THERYA, 2027, Vol. 18(1):XXX-XXX DOI: 10.12933/therya.2027.6363 ISSN 2007-3364

Bats richness and composition in the Zicuirán-Infiernillo Biosphere Reserve, Michoacán, México

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Mexico's dry tropics host high bat species richness that plays an imperative role in fundamental ecological and evolutionary processes. Protected areas are cornerstones of biodiversity conservation, including the Zicuirán-Infiernillo Biosphere Reserve (ZIBR) in the Tierra Caliente region of Michoacán, characterized by distinct climate regimes, complex topography, and tropical vegetation. This study aimed to update the taxonomic inventory of bats in the ZIBR, compare historical and contemporary species richness, and identify priority species for local conservation. Across historical (1962–1986) and contemporary (2004–2025) sampling periods, we examined the records of 1,123 bat records corresponding to 6 families, 25 genera, and 41 species. Overall, 12% (n= 5) of these are listed under national risk categories (PROY-NOM-059-SEMARNAT-2025): Endangered *Musonycteris harrisoni* (T1 n=5; 2.18% - T2 n= 6; 0.67%); Threatened *Choeronycteris mexicana* (T1 n= 1; 0,43% - T2 n= 4; 0,44 %), *Leptonycteris nivalis* (T1 n= 0 - T2 n= 7 - 0.78%), *L. yerbabuenae* (T1 n= 7; 3.05% - T2 n= 146, 16.33%); and Subject to Special Protection *Rhogeessa mira* (T1 n= 23; 10% - T2 n= 5; 0.55%). Nine species (22%) are endemic to México (*Pteronotus mexicanus, Glossophaga morenoi, Artibeus hirsutus, Chiroderma scopaeum, Molossus sinaloae, Baeodon alleni, Myotis fortidens, Rhogeessa mira,* and *R. parvula*). The most species rich families were Phyllostomidae (13 genera, 22 species) and Vespertilionidae (5 genera, 8 species). Finally, we propose a local conservation categorization framework derived from local abundance values.

Keywords: Conservation, endemic species, mammals, tropical dry forest, tropical thorn forest.

El trópico seco de México presenta una alta riqueza de murciélagos, fundamentales en procesos ecológicos y evolutivos. Las áreas naturales representan una estrategia de conservación: la Reserva de la Biosfera Zicuirán-Infiernillo (RBZI), ubicada en la Tierra Caliente del Estado de Michoacán y caracterizada por sus climas, relieves y vegetación tropical. Los objetivos planteados fueron: actualizar el inventario taxonómico de murciélagos en la RBZI; comparar la riqueza histórica y contemporánea y determinar especies prioritarias de conservación local. En el estudio se examinaron 1,123 registros de murciélagos pertenecientes a 6 familias, 25 géneros y 41 especies en un periodo histórico (1962-1986) y contemporáneo (2004-2025). El 12% de especies están registradas en la PROY-NOM-059-SEMARNAT-2025, peligro de extinción *Musonycteris harrisoni* (T1 n=5; 2.18% - T2 n= 6; 0.67%), amenazadas *Choeronycteris mexicana* (T1 n= 1; 0,43% - T2 n= 4; 0,44 %), *Leptonycteris nivalis*, (T1 n= 0 - T2 n= 7; 0.78%) y *L. yerbabuenae* (T1 n= 7; 3.05% - T2 n= 146; 16.33%), sujetas a protección especial *Rhogeessa mira* (T1 n= 23; 10 % - T2 n= 5; 0.55%). Nueve especies endémicas que representan un (22%) (*Pteronotus mexicanus*, *Glossophaga morenoi*, *Artibeus hirsutus*, *Chiroderma scopaeum*, *Molossus sinaloae*, *Baeodon alleni*, *Myotis fortidens*, *Rhogeessa mira*, y *R. parvula*). Las familias más ricas son Phyllostomidae (13 géneros y 22 especies) y Vespertilionidae (5 géneros y 8 especies). Finalmente presentamos una categorización de conservación basada en una curva de valores de abundancia local.

Palabras clave: Bosque tropical caducifolio, bosque seco espinoso, conservación, especies endémicas, mamíferos.

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The known bat fauna in Mexico is species-rich, comprising eight families, 17 genera, and 146 species representing approximately 10.42% of known global bat diversity (Marín-Ventura *et al.* 2025; Simmons and Cirranello 2026). Bat richness in the State of Michoacán accounts for roughly 53% of the total species in Mexico, with at least 77 species, 41 genera, and seven families recorded: Emballonuridae (four species), Noctilionidae (one species), Mormoopidae (four species), Phyllostomidae (29 species), Natalidae (one species), Molossidae (12 species), and Vespertilionidae (26 species) (Monterrubio-Rico *et al.* 2025a, b).

Nevertheless, species richness and diversity are not uniformly distributed across Michoacán State, due to physiological and climatic heterogeneity that drives marked differences among physiographic provinces (Antaramián and Correa 2003). Species exhibit ecological distribution patterns closely tied to temperature, precipitation, and vegetation type, with higher species richness concentrated

in areas dominated by tropical affinity vegetation. Based on 3,236 records of 71 species across 259 localities in Michoacán, a correspondence analysis highlighted these distributional patterns (Wang *et al.* 2003). More recently, records from multiple sources were re-examined across the five physiographic provinces recognized for the state based on landform-geoform and relief criteria: the Trans-Mexican Volcanic Belt, Sierra Madre del Sur, Balsas-Tepalcatepec Depression, Central Plateau, and Coastal Plain (Antaramián and Correa 2003).

