Therya Notes

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AMMAC
Asociación Mexicana de Mastozoología A.C.

THERYA NOTES tiene como propósito difundir exclusivamente notas científicas con información original e inédita relacionada con el estudio de los mamíferos en todas las disciplinas que contribuyen a su conocimiento. Es un foro abierto para profesores, investigadores, profesionales y estudiantes de todo el mundo, en el que se publican notas académicas en español e inglés. THERYA NOTES es una revista digital de publicación cuatrimestral (tres fascículos por año) que recibe propuestas para publicación durante todo el año. Tiene un sistema de evaluación por pares a doble ciego y es de acceso abierto.

En la Portada

El lamido de minerales ha sido reportado en la mayoría de los taxones de mamíferos herbívoros; sin embargo, la frecuencia de uso de saladeros por los Pilosa es rara. El perezoso de dos dedos (*Choloepus hoffmanni*), una especie herbívora de Pilosa, es nocturna y arborícola. Presentamos el primer caso de consumo de arena salina por parte de este perezoso en Costa Rica.
(Fotografía de Durán-Apuy y Mora 2023)

El logo de la AMMAC: "Ozomatli"

El nombre de "Ozomatli" proviene del náhuatl, se refiere al símbolo astrológico del mono en el calendario azteca, así como al dios de la danza y del fuego. Se relaciona con la alegría, la danza, el canto, las habilidades. Al signo decimoprimero en la cosmogonía mexica. "Ozomatli" es una representación pictórica del mono araña (*Ateles geoffroyi*), la especie de primate de más amplia distribución en México. "Es habitante de los bosques, sobre todo de los que están por donde sale el sol en Anáhuac. Tiene el dorso pequeño, es barrigudo y su cola, que a veces se enrosca, es larga. Sus manos y sus pies parecen de hombre; también sus uñas. Los Ozomatin gritan y silban y hacen visajes a la gente. Arrojan piedras y palos. Su cara es casi como la de una persona, pero tienen mucho pelo."

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Editorial

Impact of global climate change on mammals

Impacto del cambio climático global sobre los mamíferos

Global climate change, characterized by global temperature shifts and altered precipitation patterns, is a pressing issue that poses significant threats to biodiversity worldwide. Mammals, a diverse group of organisms with complex life histories and ecological roles, are particularly susceptible to these changes. Some of the best known changes include the effect of climate warming on the distribution of mammals. As global temperatures rise and precipitation patterns shift, the suitability of habitats can change, leading to range shifts in mammalian species (Sony *et al.* 2018). This is particularly important when dealing with endemic or restricted distribution species (Sántiz *et al.* 2016; Lorenzo *et al.* 2019).

While there may be direct and clear effects, there may even be implications for subtler aspects of biotic relationships between species. Climate change can alter predator-prey dynamics, leading to shifts in spatial distribution. Bastille-Rousseau *et al.* (2018) found that the distribution of snow leopards was influenced by changes in their prey's distribution, which was in turn affected by climate change. In another example, Warren *et al.* (2014) revealed that climate change could lead to a significant reduction in the suitable habitat for the Alpine marmot, a mammal species endemic to the European Alps. This proved that species with limited ranges may be particularly vulnerable to the impacts of climate change. But also, specific climate changes as seasonal change could lead to over/under estimations of the impact of climate change on a particular species. This underscores the importance of considering temporal dynamics when predicting the impacts of climate change on mammalian distribution (Smeraldo *et al.* 2018).

By the other side, climate change not only affects the distribution of mammalian species, but can also has significant implications for their reproductive processes. Changes in temperature and precipitation patterns can influence the timing of reproduction, reproductive success, and offspring survival in mammals (Van de Ven *et al.* 2020). By example, warmer or cooler temperatures may cause a giving birth earlier, indicating that climate change can lead to phenological shifts in mammalian species. Such shifts could have significant implications for reproductive success if they lead to mismatches between the timing of reproduction and the availability of resources (Bateman *et al.* 2012). Even more worrisome, climate change and human activities can lead to a decrease in the population and distribution of species, highlighting the potential for climate change to drive declines in some mammalian species reproduction and survival (Zhao *et al.* 2019).

