Colegio de Postgraduados

Diversity of terrestrial mammals visiting artificial water sources at the Technological University of Calakmul, Campeche, México

Hernández-López, Edwin[1]; Samaniego Canul, Jesús Adair[1]; López-Castilla, Héctor M. J.[1,2*]; Méndez-Saint Martín, Gabriela[1]; Contreras-Moreno, Fernando M.[1,3]

[1] Universidad Tecnológica de Calakmul, Xpujil, Calakmul, Campeche, México, C. P. 24640.
[2] Tecnológico Nacional de México campus Instituto Tecnológico de Chiná, Calle 11 s/n entre 22 y 28 C.P. 24520, Chiná, Campeche, México.
[3] World Wildlife Fund Inc.-México, Xpujil, Calakmul, Campeche, México, C. P. 24640.
* Correspondence: castilla-9@outlook.com

ABSTRACT

Objective: To evaluate the diversity of terrestrial mammals visiting artificial drinking troughs in the conservation zone of the Technological University of Calakmul, as well as their conservation status, activity patterns and behavior at these sites.

Methodology: Four artificial water sources were installed in strategic locations, each equipped with a camera trap station to record the species using the water sources and document their behavior in five categories: passing through, feeding, foraging, hydration, and temperature regulation. The data were analyzed using accumulation curves and ecological interaction networks.

Results: Twelve species were recorded, highlighting the use of water as a fundamental resource, especially during dry periods. Among the observed species, the jaguar and puma stood out as key predators in the ecosystem.

Limitations: This study was limited to a small conservation area within UTC and would benefit from greater sampling coverage.

Conclusions: Artificial water sources are an effective strategy for maintaining the availability of water during critical periods and provide important interaction points for wildlife. The data obtained in this study suggest that university conservation areas are crucial for protecting biodiversity and the academic training of students.

Key words: conservation, activity patterns, monitoring

Citation: Hernández-López, E., Samaniego Canul, J. A., López-Castilla, H. M. J., Méndez-Saint, M. G., & Contreras-Moreno, F. M. (2025). Diversity of terrestrial mammals visiting artificial water sources at the Technological University of Calakmul, Campeche, México. *Agro Productividad*. https://doi.org/10.32854/4yc4ng40

Academic Editor: Jorge Cadena Iñiguez
Associate Editor: Dra. Lucero del Mar Ruiz Posadas
Guest Editor: Daniel Alejandro Cadena Zamudio

Received: November 06, 2024.
Accepted: March 29, 2025.
Published on-line: May XX, 2025.

Agro Productividad, 18(4). April. 2025. pp: 141-149.

INTRODUCTION

Green areas and peri-urban forests are essential for the sustainability of cities, due to the various environmental benefits they provide such as noise mitigation, air purification, water infiltration, soil erosion reduction, and helping regulate the microclimate (Al-paidze and Salukvadze, 2023). These areas are of utmost importance for biodiversity, as they offer habitats and resources for the subsistence of native species (Verdú-Vázquez *et al.*, 2021).

Universities have green areas that in most cases accurately represent the local biodiversity. These areas function as conservation sites that host a high diversity of wildlife and in recent years have gained increased relevance as they serve as ideal laboratories to study the effects of urbanization on biodiversity (MacGregor-Fors, 2005; Lin *et al.*, 2020). Authors such as Faggi and Perepelizin (2006) state that species richness is lower in urban areas than in suburban peripheries. Therefore, these spaces can be reservoirs of unexplored biodiversity in different institutions and their green areas or peri-urban ecosystems.

Water is essential for all living organisms and its availability can influence the spatial distribution of wildlife to varying degrees (Paredes *et al.*, 2017). Climate change has become a topic of great importance in research, encompassing predictable climate fluctuations, impacts and adaptive or resilience responses observed in diverse ecosystems and human communities in Calakmul (Revollo and Ríos, 2023).

The implementation of artificial water sources in strategic locations is a positive measure to mitigate human-wildlife conflicts and can serve as an accessible alternative for animals in need of hydration (Contreras-Moreno *et al.*, 2024a,b). These water sourcers play a crucial role in mitigating the effects of drought on wildlife.