The Trans-Mexican Volcanic Belt province, a geographical region neighboring the tropical zone of the ZIBR, presents the highest bat species richness (49 species) in the state, including six endemics and four endangered species, which is partially explained by the proportionately larger extent and higher historical research effort (Polaco and Muñiz-Martinez 1987; Monterrubio-Rico *et al.* 2025b).

The region where this study was conducted, the Balsas-Tepalcatepec Depression (locally known as the *Tierra Caliente*, Michoacán), is dominated by tropical dry forests and tropical scrubland and harbors an estimated 43 bat species, considering that the region has historically received limited sampling effort (Monterrubio-Rico *et al.* 2025a), and presents severe climatic constraints associated with extremely high temperatures and low precipitation (Wang *et al.* 2003).

Bat communities in seasonally dry tropical forests are notable for their high species richness and variation tied to climatic seasonality, particularly during the rainy season when increased plant resources benefit nectarivorous, frugivorous, and insectivorous bats. These communities are dynamic, reorganizing during the dry season as bat assemblages optimize food resource partitioning (Medellín 1993; Ceballos *et al.* 2010). In tropical dry forests of Veracruz, Moreno and Halffter (2001) documented a species richness of 20 species belonging to only two families: Phyllostomidae (16 species) and Mormoopidae (four species).

Through past collections and field surveys conducted across localities within the ZIBR, the documented bat richness includes functional groups that provide key ecosystem services. Insectivorous bats such as *Pteronotus mexicanus* and *P. fulvus*, along with other mormoopid, vespertilionid, and molossid species, play a well-recognized role in controlling agricultural pests (Álvarez 1968; Segura-Trujillo e Iñiguez-Davalos 2023). Additional ecosystem services include nocturnal pollination performed by *Leptonycteris yerbabuenae*, *Musonycteris harrisoni*, and *Choeronycteris mexicana,* all previously recorded in this *Tierra Caliente* region. Other species function as efficient seed dispersers (*Artibeus jamaicensis*, *A. lituratus*, and *Sturnira hondurensis*) and facilitate plant cross-pollination, thereby supporting local economies dependent on tequila, mezcal, and pulque production (Núñez 2005; Ceballos *et al.* 2010). Despite recent updates on the regional distribution of bat species (Monterrubio-Rico *et al.* 2025a, b), there is a critical need to intensify sampling efforts across this province due to historically low research coverage, particularly in the eastern Balsas Basin and the central Sierra Madre del Sur.

The ZIBR was established to emphasize the conservation of tropical dry forest biodiversity, its evolutionary processes, and associated sociocultural elements. (CONANP 2014).

Seasonally dry tropical forests are currently recognized for harboring high biodiversity of flora and fauna. However, despite environmental and protection policies, they remain among the most fragmented, deteriorating, and vulnerable ecosystems in Mexico (Ceballos *et al.* 2010).

Our study aimed to provide an updated taxonomic inventory of bats in the ZIBR; we evaluated species richness and alpha (α) and beta (β) diversity considering two timeframes: historical and contemporary and identify local priority for conservation using abundance range curve of the values obtained for relative abundance.

Materials and methods

Study area. The ZIBR encompasses a perimeter bounded by coordinates 101°29′21″–102°14′12″ W and 18°11′43″–19°01′00″ N (Figure 1). It comprises four core areas totaling 22,699 ha, a buffer zone of 242,418 ha, and an influence zone covering 179,104 ha, encompassing a total area of 444,221 ha. The reserve spans parts of the municipalities of Arteaga, Churumuco, La Huacana, and Tumbiscatío within the Balsas Depression physiographic province, with an elevation range of 200–1,600 m. The ZIBR was officially established in the Official Journal of the Federation (Diario Oficial de la Federación) on November 30, 2007. (CONANP 2014).

The province forms part of a basin bounded by the Trans-Mexican Volcanic Belt and the Sierra Madre del Sur. The region is dominated by warm (Group A) and dry (Group B) climates, in areas with marked variations in precipitation and temperature (García 2004). Within the reserve, Aw climate types occur in La Huacana and Arteaga, whereas Bs climate types prevail in the drier zones of Churumuco. Temperatures are warm, with monthly averages exceeding 28°C, and lower values, ranging from 15 to 17°C, are recorded in the mountainous areas of Arteaga, Tumbiscatío, and La Huacana (CONANP 2014).

Seven vegetation types cover the reserve: pine forest, oak forest, pine-oak forest, semi-evergreen medium tropical forest, tropical dry forest (lowland deciduous forest), semi-deciduous lowland forest, thorny lowland forest, and palm grove. Human activities include rainfed and irrigated agriculture, livestock ranching, fishing, aquaculture, ecotourism services, and sport hunting (CONANP 2014; Steinmann 2021).