On the other hand, climate change not only affects the physical environment of mammals but also has profound implications for their behavior. Changes in temperature, precipitation, and seasonality can lead to shifts in foraging behavior, migration patterns, and social dynamics among mammalian species (Bastille-Rousseau *et al.* 2018). By example, Cordes *et al.* (2020) demonstrated that climate change can have contrasting effects on seasonal survival and behavior in moose. Warmer autumn temperatures increased survival but also lead to higher tick infestation rates, which can negatively impact moose behavior and health. In a significant way, climate change can influence the spatial behavior and distribution of vectors diseases that affect mammals, including humans (Chalghaf *et al.* 2018).

Also, changes in temperature and precipitation patterns have a profound impact on the habitats of mammals, altering the physical environment and resources available to these species. Changes in temperature, precipitation, and extreme weather events can lead to habitat loss, fragmentation, and shifts in habitat suitability, with significant implications for mammalian populations (Campbell *et al.* 2015; Zhao *et al.* 2019).

Climate change is undeniably having profound impacts on mammalian species worldwide, affecting their distribution, reproduction, behavior, and available habitat. Recent studies provided valuable insights into these effects, revealing complex interactions between climate variables and mammalian biology and ecology (Bateman *et al.* 2012; Campbell *et al.* 2015; Bastille-Rousseau *et al.* 2018; Cordes *et al.* 2020). Despite the wealth of knowledge gained from these studies, there are still many unanswered questions. Future research should aim to fill these gaps, focusing on under-studied species and regions, and considering the potential for adaptation and resilience. More studies are needed that investigate the combined effects of multiple climate variables, as well as the interactions between climate change and other anthropogenic stressors. Long-term studies will also be crucial for tracking the ongoing impacts of climate change and for predicting future trends.

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Bats got a place in the sun: new findings of daytime flight in Brazil

Los murciélagos ganan un lugar bajo el sol: nuevos descubrimientos de vuelo diurno en Brasil

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Most bats species are small and nocturnal. The nocturnal habit evolved mainly to avoid predators and competition. Recently, bats of the suborder Yangochiroptera have been recorded flying during daytime in Amazonia and Peninsular Malaysia. We described new events of neotropical bats flying during daytime in tropical and subtropical regions of Brazil. All records were made occasionally during bat and bird sampling with mist nets and visual searching. We provided information about the records' time, respective solar radiation, air temperature, humidity, nebulosity, and wind velocity measurements taken from the nearest available meteorological stations from the National Institute of Meteorology (INMET). In northeastern and southern Brazil, we recorded 6 species/taxa of bats from 4 families (Molossidae, Noctilionidae, Phyllostomidae and Vespertilionidae) flying at daytime in air temperatures varying from 23.5 to 35.1 ºC. Bats flying in the daytime are poorly documented in rainforests. We recorded bats flying at daytime in warm sites of Brazil, from Caatinga scrublands to the Ombrophilous Atlantic Forest, from 7º to 28º S of latitude. The size of the individuals, the characteristics of the roost and the air temperature can possibly explain the causes of these diurnal records. These records reinforce the need for studies on thermoregulatory mechanisms in bats near the equator, evidencing data on natural history, as these are essential to assess how chiropteran species will be influenced by climate change in the future.

Key words: Chiroptera; diurnal behavior; flight; Neotropics; overheating.

La mayoria de las expecies de murciélagos son pequeños y nocturnos. El hábito nocturno evolucionó principalmente para evitar depredadores y la competencia. Recientemente, se han registrado murciélagos del suborden Yangochiroptera volando durante el día en la Amazonía y Malasia peninsular. Describimos nuevos registros de murciélagos neotropicales volando durante el día en regiones tropicales y subtropicales de Brasil. Todos los registros se realizaron ocasionalmente durante el muestreo de aves y murciélagos con redes de niebla y búsqueda visual. Proporcionamos información sobre el tiempo de los registros, las respectivas medidas de radiación solar, temperatura del aire, humedad, nebulosidad y velocidad del viento tomadas de las estaciones meteorológicas disponibles más cercanas del Instituto Nacional de Meteorología (INMET). En el noreste y sur de Brasil, registramos 6 especies/taxones de murciélagos de 4 familias (Molossidae, Noctilionidae, Phyllostomidae y Vespertilionidae) volando durante el día con temperaturas del aire que varían de 23.5 a 35.1 ºC. Las causas de estos registros diurnos posiblemente pueden explicarse por el tamaño de los individuos, las características de su sitio de descanso y principalmente por la temperatura del aire. Estos registros refuerzan la necesidad de estudios sobre los mecanismos de termorregulación en murciélagos cerca del ecuador, evidenciando datos sobre su historia natural, ya que estos son esenciales para evaluar cómo las especies de quirópteros se verán influenciadas por el cambio climático en el futuro.