In the Calakmul Region, water is a major concern during the dry season, and the implementation of artificial drinking stations for wildlife is a common management practice (Contreras-Moreno *et al.*, 2024b). Therefore, these drinking stations may have a positive impact on the conservation of certain species; however, it is crucial to consider how their presence might influence the overall ecosystem and the diversity of species present (Hernández-Gómez *et al.*, 2020). Therefore, the objective of this study was to assess the diversity and conservation status of terrestrial mammals visiting the artificial drinking stations in two different vegetation types within the forest area of the Universidad Tecnológica de Calakmul (UTC).

Since the green areas of UTC are adjacent to the Voluntarily Designated Conservation Area (Área Destinada Voluntariamente a la Conservación, ADVC) Xpujil, and, in turn, to the central zone of the Calakmul Biosphere Reserve, it is expected that the mammals visiting the UTC drinking stations will be medium to large-sized species, some of which may be classified as environmentally threatened according to Mexican environmental regulations.

MATERIALS AND METHODS

Study Area

The study was conducted within the conservation zone of the Universidad Tecnológica de Calakmul (18° 31' 36.96" N, 89° 23' 59.57" W), located in the town of Xpujil, in the municipality of Calakmul, Campeche (Figure 1). The area is situated near the Calakmul Biosphere Reserve (REBICA) and the Voluntarily Designated Conservation Area (ADVC) Xpujil, which together cover over 20,000 km^2 (Reyna-Hurtado *et al.*, 2019). It includes 20 hectares of seasonally flooded lowland semi-evergreen forest and semi-deciduous medium-height forest. The area is located at an elevation of 242 meters above sea level, with an average annual temperature of 26 to 27 °C (INEGI, 2024).

Installation of Drinking Stations

Four artificial waters troughs made of black plastic (Rotoplas® brand), each with a capacity of 300 liters, were installed (Contreras-Moreno *et al.*, 2024a). These stations were distributed along the access road to the institution's forest conservation area, maintaining a minimum distance of 350 meters between each station. Their purpose was to provide water for the wildlife inhabiting the surrounding forest areas (Figure 1).

