.; Ecological Studies, Springer, Berlin, Heidelberg, Vol. 141, **2000**. https://doi.org/10.1007/978-3-642-18264-8_5
91. Elizalde-Arellano C.; López-Vidal J.C.; Hernández L.; Laundré J.W.; Cervantes F.A.; Morales-Mejía F.M.; Ramírez-Vargas M.; Dávila-Galaviz L.F.; González-Romero A.; Alonso-Spilsbury M. Registro de presencia y actividades de algunos mamíferos en el Desierto Chihuahuense, México. *Therya* **2014**, 5, 793-816. https://doi.org/10.12933/therya-14-252
92. Abáigar T.; Cano M.; Ensenyat C. Habitat preference of reintroduced dorcas gazelles (*Gazella dorcas neglecta*) in North Ferlo, Senegal. *J. Arid Environ.* **2013**, 97, 176-181. https://doi.org/10.1016/j.jaridenv.2013.06.004
93. Jacobson A.P.; Gerngross P.; Lemeris Jr. J.R.; Schoonover R.F.; Anco C.; Breitenmoser-Würsten C.; Durant S.M.; Farhadinia M.S.; Henschel P.; Kamler J.F.; Laguardia A.; Rostro-García S.; Stein A.B.; Dollar L. Leopard (*Panthera pardus*) status, distribution, and the research efforts across its range. *Peer J* **2016**, 4: e1974 https://doi.org/10.7717/peerj.1974
94. Ahumada J.A.; Silva C.E.; Gajapersad K.; Hallam C.; Hurtado J.; Martin E.; McWilliam A.; Mugerwa B.; O'Brien T.; Rovero F.; Sheil D.; Spironello W.R.; Winarni N.; Andelman S.J. Community structure and diversity of tropical forest mammals: data from a global camera trap network. *Philos. Trans. R. Soc. Lond. B. Biol. Sci.* **2011**, 366(1578), 2703-11. https://doi.org/10.1098/rstb.2011.0115
95. Huerta-Rodríguez J.O.; Rosas-Rosas O.C.; López-Mata L.; Alcántara-Carbajal J.L.; Tarango-Arámbula L.A. Camera traps reveal the natural corridors used by mammalian species in eastern Mexico. *Ecol. Process.* **2022**, 11, 51. https://doi.org/10.1186/s13717-022-00394-w
96. Durán-Antonio J.; González-Romero A.; Sosa V.J. Activity overlap of carnivores, their potential wild prey, and temporal segregation, with livestock in a Biosphere Reserve in the Chihuahuan Desert. *J. Mammal.* **2020**, 101(6), 1609-1621. https://doi.org/10.1093/jmammal/gyaa120
97. Pérez-Solano L.A.; Gallina-Tessaro S. Activity patterns and their relationship to the habitat use of mule deer (Odocoileus hemionus) in the Chihuahuan Desert, Mexico. *Therya* **2019**, 10(3), 323. https://doi.org/10.12933/therya-19-875
98. Wearn O.R.; Rowcliffe J.M.; Carbone C.; Pfeifer M.; Bernard H.; Ewers R.M. Mammalian species abundance across a gradient of tropical land-use intensity: a hierarchical multi-species modelling approach. *Biol. Conserv.* **2017**, 212, 162-171. https://doi.org/10.1016/j.biocon.2017.05.007
99. Greenville A.C.; Wardle G.M.; Dickman C.R. Desert mammal populations are limited by introduced predators rather than future climate change. *R. Soc. Open Sci.* **2017**, 4, 170384. http://dx.doi.org/10.1098/rsos.170384
100. Kuipers K.J.J.; Hilbers J.P.; Garcia-Ulloa J.; Graae B.J.; May R.; Verones F.; Huijbregts M.A.J.; Schipper A.M. Habitat fragmentation amplifies threats from habitat loss to mammal diversity across the world's terrestrial ecoregions. *One Earth* **2021**, 4, 1505-1513, https://doi.org/10.1016/j.oneear.2021.09.005.