Palabras clave: Calentamiento excesivo; comportamiento diurno; neotrópicos; quirópteros; vuelo.

Diurnal flight is commonly known for some insectivorous bats in temperate zones and pteropodid bats (Moore 1975; Speakman *et al.* 1994; Russo *et al.* 2011). This behavior is associated with a lack or low number of predators, sunlight for a long period in the circadian cycle, and a higher abundance of food resources during the nighttime period (Speakman *et al.* 1994). More recently, bats flying under sunlight or inside forests during the day were recorded in tropical regions for Brazilian Amazon (Bôlla *et al.* 2017), Peninsular Malaysia (Chua and Aziz 2018) and in a rainforest of Colombia (Vivas-Toro and Murillo- García 2020). Conversely to most temperate regions, tropical areas shelter lots of avian predators (Willig *et al.* 2003), feature high air temperatures with small seasonal variation (Feng *et al.* 2013), and have a high abundance of food items as insects (Bale 2002).

High air temperatures and predators' abundance seems to be the most important reasons which make bats avoid sunlight in the tropics (Rydell and Speakman 1995). However, diurnal flight in tropical bats may be due higher evapotranspiration rates and the consequent need to replenish body water since some individuals have already been recorded drinking water in ponds and streams (Bôlla *et al.* 2017). Additionally, some Neotropical bat species may emerge earlier than others to reach the required energy intake, diminishing competition by shifting foraging time (Bôlla *et al.* 2017).

Herein we describe 6 events of bats flying in daytime during bat and bird sampling expeditions for a decade (2010 to 2020) in 2 Brazilian biomes, Caatinga and Atlantic Forest.

The Caatinga climate is classified as Köppen's BSh (semi-arid climate with annual rainfall dropping on average to less than 800 mm), and the vegetation type is Forested Steppe Savannah (IBGE 2012; Alvares *et al.* 2013). The Atlantic Forest from southeastern and southern Brazil's climate is classified as Aw (markedly seasonal with annual rainfall ranging from 1,300 to 1,900 mm), and Cfa (subtropical climate with hot summers and no dry season) respectively, and vegetation type is Dense Ombrophilous Forests (IBGE 2012; Alvares *et al.* 2013).

Weather data was extracted from the National Institute of Meteorology (INMET) website, which has stations in most Brazilian municipalities that upload meteorological data measured in 15-minute intervals. Then we accessed the time series to extract the data from the exact or nearest time we observed the bats from the nearest station with the area where records were made. The heat index was calculated by the Agricultural Research and Rural Extension Company from Santa Catarina (EPAGRI 2023). This index takes air temperature and humidity to calculate how the air temperature feels for a human body. It is a way to measure how hot a day feels like for a mammal.

All records were made before the bat sampling that would be carried out during the same night and area. We noticed the bats flying during the daytime and captured them with the same mist nets that would be opened at night. The two exceptions were the fourth and sixth records. The fourth record was made with the capture of the bat using an improvised insect net with cotton fabric, and the sixth record was during a bird sampling using binoculars. The individuals from the last record were not captured, then they could not be identified at the species level.

The first record was made on June 23 (during the dry season) 2010, in the Serra da Jitirana, São João do Piauí, Piauí (08° 18' 28" S, 42° 01' 19" W). Using mist nets, we captured a female *Neoplatymops mattogrossensis* (family Molossidae) leaving the roost at around 15:30 hr. This individual belonged to the colony roosting in a sandstone outcrop crevice we found beforehand. The bats from this colony emerged from the roost between around 15:00 and 17:00 hr, in broad daylight, and did not return until the 21:00 hr, when we captured 6 individuals returning to the roost with mist nets.