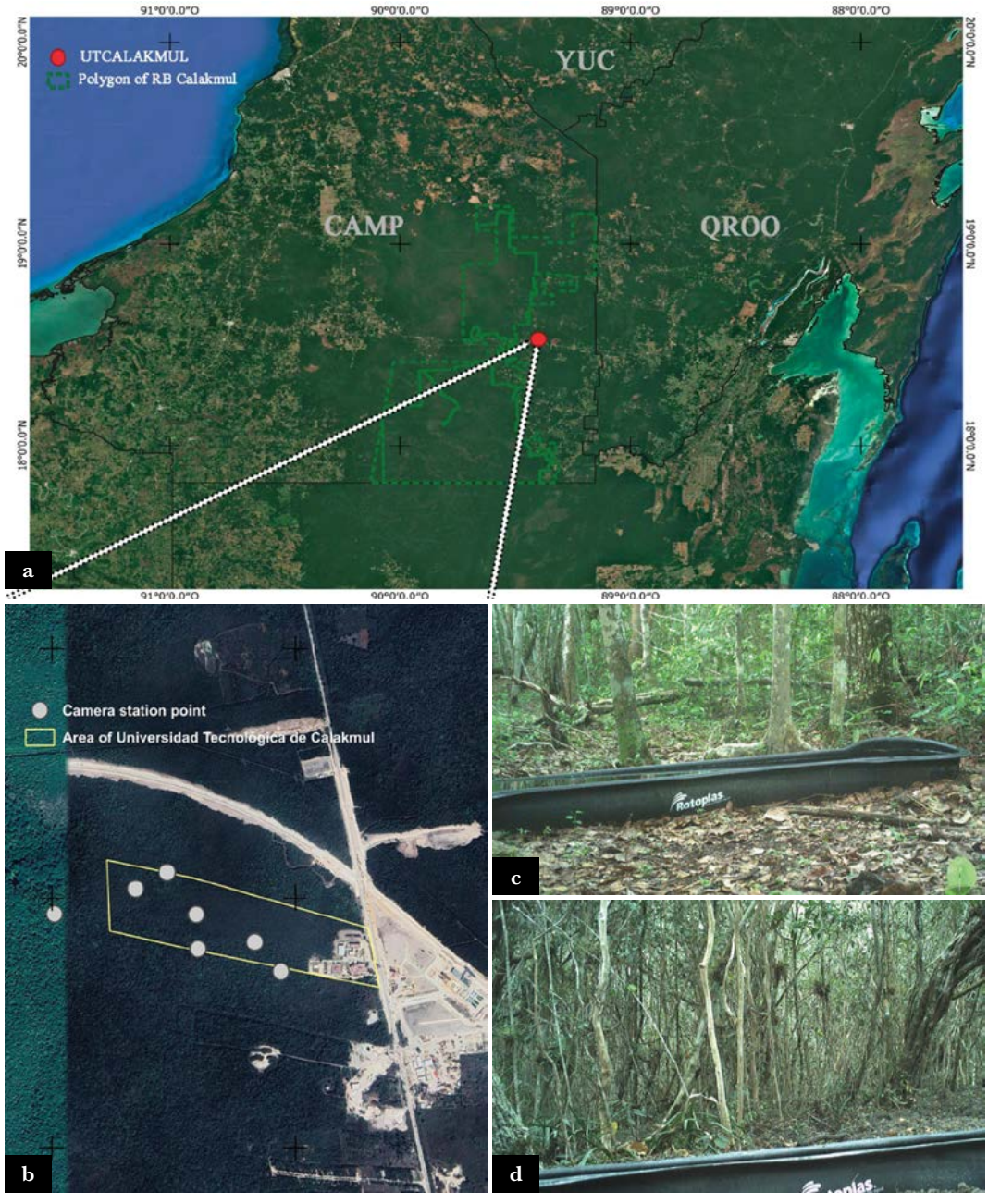

Figure 1. Geographical location. a) Location of the Technological University of Calakmul on the Yucatan Peninsula, b) polygon of the university and sampling sites, c) artificial water trough in medium sub evergreen forest, d) artificial water trough in seasonally flooded lowland forest.

Statistical analysis

To assess sampling completeness, accumulation and extrapolation curves were generated using the iNEXT software in its different orders (Chao *et al.*, 2016). To determine the reasons for visiting the drinking troughs by terrestrial mammals, ecological interaction networks were performed in the Rstudio software using the Bipartite interface (Dormann *et al.*, 2008). Mammal activities were categorized based on photographic evidence into five behavioral types: passing, feeding, foraging, hydration, and temperature regulation. Similarly, to identify the abundance of mammal species and their presence across camera trap stations and vegetation types, chord diagrams were creating using OriginPro software (OriginPro, 2023). Finally, to determine the conservation status of the recorded species, the Mexican Official Standard NOM-059-SEMARNAT-2010 (SEMARNAT, 2010) and the IUCN Red List of Threatened Species (IUCN, 2022) were consulted, and a systematized list was generated.

RESULTS AND DISCUSSION

With a sampling effort of 155 nights/trap, 12 species of medium and large terrestrial mammals were identified, representing six orders and nine families. The most diverse family was Felidae, with three species: jaguar (*Panthera onca* Linnaeus), puma (*Puma concolor* Linnaeus), and ocelot (*Leopardus pardalis* Linnaeus). In contrast, Myrmecophagidae and Sciuridae were the least diverse, each represented by a single species. The species with the highest number of records was the gray fox (*Urocyon cinereoargenteus* Schreber) (n=156), followed by the sereque (*Dasyprocta punctata* Gray) (n=24). In contrast, the species with the fewest records were the Yucatan squirrel (*Sciurus yucatanensis* J. A. Allen) (n=1) and the anteater (*Tamandua mexicana* Saussure) (n=1) (Figure 2a). The vegetation type with the greatest mammal diversity was seasonally flooded lowland forest, with a total of 13 species, compared to the semi-evergreen medium-height forest, where only four species were recorded (Figure 2b).

The results of this study confirms that artificial water troughs is a functional alternative to ensure water availability for wildlife in the Calakmul region (Contreras-Moreno *et al.*, 2024a). Although the sampling effort was significantly lower than that of Contreras-Moreno *et al.* (2024a, b), the detection of ecologically important and elusive species, such as jaguar and puma, suggests that the UTC conservation area maintains exceptional conditions with a high degree of conservation. The presence of three of the region's large felids —puma, jaguar, and ocelot— underscores the conservation value of the area and the urgent need to ensure its continued protection.