Species occurrence records. To compile the taxonomic inventory, we conducted field sampling and integrated a comprehensive occurrence database based on historical and contemporary records before this study. We compiled data from published literature, databases from the Comisión Nacional para Conocimiento y Uso de la Biodiversidad (CONABIO projects: P20, P130, T009 and A003) via its geoportal (CONABIO 2025), and research

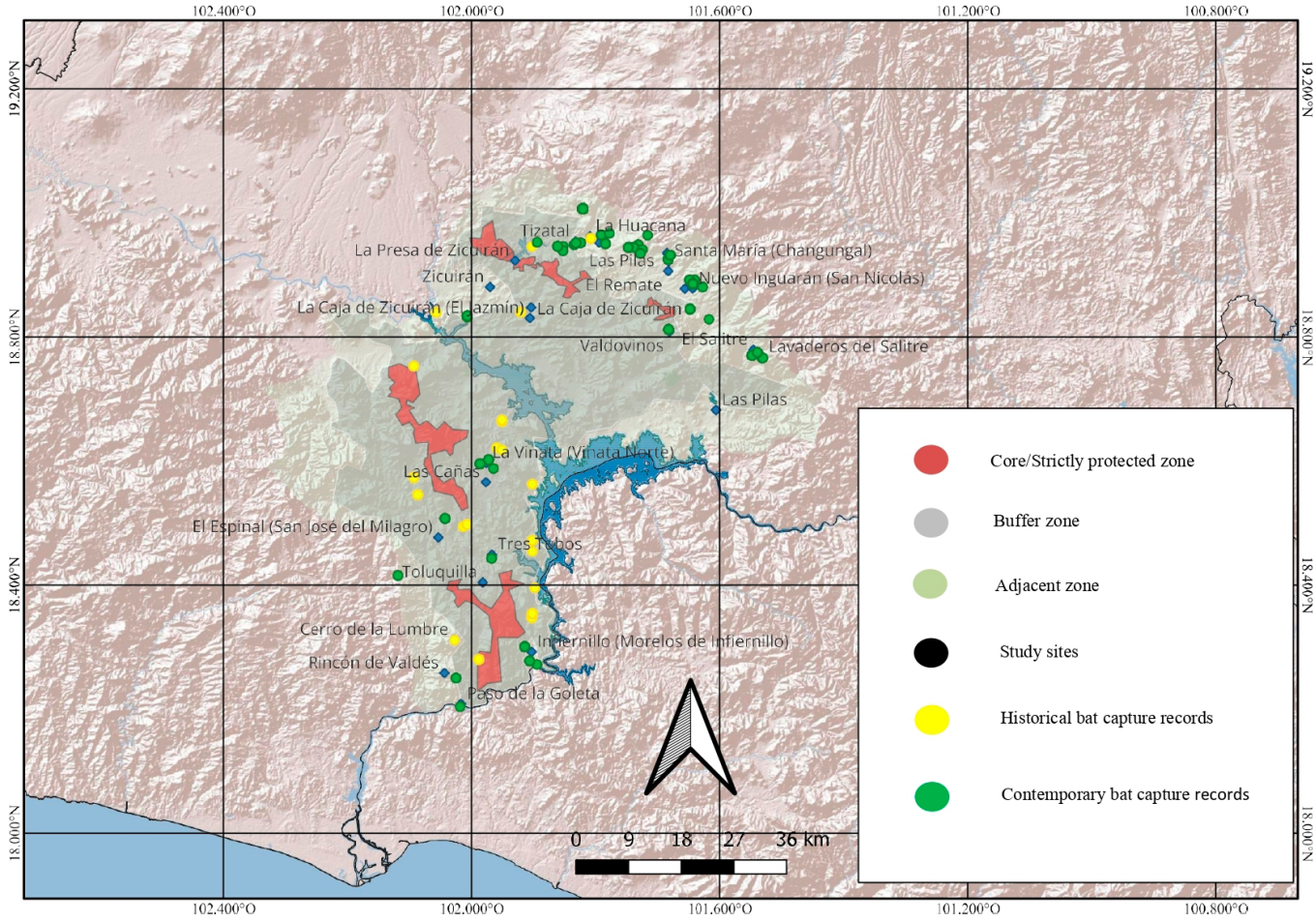

Figure. 1 Spatial distribution of bat occurrence records across the Zicuirán-Infiernillo Biosphere Reserve (ZIBR).

outputs, including academic theses. Furthermore, we reviewed historical literature, including Hall and Villa-Ramírez (1949, 1950), Álvarez and Aviña (1965), Álvarez (1968), LaVal (1973), Garrido (1980), Uribe-Peña *et al.* (1981), Sánchez-Hernández *et al.* (1985), Polaco and Muñiz-Martínez (1987), Enríquez (1996), Villalpando and Arroyo-Cabrales (1996), and Sánchez-Hernández *et al.* (1999). Contemporary occurrence data were gathered from Núñez (2005), Lorenzo *et al.* (2006), Castro-Vázquez (2012), Colín-Soto (2012), Flores-Hernández (2013), Suárez (2014), Monterrubio *et al.* (2014), and SEMARNAT-CONANP (2014). Notably, no published records were found for the period between 1987 and 2003. Although records were examined at the physiographic province level, only those located strictly within the spatial boundaries of the ZIBR were included in the analyses. Occurrence records were grouped and analyzed across two distinct time periods: historical (1962–1986) and contemporary (2004–2025).