The second record was made in Piauí River, São João do Piauí, Piauí (08° 26' 48' 'S, 42° 10' 59' 'W) on October 3 (during the dry season) 2011. We recorded many individuals of *Noctilio albiventris* (family Noctilionidae) flying over a river from around 14:50 hr. These bats flew in semicircles and very close to the water's surface. The bats emerged from cavities in the sandstone outcrops on the riverbank. However, it was not possible to find the roost or count the number of individuals, since there were plenty of them simultaneously.

The third record was made on December 24 (during the summer) 2012, at Pedras Grandes, Santa Catarina (28° 26′ 58″ S, 49° 11′ 31″ W), in the Atlantic Forest, where we recorded 3 sights (Table 1), during monthly field campaigns to monitoring a *Myotis nigricans* (family Vespertilionidae) colony in a house roof. Some individuals of a colony are estimated to have from 596 to 1,050 individuals (more details in Mottin *et al.* 2018). According to the heat index (Table 1), it was an atypical hot day when some individuals started flying outside the roost near 13:00 hr (35 ºC, the greatest value for the heat index of all records here described). It was impossible to count exactly how many individuals were flying. However, we managed to register that more than 10 individuals were flying simultaneously. After 30 minutes, about 20 individuals flying outside the colony were lying on the ground dead.

The fourth record in Atlantic Forest was made on May 15 (during the dry season) 2014, at the Fiocruz Atlantic Forest Biological Station settled in the Pedra Branca Massif, Rio de Janeiro (22° 56′ 29″ S, 46° 24′ 36″ W). A male of *Myotis riparius* (family Vespertilionidae) was captured with the help of an improvised entomological net made with a cotton fabric at 14:15 hr after being observed for more than 15 minutes foraging in an Ombrophilous Dense Forest clearing near a river. The sky was cloudy, and the forest interior seemed to the authors to have low luminosity, even though it was not measured directly.

Table 1. Bat species, sites and meteorological data in day and time of the diurnal records. All data were extracted from the nearest automatic or regular meteorological stations of the record sites, provided by the National Institute of Meteorology (INMET) and accessed online in November 19, 2020. Temp. = Temperature; ºC = degrees Celsius; KJ = Kilojoule; m^2 = square meter; m = meter; s = second and % = per cent.

Site	Taxa	Time	Temp.	Heat index (ºC)	Humidity (%)	Radiation (KJ/m^2)	Wind velocity (m/s)	Nebulosity (%)
Serra da Jitirana	*Neoplatymops mattogrossensis*	15:30	33.4	34	36	2099.00	2.7	10
Rio Piauí	*Noctilio albiventris*	14:50	35.1	34	28	2619.18	3.4	65
Pedras Grandes	*Myotis nigricans*	13:00	32.9	35	44	3023.51	0.5	-
Maciço da Pedra Branca	*Myotis riparius*	14:15	26.7	27	47	2471.30	0.9	-
Chapada do Araripe	*Glossophaga soricina*	11:54	29.0	28	33	3408.00	3	0
Urban site	Undetermined Molossidae	11:40	23.5	23	55	2114.44	2.4	-

The fifth record was made in Chapada do Araripe, Crato, Ceará (07° 19' 55" S, 39° 24' 46" W) at 11:54 hr on October 23 (during the dry season) 2017. About 7 individuals of *Glossophaga soricina* (family Phyllostomidae) were flying around a cave entrance localized in a humid Tropical Subperennial Forest. These bats kept flying for more than 10 minutes and were already flying when one of the researchers approached the cave to take photographs from them (Figure 1). The bats kept flying after the photos were taken, but the total flying time could not be recorded.

Finally, the sixth record was made in an urban site of Criciúma, Santa Catarina (28° 41′ 36″ S, 49° 27′ 42″ W) at 11:40 hr on October 12 (during the spring) 2020. One individual of the Molossidae family was observed, using binoculars, flying in circles and drinking water over a small artificial lake (Figure 1) with the aquatic macrophytes (*Eleocharis* sp. and *Schoenioplectus californicus*) amidst eucalyptus stands and a remnant of Dense Submontane Rainforest. The observation was about 2-3 min long.