The species accumulation and extrapolation curve show asymptotes for the forest conservation area, with the lowland flooded forest exhibiting a higher sampling effort, while the medium sub-evergreen forest does not reach its asymptote (Figure 3a and b). The species interaction networks and their activity at the artificial watering troughs reveal that a total of 11 species visit the troughs in a passing manner, followed by seven species classified under the hydration category, with the gray fox being the species with the highest number of visits (Figure 3c).

Figure 2. String diagrams. a) abundance of individuals in the different camera trap stations, b) abundance in vegetation types.

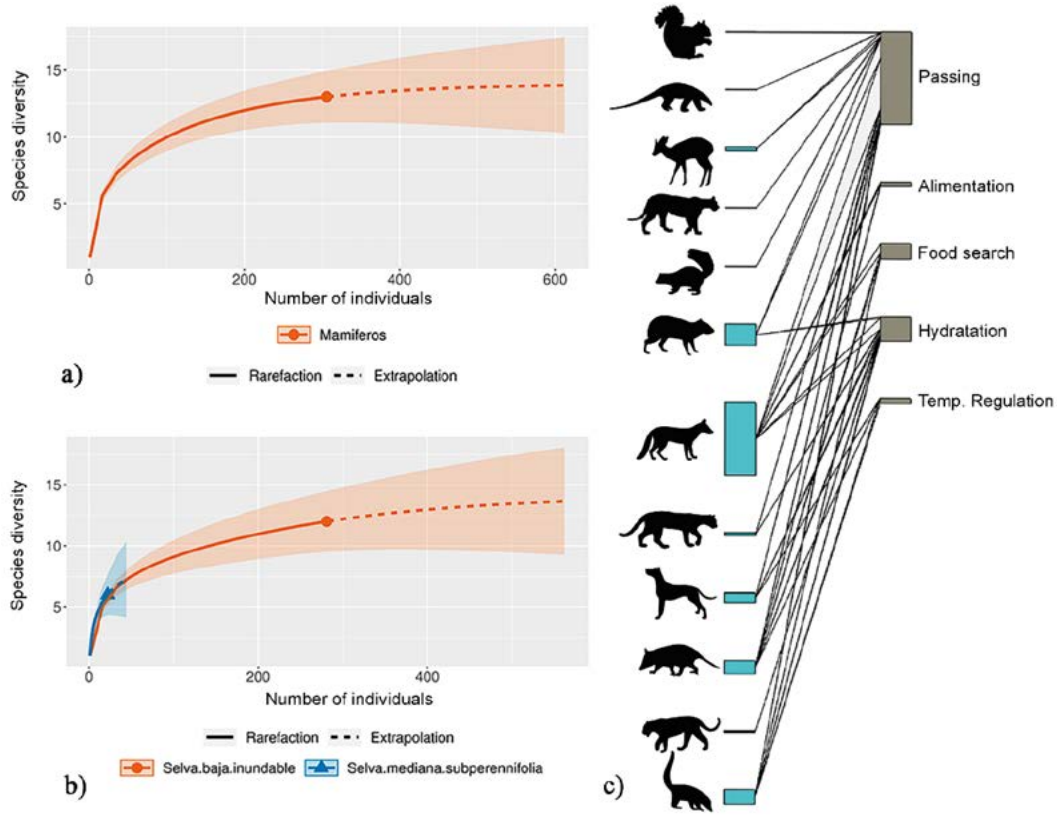

Figure 3. Accumulation curves and interaction networks. a) Species accumulation curve for the study site, b) species accumulation curve for the two vegetation types, and c) ecological interaction network of species and their visitation activity at the watering holes.

The presence of seven species from the carnivore group detected in this study highlights a spatial coexistence between these species. Coexistence among large predators has primarily been studied along three axes: feeding, space, and time (Ávila-Nájera *et al.*, 2016). The fact that these species coexist in the UTC conservation area suggests that the region likely maintains a sufficient availability of prey, which helps sustain the ecological balance. In this regard, it has been suggested that coexistence between top predator species is mediated by the selection of prey with different activity patterns (Hernández-Sánchez and Santos-Moreno, 2020).

Of the 12 species recorded, some are listed under different protection categories according to NOM-059-SEMARNAT-2010. In total, 33.33% of the species are considered at risk, including felines such as the ocelot and jaguar, which are classified as Endangered (Table 1; Figure 3).