Field sampling comprised monthly surveys conducted from May 2024 to September 2025 across an altitudinal gradient, prioritizing historical data gaps. Mapped sites spanned primary, secondary, and anthropogenic vegetation as well as aquatic habitats across both dry and rainy seasons. Site selection balanced habitat representation with physical accessibility, landholder permissions, and safety protocols. Each location was surveyed over three consecutive nights, accumulating an effective sampling effort of 51 nights.

For open-air surveys, eight mist nets (6 × 3 m) were operated nightly from 18:00 to 03:00 h, accompanied by systematic recording of individual morphometrics, geographic coordinates, elevation, vegetation type, and local land-use patterns. For enclosed roosts, mist nets were set across primary entrances and subterranean passages from 17:00 to 21:00 h to capture peak emergence activity of cave-dwelling colonies.

Bats were preliminarily identified in the field following Medellín *et al.* (2008). All individuals were released at the capture site, except for minor net-mortality triggered by physiological stress. Taxonomically complex specimens, specifically within *Glossophaga* and *Myotis*, were verified in consultation with co-author Joaquín Arroyo-Cabrales using key diagnostic traits (incisor arrangement, forearm length, pelage distribution, uropatagium and digital furring, calcar keel, and uropatagial margin morphology). Vouchered specimens were deposited at the Faculty of Biology (Universidad Michoacana), to support comparative osteological research on modern and paleontological reference in the Paleontology Laboratory.

Occurrence records were compiled into a master database referencing Wilson and Reeder (2005) and Ramírez-Pulido *et al.* (2014), as base taxonomic authorities, with updates incorporating taxonomic revisions published between 2016 and 2024. We accounted for revised geographic distributions and taxonomic changes, such as those established for the genera *Pteronotus* (Pavan and Marroig 2016), *Glossophaga* (Calahorra-Oliart *et al.* 2021), *Myotis* (Novaes *et al.* 2022), and the recognition of the genus *Neoeptesicus* split from *Eptesicus* (Cláudio *et al.* 2023).

Historical and contemporary occurrences were compiled into a centralized database capturing taxonomic hierarchy (order to species level, including synonyms), demography (sex, reproductive status, age), temporal metadata, sampling methods, and photographic vouchers. Spatial and ecological attributes included locality, municipality, elevation, roost or habitat type (e.g., subterranean vs. open sites), land cover, and source provenance. Finally, we acknowledge substantial limitations regarding sampling effort when comparing study periods. Consequently, we analyze T1 and T2 as independent observational windows rather than a controlled, long-term monitoring trial.

Systematics followed Marín-Ventura *et al.* (2025) and Monterrubio-Rico (2025b). Conservation status was designated according to Mexican official standards (PROY-NOM-059-SEMARNAT-2025) and IUCN Red List criteria (IUCN 2025).

Diversity analysis. In an initial stage, we evaluated the alpha (α) diversity of species during the historical (T1) and contemporary (T2) periods, based on observed species richness, both separately and combined. The non-parametric Chao 2 estimator was used to examine contemporary field records in order to assess the effectiveness of the sampling effort.

Beta diversity. To evaluate spatiotemporal variations in community composition despite differences in sampling effort that preclude strict mathematical comparisons. We assessed beta diversity (β) using Baselga's (2010, 2012, 2013) partition framework based on presence-absence matrices. This quantitative approach allowed us to compare compositional dissimilarity between open habitats (primary and secondary vegetation, habitat edges, water bodies, and anthropogenically disturbed areas) and closed habitats (caves and mines), incorporating both Jaccard and Sørensen (β_{sor}) dissimilarity metrics. By explicitly accounting for shared and unique species, total community dissimilarity was partitioned into two ecologically independent components: species turnover ($\beta_{turnover}$) and nestedness ($\beta_{nestedness}$).

Priority species for conservation. Based on the bat species list compiled for the ZIBR, we established four vulnerability categories derived from abundance, following the framework proposed by Rabinowitz (1981), Segura-Trujillo and Navarro-Pérez (2010), grounded in the conceptual rarity framework of Arita *et al.* (1990). Species were assigned to four distinct categories by intersecting geographic range size (widespread vs. restricted/endemic) with local relative abundance (high ≥1.1% vs. low < 1.1%). Categories were defined as follows: *restricted distribution and high local abundance* (species with narrow geographic ranges or endemic status in Mexico/Mesoamerica that exhibit high local population densities); *widespread distribution and high local abundance* (generalists and dominant distributed broadly across the Neotropics with high local abundance); *restricted distribution and low local abundance* (doubly rare taxa exhibiting narrow geographic distributions and low local densities, representing the highest priority for in situ conservation), and *widespread distribution and low local abundance* (taxa with a broad continental distribution but low local frequency, predominantly reflecting an apparent rarity resulting from sampling or a transient condition). Species geographic categories were assigned following the macroecological framework and range-size criteria established by Arita *et al.* (1990).

Results

Species richness. We examined a total of n=1,123 (n=229 historical and n=894 contemporary) occurrence records corresponding to six families, 25 genera, and 41 species, thereby updating the taxonomic checklist of bats in the ZIBR (Supplementary data SD1).

Historical records. Comprised 229 bat records in six families, 17 genera, and 26 species. The species with the highest number of records were *Balantiopteryx plicata* (12.2%, n = 28 records), followed by *Rhogeessa mira* (10.04%, n = 23), *Glossophaga morenoi* and *Artibeus hirsutus* (9.6%, n = 22 each), and *Macrotus waterhousii* (7.4%, n = 17), with all remaining species accounting for less than 6% of records each. The oldest documented specimen is an individual of *Pteronotus fulvus*, collected on February 17, 1962, in the municipality of Arteaga. The most recent record in the historical period was dated August 22, 1986, representing a specimen of *Rhogeessa mira* from the municipality of La Huacana.