Bats recorded in the present study were flying at the daytime in the hot climate of Brazil located in Caatinga scrublands and in the subtropical region located in the Ombrophilous Atlantic Forest, from 7 to 28° S of latitude. Modeling the overheating in bats flying in daytime, Speakman *et al.* (1994) wrote that "... as one moves away from the equator, and temporally away from the noon, the problem of heat stress for bats flying in daylight becomes less severe". Even though this is a predictable assumption for many small nocturnal animals, heat stress during daytime in bats may not avoid their diurnal flight near the equator, and these bats may try to keep homeostasis in different ways, depending on physiological and morphological traits, like reproductive status and body mass (see Speakman 1995).

Speakman (1990) reinforced the idea that size matters in overheating: small bats would support and dissipate greater amounts of heat than larger bats due to the relation between the areas of the body and wing and/or tail membranes. In Neotropical bats, heat stress in roosts may be reduced through flight. In this case, most heat is dissipated from the wing and tail membranes (Speakman *et al.* 1994), which may force bats to leave roosts for a while, even in sunlight. Then, in general, large bats dissipate less endogenous heat than small bats but dissipate it better on wings by radiation and less per unit area by convection (Speakman *et al.* 1994; Webb *et al.* 1995).

Considering bats lose ample proportions of water by evapotranspiration when flying (Carpenter 1969), it is likely that, when bats are forced to leave roosts because of overheating, they have already lost so much water (in the roost and during flight) that it is necessary replenishing it before coming back to roosts (Webb *et al.* 1995). Therefore, if small bats (like neotropical *Myotis* and *Neoplatymops*) would better avoid overheating faster than bigger ones (like *Noctilio*), by folding flight membranes away, flying near the roost and away enough from other bats in the colony, bigger bats should spend more time flying to solve the excessive heat and, this way, ingesting water becomes necessary to replenish the deficit caused by evapotranspiration (*e.g.*, Carpenter 1969; Speakman and Racey 1988; Webb *et al.* 1995).

The bats we recorded are small to medium-sized. Speakman and collaborators' models (1994) suggested that the probability of a small bat with 9 g of body mass (as *M. nigricans*, *M. riparius*, *N. mattogrossensis*, and *G. soricina*) flying at 14:30 hr at latitude 10 (near Piauí latitude) would be constrained and, at latitude 20 (near Rio de Janeiro latitude), this flight will be less probable than 10 % to occur. Also, the probability of large-sized bats with 90 g of body mass (more than a half bigger than *N. albiventris*) would be less than 5 % to have its diurnal flight constrained at latitude 10. Speakman *et al.* (1994) models proposed that larger bats are less likely to perform diurnal flights than small bats. However, the medium-sized bat *Macronycteris commersoni* (mean body mass: females = 46.3 g; males = 79.6 g) was

Figure 1. Bats in daytime flight from Brazil: A) individuals of *Glossophaga soricina* flying in the entrance of a cave in daylight in Chapada do Araripe, Crato, Ceará, Brazil; B) Molossid bat flying in the border of an urban remnant in Criciúma, Santa Catarina, Brazil.

recorded doing torpor and microtorpor under high temperature conditions in Madagascar (Reher and Dausmann 2021). Also, these physiological responses are newly discovered to be associated with hyperthermia, and not only hypothermia, shedding light on how tropical bats cope with the increasing hot weather (Reher and Dausmann 2021). We still lack information on how bats respond when the air temperature exceed their torpor threshold ability, how many tropical bats can undergo these responses, and if the species reported here, whether big or small, were or will be able to adapt to hyperthermia.

Even though we did not record large species, Bôlla *et al.* (2017) described the behavior of larger bats (*Phyllostomus* sp.) leaving their roosts to forage and drink water during the daytime. In the present study, we observed individuals of the medium-sized *N. albiventris* (body mass < 40 g; Hood and Pitocchelli 1983) drinking water during the daytime. Studier (1970) recorded vespertilionid bats losing 15-16 % of body mass, attributed to water loss when roosting for about 12 hr in natural roosts. It reinforces the idea that the bigger the bat gets, the harder it gets to control overheating only by flying, making water ingestion necessary. We now believe that dehydration may be one of the most important issues large bats face since water ingested to keep body temperature may avoid overheating in tropical regions, as recorded here. Another factor constraining bat diurnal flights is the abundance of predators in the Neotropical region, which is not true for the former records made in Europe (Speakman 1990, 1991, 1995; Speakman *et al.* 1994, 2000), an island of Africa (Russo *et al.* 2011) and a desert in Oceania (Bondarenco *et al.* 2014). Mobbing by predators is an important factor for bats, especially for species that commonly roost in open habitats and have small body sizes (Mikula *et al.* 2016).