Access to water is a matter of life and death for wildlife in the Maya Forest, as it has been observed that the lack of water can lead to dehydration and death in large animals such as jaguars, tapirs, and white-lipped peccaries (Gandiwa *et al.*, 2016). In this regard, the use of artificial drinking troughs serves as an alternative to ensure water availability during the dry season for predators and other species (Mandujano-Rodríguez and Hernández, 2019), thus helping to mitigate the issue of water scarcity.

Table 1. List of registered terrestrial mammal species. NOM-059-SEMARNAT-2010 categories: endangered (P), threatened (A), subject to special protection (SP). IUCN category: endangered (EN), vulnerable (VU), near threatened (NT), least concern (LC), not assessed (NA). Vegetation type: lowland flooded forest (LFF) and medium sub evergreen forest (MSEF).

Family	Specie	NOM-059	IUCN	LFF	MSEF
Canidae	*Canis familiaris*	—	—	22	—
	Urocyon cinereoargenteus	—	LC	146	9
Cervidae	*Mazama pandora*		VU	5	2
Dasyproctidae	*Dasyprocta punctata*	—	LC	45	—
Didelphidae	*Didelphis marsupialis*	—	LC	28	—
Felidae	*Leopardus pardalis*	A	NT	6	—
	Panthera onca	P	NT	3	—
	Puma concolor		LC	1	1
Mephitidae	*Spilogale angustifrons*	—	DD	2	—
Myrmecophagidae	*Tamandua mexicana*	—	LC	1	—
Procyonidae	*Nasua narica*	—	LC	30	1
Sciuridae	*Sciurus yucatanensis*	Pr	LC	1	—

Figure 4. Photographic record of species. a) *Didelphis marsupialis* Linnaeus, b) *Mazama pandora* Merrian, c) *Urocyon cinereoargenteus* calves, d) female and calf of *Urocyon cinereoargenteus* Schreber, e) *Dasyprocta punctata* Gray, f) *Nasua narica* Linnaeus, g) *Leopardus pardalis* Linnaeus, and h) *Panthera onca* Linnaeus.

The high diversity of species that continuously visit the troughs during the dry season in the Maya Forest underscores the effectiveness of the water supply strategy provided by artificial troughs in the UTC conservation zone. In addition to allowing individuals to access water, the troughs facilitate interactions among individuals from different populations, which could be considered a site for socialization (Contreras-Moreno *et al.*, 2024a).

Based on the results obtained, it is expected that there will be increased interest in conducting research at sites near urban areas, such as botanical or ethnobiological gardens, and green areas within educational institutions.

CONCLUSIONS

This study demonstrated that the UTC conservation area supports mammal species of high ecological value. Maintaining the habitat quality of this area could serve as a functional refuge for large mammals, especially if water is supplied through artificial drinking troughs during the dry season.

ACKNOWLEDMENTS

To World Wildlife Fund Inc. (WWF-Mexico) for their donation of water troughs, as part of the "Saving the jaguar: an ambassador for the Americas" initiative. To students and professors of Universidad Tecnológica de Calakmul who supported the installation of the water troughs. To Mario Garcia for helping in the revision of the translation of the manuscript.

REFERENCES

Alpaidze, L., & Salukvadze, J. (2023). Green in the city: estimating the ecosystem services provided by urban and peri-urban forests of Tbilisi municipality, Georgia. *Forests, 14*(1): 121. https://doi.org/10.3390/f14010121

Ávila-Nájera, D. M., Chávez, C., Lazcano-Barrero, M. A., Mendoza, G. D., & Perez-Elizalde, S. (2016). Traslape en patrones de actividad entre grandes felinos y sus principales presas en el norte de Quintana Roo, México. *Therya, 7*(3):439-448.

Chao, A., Ma, K. H., & Hsieh, T. C. (2016). User's guide for iNEXT online: Software for interpolation and extrapolation of species diversity. Institute of Statistics. Recuperado de http://chao.stat.nthu.edu.tw/wordpress/software_download.

Contreras-Moreno, F. M. (2020). Crisis de los tapires en Calakmul, un efecto del cambio climático. *Revista Hypatia*, 53:10-14.