Contemporary records. In total, 894 records were captured, representing six families, 24 genera, and 37 species. The most frequently recorded species were *Leptonycteris yerbabuenae* (16.3%, n = 146 records), *Pteronotus mexicanus* (13.8%, n = 124), *P. fulvus* (10.4%, n = 93), *Mormoops megalophylla* (9.62%, n = 86), *Macrotus waterhousii* (7.0%, n = 63), and *Balantiopteryx plicata* (6.4%, n = 58), with all remaining species each accounting for less than 6% of captures. Within this group, the earliest record was a specimen of *Glossophaga mutica* collected on December 3, 2004, and last record was an individual of *Pteronotus fulvus* captured on July 25, 2025, in the municipality of La Huacana.

Five of these species (12% of total richness) are listed under Mexican environmental legislation (PROY-NOM-059-SEMARNAT-2025): Endangered (*Musonycteris harrisoni*); Threatened (*Choeronycteris mexicana*, *Leptonycteris nivalis*, and *L. yerbabuenae*); and under Special Protection *Rhogeessa mira*. And nine endemic species (*Pteronotus mexicanus*, *Glossophaga morenoi, Artibeus hirsutus, Chiroderma*

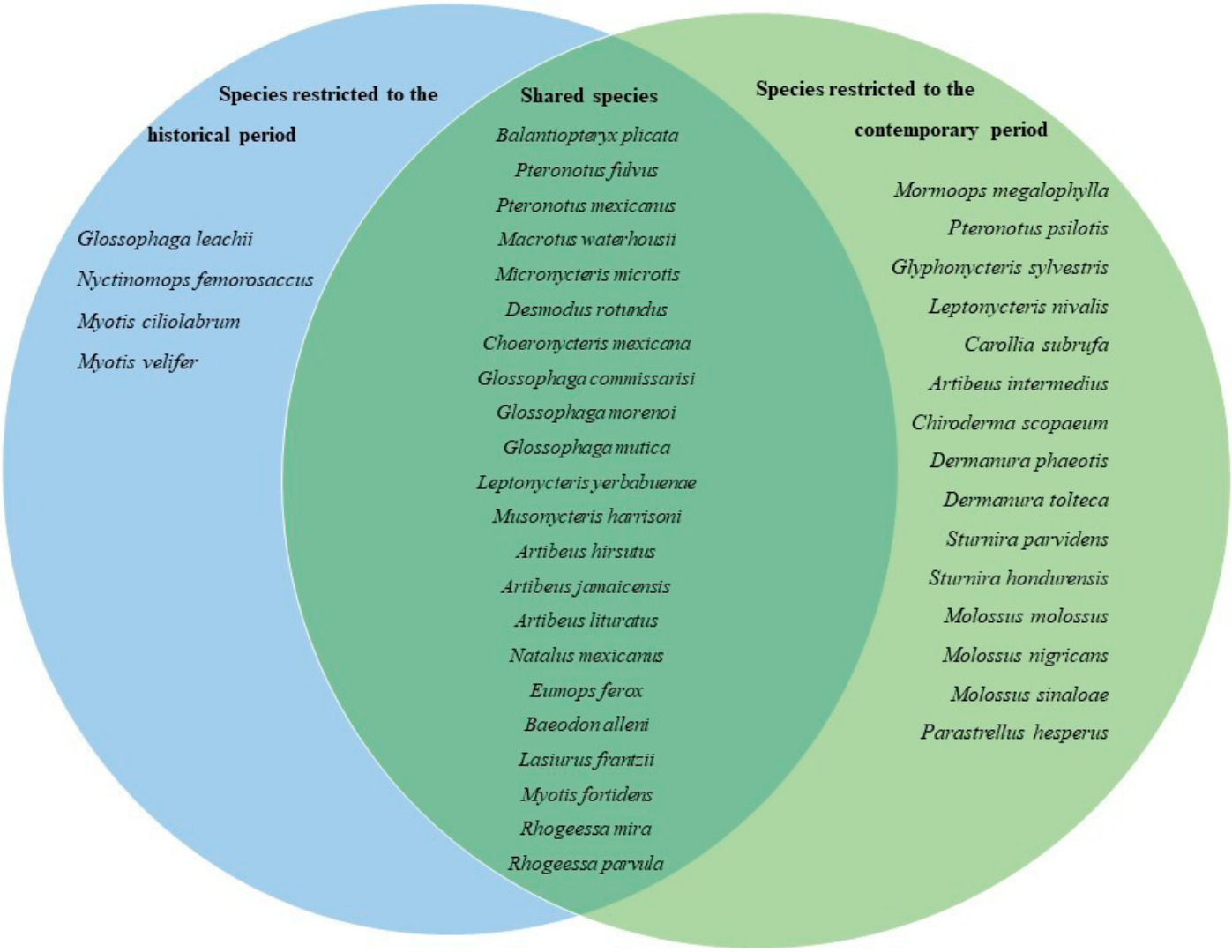

Figure. 2 Temporal partitioning of bat species composition in the ZIBR. Venn diagram illustrating unique and shared species richness between historical collections and contemporary systematic surveys across the Zicuirán-Infiernillo Biosphere Reserve.

scopaeum, Molossus sinaloae, Baeodon alleni, Myotis fortidens, Rhogeessa mira, and *R. parvula*), representing 22% of total richness.