101. Lewin A.; Murali G.; Rachmilevitch S.; Roll U. Global evaluation of current and future threats to drylands and their vertebrate biodiversity. Nat. Ecol. Evol. **2024**, 8(8), 1448-1458. https://doi.org/10.1038/s41559-024-02450-4
102. Derebe B.; Derebe Y.; Gedamu, B. Composition, relative abundance, and diversity of medium and large mammals in the Lake Tirba Awi area, Ethiopia. *Anthropocene Sci.* **2023**, 2, 71–80. https://doi.org/10.1007/s44177-023-00050-8.
103. Ojeda, R.A.; Tabeni, S. The mammals of the Monte Desert revisited. *J. Arid Environm.* **2009**, 73(2), 173-181. https://doi.org/10.1016/j.jaridenv.2007.09.008
104. Quiroga-Pacheco C.J.; Velez-Liendo X.; Zedrosser A. Effects of seasonality on the large and medium-sized mammal community in mountain dry forests. *Diversity* **2024**, 16(7), 409. https://doi.org/10.3390/d16070409
105. Rojas-Sánchez J. V.; Coates R.I.; Sánchez-Cordero V.; Lavariega M.C.; Flores-Martínez J.J. Diversity and abundance of the species of arboreal mammals in a tropical rainforest in southeast Mexico. *Ecol. Evol.* **2025**, 15(1), e70812. https://doi.org/10.1002/ece3.70812
106. Edwards S.; Gange A.C.; Wiesel I. An oasis in the desert: the potential of water sources as camera trap sites in arid environments for surveying a carnivore guild. *J. Arid Environ.* **2016**, 124, 304-309. https://doi.org/10.1016/j.jaridenv.2015.09.009
107. Monroy-Vilchis O.; Zarco-González M.M.; Ramírez-Pulido J.; Aguilera-Reyes U. Diversidad de mamíferos de la Reserva Natural Sierra Nanchititla, México. *Rev. Mex. Biodivers.* **2011**, 82(1), 237-248. Recuperado en 08 de octubre de 2025, de http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S1870-34532011000100021&lng=es&tlng=es.
108. Beukes M.; Perry T.; Parker D.M.; Mgqatsa N. Refining camera trap surveys for mammal detection and diversity assessment in the Baviaanskloof Catchment, South Africa. *Wild* **2025**, 2(2), 15. https://doi.org/10.3390/wild2020015
109. Pacifi M.; Di Marco M.; Watson J.E.M. Protected areas are now the last strongholds for many imperiled mammal species. *Conserv. Lett.* **2020**, 13, e12748. https://doi.org/10.1111/conl.12748
110. Torres-Romero E.J.; Eppley T.M.; Ripple W.J.; Newsome T.M.; Carter N.H.; Ordiz A.; de Oliveira T.G.; Selva N.; Penteriani V. Global scale assessment of the human-induced extinction crisis of terrestrial carnivores. *Sci. Adv.* **2025**, 11, eadq2853. https://doi.org/10.1126/sciadv.adq285

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IV. CONCLUSIONES GENERALES

De acuerdo con los resultados obtenidos, la heterogeneidad del hábitat se identificó como la variable principal que determina la composición y diversidad de mamíferos en el área de estudio. En las especies de talla mediana y grande, la diversidad se mantuvo relativamente estable entre temporadas y estuvo influenciada por el tipo de vegetación, alcanzando una cobertura de muestreo cercana al 100% y mostrando una alta correlación entre la ocupación naive y la tasa fotográfica. En los pequeños roedores, el matorral xerófilo concentró la mayor diversidad, mientras que el zacatal semidesértico presentó la mayor abundancia, con un bajo recambio faunístico entre comunidades. Estos patrones, junto con la presencia de especies endémicas y amenazadas, destacan la importancia de conservar pastizales como hábitats clave dentro de los paisajes productivos de la región sureste de Coahuila.

V.REFERENCIAS

Aragón, P. E. E., Muñiz, M. R., Garza H. A. 2012. Roedores de Durango, México. Ed. Cervantes A. y Ballesteros, B. C. Estudios sobre la biología de Roedores Silvestres Mexicanos. Universidad Nacional Autónoma de México. México, D.F. P. 165-183.