Until now, most of the diurnal events were recorded in the Northern Hemisphere, where bat species are predominantly insectivores (Speakman 1990, 1991, 1995; Speakman *et al.* 1994, 2000) and where phytophagous bats are rare or do not occur. However, other insectivorous bats were recorded during daytime incursions in Africa and Oceania, and an omnivorous bat was recorded feeding on termites in Brazil (Russo *et al.* 2011; Bondarenco *et al.* 2014; Bôlla *et al.* 2017). The species here recorded in southeastern and northeastern Brazil were predominantly insectivores. However, the sample includes a primary nectarivore, *G. soricina*, which consumes insects in its diet (Clare *et al.* 2014). Insectivores are the most documented bats flying during daytime, probably because they do not acquire as much water from the diet as frugivores and can suffer more severely from dehydration.

Diurnal incursions are expected to be more tolerable on cloudy days (Speakman *et al.* 1994). A hypothetical small bat (6 g of body mass) flying in the daytime with 60 % nebulosity can tolerate up to 37.8 ºC, at 10 % to 33.8 ºC and 34.8 ºC when clouds are absent. Since large bats may hardly deal with high temperatures compared to small ones, individuals of *N. albiventris* we recorded would be near lethal risk since it was recorded flying at 35.1 ºC (maximum non-lethal temperature: 37.8 ºC). *Neoplatymops mattogrossensis* were recorded flying at 33.4 ºC, only 0.45 ºC below the maximum non-lethal temperature for a bat with a similar body mass. Another small bat (7-12 g of body mass), *G. soricina* was recorded when the air temperature was 5.85 ºC below the maximum non-lethal for no cloud days.

Myotis nigricans, the only species with known records (third record here described) of a possible lethal overheating in Neotropics, is a very small bat (3-4 g) recorded while flying close to noon at very high air temperatures and solar radiation. According to the Speakman *et al.* (1994) models, a bat of 9 g would die at the air temperature of 33.85 ºC, and many bats of this colony died at only 32.9 ºC. It is possible that, as roosting on a house roof, the colony was facing higher temperatures than those recorded by the meteorological station from which we obtained the related information because of the roof characteristics as well as the high number of individuals roosting together, which may have reached the temperature of < 33.85 ºC modeled by Speakman *et al.* (1994).

Air temperature, humidity, and airflow could be the most important environmental factors influencing bats in selecting diurnal roosts (Tuttle and Stevenson 1982; Hill and Smith 1984). Three of the 5 records we made were obtained from bats roosting in rocky environments: sandstone outcrops and caves. Webb *et al.* (1996) proposed that, in ambient humidity lower than 50 %, as in the sites here recorded, low temperatures' roosts may aid bats to lose less water for evapotranspiration, but savings are still marginal (average evaporative water loss in resting *Plecotus auritus* = 1,0075 ul.min^{-1}). However, humidity seems to play a small role in roost selection in Neotropical areas compared to air temperature (Avila-Flores and Medellín 2004), since the authors could not find any pattern relating temperature and roost selection in México. The availability of rocky-type roosts in very hot areas as those in Brazil, may work in favor of bats, mainly the large species, since roosts as caves are thermally insulated systems (Badino 2004). Despite this, the stable temperature in rocky environments does not seem to avoid bat overheating and daytime incursions, as we recorded.

Bats flying during daytime is poorly documented in the Neotropics, with very dubious and old records related to Rabies virus infections in the Brazilian Amazon and Atlantic Forest (Carini 1911; Silva 1967). Since bats were not tested for Rabies; and more recent records involving 3 bat genera also in Amazon Forest (Bôlla *et al.* 2017) and *Saccopteryx leptura* in a rainforest of Colombia (Vivas-Toro and Murillo-García 2020), we believe that this kind of event is more common than documented in scientific literature, but its causes remain unknown.