Diversity analysis. The Chao2 estimator yielded an expected theoretical species richness of SChao2= 30.15 (~ 30 species), for the historical period, achieving 86.2% sample completeness, whereas the contemporary period reached SChao2 = 39.25 (~ 40 species) with 94.3% completeness. Bat assemblage composition varied substantially between sampling periods (Figure 2).

Beta (β) diversity. Temporal analysis between study periods, using the diversity partitioning method proposed by Baselga, revealed high species persistence relative to the historical community (βsor = 0.302; 84.6%; a = 22, b = 4). This temporal change showed nearly equal contributions from species turnover (βsim = 0.154; 51%) and differences in species richness (βness = 0.148; 49%). However, the dynamics varied notably by habitat type: while temporal changes in open habitats were primarily driven by turnover (67%), subterranean refuges (caves and mines) exhibited complete temporal dissimilarity (βsor = 1.0000)—a finding that may suggest that cave-dwelling bats were not exhaustively recorded during the historical period. Consequently, the high contemporary spatial dissimilarity (β = 0.8049) confirms that subterranean refuges serve as critical shelters and represent a specialized subset of the regional species pool within the ZIBR (Table 1).

Proposed local conservation categories and categorical vulnerability assessment, based on contemporary local abundance and grounded in the conceptual rarity framework of Arita *et al.* (1990): *Restricted distribution and high local abundance:* Represented by S = 5 species, accounting for 13.51% of species richness and 57.61% of cumulative abundance. *Widespread distribution and high local abundance:* comprising S = 8 species (21.62% of species richness; 30.61% of cumulative abundance). *Restricted distribution and low local abundance:* encompassing S = 8 species (21.62% of species richness; 4.35% of cumulative abundance). And *widespread distribution and low local abundance:* constituting S = 16 species, representing 43.24% of species richness and 7.42% of cumulative abundance. (Table 2).

Table 1. Decomposition of bat β-diversity across the Zicuirán-Infiernillo Biosphere Reserve. Beta diversity partitioning using Jaccard (β jac), and Sørensen (β sor), dissimilarity families across three analytical level, detailing the additive contribution of species replacement (βturn) and nestedness resultant dissimilarity (βnes).

Comparison order	Comparison	Shared species (a)	Uniques species T1 (b)	Uniques species T2 (c)	Richness T1	Richness T2	Jaccard (β jac)	Sørensen (β sor)	Turnover (β sim)	Nestedness (β nes)
Temporal by habitat	Open H vs Open C	20	6	15	26	35	0.5122	0.3443	0.2308	0.1135
	Mines-caves H vs. Mines-caves C	0	0	6	0	6	1.0000	1.0000	0.0000	1.0000
Spatial by period	Open H vs Mines-caves H	0	26	0	26	0	1.0000	1.0000	0.0000	1.0000
	Open C vs Mines-caves C	4	31	2	35	6	0.8919	0.8049	0.3333	0.4715
Global chance	Total H - Total C	**22**	**4**	**15**	**26**	**37**	**0.4634**	**0.3016**	**0.1538**	**0.1478**

Analytical symbology and parameters: T1, historical sampling period; T2, contemporary sampling period; Open H, historical sampling in open habitats; Open C, contemporary sampling in open habitats; Mines H, historical sampling in subterranean mine-caves roosts; Mines C, contemporary sampling in subterranean mine-caves roosts. Baselga's dissimilarity parameters: a, species shared between periods; b, species exclusive to the historical period (T1); c, species exclusive to the contemporary period (T2).

Table 2. Proposed local conservation categories for species occurring in the Zicuirán-Infiernillo Biosphere Reserve (ZIBR),
The geographic distribution categories assigned to the bat species in the following table were classified according to the macroecological criteria and geographic range standards defined by Arita *et al.* (1990).

Proposed categories	Species	Abundance of local relatives
Restricted distribution and high local abundance	*Leptonycteris yerbabuenae*	16.33%
	Pteronotus mexicanus	13.87%
	Pteronotus fulvus	10.40%
	Mormoops megalophylla	9.62%
	Glossophaga mutica	6.04%
Widespread distribution and high local abundance	*Macrotus waterhousii*	7.04%
	Balantiopteryx plicata	6.48%
	Artibeus jamaicensis	6.48%
	Glossophaga commissarisi	2.79%
	Artibeus intermedius	2.12%
	Desmodus rotundus	1.90%
	Dermanura tolteca	1.56%
	Carollia subrufa	2.01%
Restricted distribution and low local abundance (Critical rarity)	*Glossophaga morenoi*	0.89%
	Leptonycteris nivalis	0.78%
	Musonycteris harrisoni	0.67%
	Rhogeessa mira	0.55%
	Micronycteris microtis	0.44%
	Artibeus hirsutus	0.33%
	Glyphonycteris sylvestris	0.33%
	Baeodon alleni	0.44%
Widespread distribution and low local abundance	*Natalus mexicanus*	1.34%
	Artibeus lituratus	0.78%
	Dermanura phaeotis	0.78%
	Sturnira parvidens	0.78%
	Molossus sinaloae	0.78%
	Molossus molossus	0.78%
	Sturnira hondurensis	0.78%
	Chiroderma scopaeum	0.55%
	Parastrellus hesperus	0.55%
	Rhogeessa parvula	0.44%
	Eumops ferox	0.22%
	Molossus nigricans	0.22%
	Choeronycteris mexicana	0.44%
	Lasiurus frantzii	0.11%
	Myotis fortidens	0.11%
	Pteronotus psilotis	0.11%