Aranda, M. (2012). Manual para el rastreo de mamíferos silvestres de México.

Avenant, N. (2011). The potential utility of rodents and other small mammals as indicators of ecosystem 'integrity' of South African grasslands. Wildlife Research, 38, 626-639. https://doi.org/10.1071/wr10223.

Ayodele, A. (2025). Small mammal communities as indicators of habitat health: A review. International Journal of Science and Research Archive. https://doi.org/10.30574/ijsra.2025.15.2.1413.

Baker, M. A., Brown, J. H., & Ernest, S. K. (2020). Rodent community dynamics across desert ecosystems: Linking climate and productivity. Journal of Arid Environments, 181, 104227. https://doi.org/10.1016/j.jaridenv.2020.104227

Blumstein, D., & MacManes, M. (2023). When the tap runs dry: the physiological effects of acute experimental dehydration in Peromyscus eremicus. The Journal of Experimental Biology, 226. https://doi.org/10.1242/jeb.246386.

Ceballos, G. 2014.Orden Rodentia. Ed. Ceballos G. Mamíferos de México. Johns Hopkins University Press. Baltimore. P. 232-434

Chávez, C., A De La Torre, H. Bárcenas, R.A. Medellín, H. Zarza Y G. Ceballos. 2013. Manual de fototrampeo para estudio de fauna silvestre. El jaguar en

México como estudio de caso. Alianza WWF-Telcel, Universidad Nacional Autónoma de México, México.

Chillo, V., Ojeda, R., Anand, M., & Reynolds, J. (2015). A novel approach to assess livestock management effects on biodiversity of drylands. Ecological Indicators, 50, 69-78. https://doi.org/10.1016/j.ecolind.2014.10.009.

Dong, J., Chen, H., Shi, P., Dong, H., & Zhao, W. (2024). Rodent disturbances in arid regions drive ephemeral plant diversity but deteriorate soil health. CATENA. https://doi.org/10.1016/j.catena.2023.107582.

Ezcurra, E. (2024). Los corredores biológicos desde las ciencias ambientales. En J. E. Bezaury-Creel (Ed.), Conectividad para la conservación de la biodiversidad en México: estado actual, retos y perspectivas (pp. 22-25). Ciudad de México. Agencia Francesa de Desarrollo.

Gallina, S., & López-González, C. 2011. Manual de técnicas para el estudio de la fauna.Volumen I. Universidad Autónoma de Querétaro-Instituto de Ecología, AC, Querétaro, México. 377 pp.

Gedir, J., Cain, J., Swetnam, T., Krausman, P., & Morgart, J. (2020). Extreme drought and adaptive resource selection by a desert mammal. Ecosphere, 11. https://doi.org/10.1002/ecs2.3175.

González-Saucedo, Z., González-Bernal, A., & Martínez-Meyer, E. (2021). Identifying priority areas for landscape connectivity for three large carnivores in northwestern Mexico and southwestern United States. Landscape Ecology, 36, 877 - 896. https://doi.org/10.1007/s10980-020-01185-4.

Hernández B., S. F., Cimé Pool. A., Y Chablé, S. J. 2010. Pequeños roedores. Biodiversidad y Desarrollo Humano en Yucatán. 272-273.

Hernández B., S., A. Cimé Pool, J. Sosa-Escalante, J. Pech Canché Y J. Chablé Santos. 2010. Mamíferos terrestres. Pp. 268-272. En: Biodiversidad y Desarrollo Humano en Yucatán (R. Durán y M. Méndez, eds.). CICY, PPD-FMAM, CONABIO, SEDUMA. México. 508 páginas.

Klenner, W., & Sullivan, T. (2025). Effect of type and extent of vegetative cover on terrestrial small mammals in the semi-arid Okanagan Valley, British Columbia. Journal of Arid Environments. https://doi.org/10.1016/j.jaridenv.2025.105325.

Krebs, C. J. 1985. Ecología: estudio de la distribución y la abundancia No. 574.5 K92e. México, MX: Edit. Harla.