Contreras-Moreno, F. M., Jesús-Espinosa, D., Cruz-Romo, L., Sanchez-Pinzon, K. G., Mendez-Tun, J. M., Perez-Mendez, F., Tamay-Yah, L., Gutierrez-Cortes, E., Duque-Moreno, V. D., Diaz-Ruiz, Y., Servin-Camacho, D. Y., Mendez-Saint, M. G., Simá-Pantí, D., & Bautista-Ramírez, P. (2024a). Water supply in artificial troughs: A strategy to mitigate the impacts of climate change in the Maya Forest. *AgroProductividad, 17*(4):69-77. doi: 10.32854/agrop.v17i4.2647

Contreras-Moreno, F. M., Jesús-Espinosa, D., Sánchez, K., Méndez-Tun, J., & Cruz-Romo, L. (2024b). Use of artificial water troughs by deer in the Maya Forest, México. *Therya, 15*(1):103-111.

Dormann, C. F., Gruber, B., & Fründ, J. (2008). Introducing the bipartite package: Analysing ecological networks. *Interaction, 1*(0.2413793).

Faggi, A., & Perepelizin, V. (2006). Riqueza de aves a lo largo de un gradiente de urbanización en la ciudad de Buenos Aires. *Museo Argentino de Ciencias Naturales Bernardino Rivadavia, 8*(2):289-297.

Gandiwa, E., Heitkönig, I. M., Eilers, P. H., & Prins, H. H. (2016). Rainfall variability and its impact on large mammal populations in a complex of semi-arid African savanna protected areas. *Tropical Ecology, 57*(2):163-180.

Hernández-Gómez, C. A., Andrade-Ponce, G. P., Velásquez-C, K. L., & Mandujano, S. (2020). Uso de bebederos artificiales por pequeños roedores en un bosque tropical seco en Oaxaca, México. *Mammalogy Notes, 7*(2):179-182.

Hernández-Sánchez, A., & Santos-Moreno, A. (2020). Activity patterns in a feline assemblage in south-west Mexico, and their relationship with prey species. *Journal of Tropical Ecology, 36*(5):225-233.

Lin, P., Yang, L., & Zhao, S. (2020). Urbanization effects on Chinese mammal and amphibian richness: A multi-scale study using the urban-rural gradient approach. *Environmental Research Communications, 2*(12):125002. doi: 10.1088/2515-7620/abd1c5

MacGregor-Fors, I., Avendaño-Reyes, S., Bandala, V. M., Chacón-Zapata, S., Díaz-Toribio, M. H., González-García, F., & Escobar, F. (2015). Multi-taxonomic diversity patterns in a neotropical green city: A rapid biological assessment. *Urban Ecosystems*, 18:633-647.

Mandujano-Rodríguez, S., & Hernández, C. (2019). Uso de bebederos artificiales por venado cola blanca en una UMA extensiva en la reserva de biosfera Tehuacán-Cuicatlán, México. *AgroProductividad, 12*(6):37-42.

Origin(Pro), Version (2023). OriginLab Corporation, Northampton, MA, USA.

Revollo, D., & Ríos, A. (2023). Presente y futuro de las Aguadas de Calakmul, México: Un análisis de las instituciones formales e informales de los habitantes frente al cambio climático. Sobre México: *Revista Sobre México, 2*(4):114-130.

Reyna-Hurtado, R., Sima-Pantí, D., Andrade, M., Padilla, A., Retana-Guaiscón, O., Sánchez-Pinzón, K., & Domínguez, N. A. (2019). Tapir population patterns under the disappearance of freestanding water. *Therya, 10*(3):353-358.

SEMARNAT [Secretaría de Medio Ambiente y Recursos Naturales]. (2010). Norma Oficial Mexicana NOM-059-SEMARNAT-2010, Protección Ambiental-Especies nativas de México de flora y fauna silvestres-Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio-lista de especies en riesgo. Diario Oficial de la Federación. Segunda Sección. D.F., México.

UICN [Unión Internacional para la Conservación de la Naturaleza]. (2024). IUCN 2024. The IUCN Red List of Threatened Species. Version 2024-2. <https://www.iucnredlist.org>. https://www.iucnredlist.org [Consultado en octubre de 2024].

Verdú-Vázquez, A., Fernández-Pablos, E., Lozano-Diez, R. V., & López-Zaldívar, Ó. (2021). Green space networks as natural infrastructures in peri-urban areas. *Urban Ecosystems*, 24, 187-204. https://doi.org/10.1007/s11252-020-01019-w