Discussion

The bat species richness observed in our study aligns with values reported across other tropical biosphere reserves in México, accounting for 53% of Michoacán state-level richness. For comparison, species richness across similar Mexican reserves ranges from 25 to 45 species, including Chamela-Cuixmala (40–45 species), Tehuacán-Cuicatlán (30–40), Sierra de Huautla (30–38), Cañón del Sumidero (35), and Ría Lagartos/Yum Balam (25–35) (Rojas-Martínez and Valiente-Banuet 1996; Stoner 2005; Sélem-Salas *et al.* 2012; Arroyo-Chacón *et al.* 2013; Orozco-Lugo *et al.* 2014).

Evaluating bat species richness in the ZIBR across historical (1962–1986, pre-designation) and contemporary (2004–2025) periods establishes a crucial baseline to contextualize long-term community dynamics.

The Chao 2 estimate refers to bat assemblage composition varied substantially between study periods (Figure 2), featuring four historically exclusive species (*Glossophaga leachii*, *Nyctinomops femorosaccus*, *Myotis ciliolabrum*, and *Myotis velifer*) and 15 contemporaneously exclusive species

(*Mormoops megalophylla*, *Pteronotus psilotis*, *Leptonycteris nivalis*, *Carollia subrufa*, *Glyphonycteris sylvestris*, *Artibeus intermedius*, *Chiroderma scopaeum*, *Dermanura phaeotis*, *Dermanura tolteca*, *Sturnira hondurensis*, *Sturnira parvidens*, *Molossus molossus*, *Molossus nigricans*, *Molossus sinaloae*, and *Parastrellus hesperus*). Overall, we assume that the contemporary assemblage maintains the historical structural baseline while registering new taxa through the geographical expansion of the survey effort, ultimately updating and complementing the bat reserve inventory. Historical species not detected during the contemporary period may reflect differences in detectability and spatial coverage between sampling intervals, or the need for complementary acoustic monitoring methodologies to ensure their detection.

Differences in observed species richness and total records between periods (Sobs= 26, n=229 in T1 vs. Sobs=37, n=894 in T2), primarily reflect discrepancies in sampling effort and detectability during the contemporary period, as evidenced by equivalent accumulation trajectories in interpolation and rarefaction analyses. Ultimately, both periods represent temporal complementarity, demonstrating that while estimated richness and bat assemblage composition dynamically shift over time, core diversity persists within the ZIBR.

Baselga's beta-diversity partitioning framework revealed that the spatiotemporal dynamics of the ZIBR bat community are likely driven by non-mutually exclusive processes. These include habitat-dependent responses to environmental fluctuations, seasonal resource availability, ongoing land-use changes, and potentially, variations in sampling design. Within our dataset, temporal changes in open habitats were predominantly driven by species replacement (67.0% turnover). Conversely, subterranean roosts (mines) exhibited complete temporal nestedness (βsor = 1.0). This latter pattern suggests a previously undocumented historical occupancy, as current sampling confirmed the presence of five strictly cave-dwelling species: *Balantiopteryx plicata*, *Mormoops megalophylla*, *Pteronotus fulvus*, *P. mexicanus*, and *Leptonycteris yerbabuenae*. Because subterranean roosts (caves and mines) lacked historical baselines and were assessed exclusively during this study, implementing long-term monitoring for these cave-dwelling bats remains critical.

Local conservation categories and categorical vulnerability assessment Arita *et al.* (1990). *High local abundance and restricted distribution:* it is dominated by cave-dependent (*Pteronotus* spp., *Mormoops megalophylla*) and migratory nectarivorous species (*Leptonycteris yerbabuenae* and *L. nivalis*). Despite their high local densities, these populations exhibit acute regional vulnerability due to an extreme reliance on specialized roost microhabitats (hot caves), where the disruption of a single key roost could trigger severe population collapses. *Low local abundance and restricted range:* represents the highest in situ conservation priority due to "critical rarity." Featuring narrow geographic ranges and endemic taxa (*Musonycteris harrisoni*, *Rhogeessa mira*, *Artibeus hirsutus*), heightening their susceptibility to extirpation from habitat fragmentation. *Low local abundance and widespread distribution:* low capture rates among widespread taxa stem from mist-netting biases that underrepresent high-canopy fliers (e.g., Molossidae) and transient species. And *high local abundance and widespread distribution:* constitutes the functionally resilient core of the community (e.g., *Artibeus jamaicensis*, *Macrotus waterhousii*), sustaining key ecosystem services such as seed dispersal and insect control amid anthropogenic disturbances.