Lacher, T., Davidson, A., Fleming, T., Gómez-Ruiz, E., McCracken, G., Owen-Smith, N., Peres, C., & Wall, S. (2019). The functional roles of mammals in ecosystems. Journal of Mammalogy. https://doi.org/10.1093/jmammal/gyy183.

López-Tello, E., y Mandujano, S. (2017). Paquete camtrapR para gestionar datos de foto-trampeo: Aplicación en la Reserva de la Biosfera Tehuacán-Cuicatlán. Revista Mexicana de Mastozoología (Nueva Época), 7(2), 13-37.

Macswiney, M. C., Hernández-Betancourt. S. F., Panti, M. J. A., y Pech C. J. M. 2012. Ecología poblacional del ratón yucateco Peromyscus yucatanicus Rodentia: Cricetidae en las selvas de Quintana Roo, México. Estudios sobre la biología de roedores silvestres mexicanos. Instituto de Biología

UNAM, Unidad Iztapalapa Universidad Autónoma Metropolitana, México. 237-246.

Magioli, M., Ferraz, K., Setz, E., Percequillo, A., Rondon, M., Kuhnen, V., Da Silva Canhoto, M., Santos, K., Kanda, C., De Lima Fregonezi, G., Prado, H., Ferreira, M., Ribeiro, M., Villela, P., Coutinho, L., & Rodrigues, M. (2016). Connectivity maintain mammal assemblages functional diversity within agricultural and fragmented landscapes. European Journal of Wildlife Research, 62, 431-446. https://doi.org/10.1007/s10344-016-1017-x.

Mason, S., Hill, R., Whittingham, M., Cokill, J., Smith, G., & Stephens, P. (2022). Camera trap distance sampling for terrestrial mammal population monitoring: lessons learnt from a UK case study. Remote Sensing in Ecology and Conservation, 8. https://doi.org/10.1002/rse2.272.

Mattos, I., Zimbres, B., & Marinho-Filho, J. (2021). Habitat Specificity Modulates the Response of Small Mammals to Habitat Fragmentation, Loss, and Quality in a Neotropical Savanna. , 9. https://doi.org/10.3389/fevo.2021.751315.

Misher, C., Vats, G. y Vanak, A. (2022). Respuestas diferenciales de pequeños mamíferos a la invasión leñosa en una pradera semiárida., 10. https://doi.org/10.3389/fevo.2022.755903

Ramírez-Pulido, J., González-Ruiz, N., & Contreras-Balderas, A. J. (2018). Mamíferos: Listado de mamíferos del estado de Coahuila. En Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO) & Gobierno del Estado de Coahuila de Zaragoza (Eds.), La biodiversidad en Coahuila: Estudio de Estado (pp. 457–470). CONABIO/Gobierno del Estado de Coahuila de Zaragoza.

Rodríguez-Barrera, M., Kühn, I., Estrada-Castillón, E., & Cord, A. (2022). Grassland type and seasonal effects have a bigger influence on plant functional and taxonomical diversity than prairie dog disturbances in semiarid grasslands. Ecology and Evolution, 12. https://doi.org/10.1002/ece3.9040.

Thibault, K. M., Ernest, S. M., White, E. P., Brown, J. H., & Goheen, J. R. (2010). Long-term insights into the influence of precipitation on community dynamics in desert rodents. Journal of Mammalogy, 91(4), 787-797. https://doi.org/10.1644/09-MAMM-S-142.1

Tyrrell, P., Russell, S., & Western, D. (2017). Seasonal movements of wildlife and livestock in a heterogenous pastoral landscape: Implications for coexistence and community based conservation. Global Ecology and Conservation, 12, 59-72. https://doi.org/10.1016/j.gecco.2017.08.006.

Zimbres, B., Peres, C., & Machado, R. (2017). Terrestrial mammal responses to habitat structure and quality of remnant riparian forests in an Amazonian cattle-ranching landscape. Biological Conservation, 206, 283-292. https://doi.org/10.1016/j.biocon.2016.11.033.