Caves roosts in the ZIBR lack severe internal disturbance aside from active guano extraction despite widespread surrounding agriculture, grazing, and mining. Although livestock host availability is high, *Desmodus rotundus* exhibited a low relative abundance (0.0190), consistent with its restricted classification by Segura-Trujillo and Navarro-Pérez (2010). This low density may reflect municipal rabies control campaigns, highlighting the need for collaborative Secretaría de Agricultura y Desarrollo Rural (SADER).

An additional case is the micro-endemic Michoacán yellow bat (*Rhogeessa mira*), whose populations remain poorly understood; available knowledge is largely limited to the foundational works of Arroyo-Cabrales and Polaco (1997) and Suárez (2014). In this context, the ZIBR serves as a critical geographic sanctuary for its conservation.

Conclusions

The ZIBR functions as a vital ecological corridor linking distinct physiographic regions across Michoacán, supporting evolutionary, reproductive, and migratory processes as well as critical ecosystem services. Within the reserve, we identified key roosting sites harboring large colonies of reproductive male *Leptonycteris yerbabuenae*, as well as major assemblages of cave-dwelling species including *Balantiopteryx plicata*, *Pteronotus mexicanus*, *P. fulvus*, *Mormoops megalophylla*, *L. yerbabuenae*, and *Natalus mexicanus*.

The ZIBR is a geographic area of paramount conservation importance within the tropics of Michoacán and Mexico. Despite exhibiting moderate to high similarity between study periods, the reserve has accommodated new taxa across diverse habitats. These incoming species utilize food resources, roosts, maternity sites, and migratory pathways during contemporary times, enriching the overall assemblage while preserving its historical evolutionary integrity. Over time, the reserve has facilitated a positive restructuring of the bat community, where environmental heterogeneity across primary, secondary, and human-modified spaces provides a suite of vital resources that foster species coexistence across the region.

Securing regional bat conservation across the ZIBR's vast territory hinges on engaging local stakeholders via environmental education, participatory monitoring, and community-based stewardship.

However, the region exhibits a high proportion of endemism, hosting nine bat species to Mexico most notably *R. mira*, a microendemic species restricted to the Zicuirán region. The ZIBR harbors the Michoacán yellow bat (*Rhogeessa mira*), a microendemic strictly confined to the *Tierra Caliente* region. Where the reserve provides the essential environmental conditions that sustain its spatial distribution, population persistence, and evolutionary lineage.

A critical conservation case is the endemic Balsas yellow bat (*Rhogeessa mira*), for which we propose up-listing under Mexican legislation (PROY-NOM-059-SEMARNAT-2025) from Subject to Special Protection (SSP) to Endangered (E). This recategorization is justified by its restricted microgeographic distribution (6,732 km2 extent of occurrence across Arteaga and La Huacana), occurrence at only five recorded localities (four historical, one contemporary), and a global sample size of just 27 records. Currently listed as vulnerable by the IUCN due to habitat degradation from land-use change, dam construction, and altered flow regimes, *R. mira* depends heavily on the ZIBR, where 87% of the territory provides suitable habitat (Suárez 2014; Arroyo-Cabrales and Ospina-Garcés 2016) essential for its long-term persistence.

Acknowledgments

We thank the SECIHTI for scholarship support (Grant No. 299005) and the Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) for issuing the scientific collection permit (SPARN/DGVS/04724/24). We extend our sincere gratitude to M.Sc. Margarito Álvarez Jara for his insightful comments and technical advice regarding GIS analyses. To Dr. Alan Malagón Pacheco for his contributions to the translation and review of the document. We thank Dr. Hugo Zepeda Castro, Director of the Zicuirán-Infiernillo Biosphere Reserve, for facilitating field logistics and research permits. We also acknowledge the UIIM social service team (Ana Luisa Valdez, Rafael Goche, and Guillermo Camacho). Special thanks go to our local guides and friends who opened their homes and shared their meals with us, as well as to all community members who assisted during visits to their ejidos and local communities. Finally, we dedicate this work to the memory of Abel Rodríguez Renteria† our dear and esteemed friend, who welcomed us into his home in Ejido Ichamio, and to Wendy Pacheco Malagón†, a big hug wherever you are.

Declaration of Artificial Intelligence use

The author declare that the free IA tool Gemini was used to assist with translation, style suggestions, textual clarity and the review of Englis grammar and syntax, both in the preliminary versions.

Author contributions

Iván Díaz Pacheco: conceptualization, coordination of experimental design, fieldwork planning, collection of biological samples and data, structuring, analysis and interpretation of results, and writing of original draft and subsequent manuscript revisions. Joaquín Arroyo-Cabrales: Conceptualization, field study coordination and design, supervision of species identification, and critical revision of manuscript drafts at all stages. Tiberio César Monterrubio-Rico: conceptualization, experimental design and coordination of field study, provision of sampling materials, database review, oversight of quantitative estimators, and critical revision of Spanish and English manuscript drafts. Felipe León Silva: field logistics planning and coordination, assistance with biological sampling and mammalogical data collection, community engagement and liaison with local authorities, leaders, and decision-makers within the ZIBR. María Luisa Herrera Arroyo: doctoral academic supervision, institutional mentorship and conceptualization.

Supplementary data

SD1. Taxonomic richness, population density, conservation status, and regional endemism of the bat assemblage in the ZIBR.

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Associated editor: Luis F. Aguirre
Submitted: August 26, 2026; Reviewed: September 21, 2026
Accepted: October 26, 2026; Published online: November 24, 2026