Unfortunately, studies on thermoregulatory mechanisms in bats, evidencing data on the natural history of bat species as we provided here are very scarce near the equator even it may be essential to model the how different aspects of species (including physiological and distributional aspects) will be influenced by climate change in the future (Jones and Rabelo 2013). Deforestation, land conversion into large agricultural fields and urban development can increase global warming (Letcher 2021) forcing different species to adapt their behaviors and physiology to new climatic conditions and resources or they can be led to extinction (see Festa *et al.* 2022). We recommend more studies to be carried out in hot regions that assess how bats would deal mainly with higher temperatures, including monitoring it in roost sites and contemplating physiological questions on tropical and subtropical bat species.

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Efectos de la variabilidad de temperatura y precipitación causadas por el cambio climático sobre la reproducción de los murciélagos

Effects of temperature and precipitation variability caused by climate change on bat reproduction

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La reproducción en murciélagos es regulada por factores endógenos y exógenos, por lo que las variaciones en las condiciones climáticas pueden impactar en su éxito reproductivo. Se presenta una revisión de literatura y análisis de los efectos de la variabilidad de la temperatura y precipitación causadas por el cambio climático sobre la reproducción de los murciélagos. Se realizó una búsqueda de literatura científica publicada de 2000 a 2023, basada en la combinación de 3 elementos clave referentes a la variabilidad de la temperatura y precipitación, cambio climático y reproducción de murciélagos. Los efectos descritos fueron analizados y la información se reporta en una síntesis cualitativa. Un total de 41 artículos científicos y 3 capítulos de libros de 15 países abordaron el efecto de la variabilidad climática en la temperatura y precipitación causada por el cambio climático en la reproducción de murciélagos. Se evidencia la capacidad de algunas especies para modificar su patrón reproductivo en respuesta a esta variabilidad y que las variables ambientales pueden modificar el momento de los eventos reproductivos. Debido a la diversidad en su biología reproductiva y la capacidad para maximizar su eficiencia reproductiva ante diferentes condiciones ambientales, no se puede generalizar sobre los efectos del cambio climático en la reproducción de murciélagos, ya que se han demostrado diferencias intra e interespecíficas en la capacidad para maximizar su éxito reproductivo. Se requiere de mayor investigación que aborde los efectos de las variables climáticas sobre los eventos reproductivos.

Palabras clave: Calentamiento global; ciclos reproductivos, Chiroptera; lactancia; lluvias; momento de parto; sequías.

Reproduction in bats is regulated by endogenous and exogenous factors, so variations in climatic conditions can impact their reproductive success. A literature review and analysis of the effects of temperature and precipitation variability caused by climate change on bat reproduction are presented. A search of scientific literature published from 2000 to 2023 was carried out, based on the combination of three key elements related to temperature and precipitation variability, climate change and bat reproduction. The described effects were analyzed and the information is reported in a qualitative synthesis. A total of 41 scientific articles and 3 book chapters from 15 countries addressed the effect of climate variability in temperature and precipitation caused by climate change on bat reproduction. The ability of some species to modify their reproductive pattern in response to this variability is evidenced. In addition, it is evident that environmental variables can modify the timing of reproductive events. Due to the diversity in their reproductive biology and the ability to maximize their reproductive efficiency under different environmental conditions, it is not possible to generalize about the effects of climate change on bat reproduction, since intra and interspecific differences have been demonstrated in the ability to maximize their reproductive success. Further research is required to address the effects of climatic variables on reproductive events.

Key words: Chiroptera, droughts; global warming; lactation; rains; reproductive cycles; timing of parturition.

Los efectos del cambio climático son reconocidos como una de las principales amenazas a la biodiversidad de murciélagos a nivel mundial (Frick *et al.* 2020). El clima influye en su distribución geográfica, la disponibilidad de alimento, la fenología de la hibernación, la frecuencia y duración de letargo, la tasa de gasto de energía y la reproducción

(Sherwin *et al.* 2013). Diversos estudios han evidenciado cómo los murciélagos son afectados y responden a la variabilidad climática derivada de los efectos del cambio climático (La Val 2004; Mistry y Moreno-Valdez 2008; Adams 2010; Amorim *et al.* 2015; Festa *et al.* 2023), y concluyen que se puede tener un mejor entendimiento de esto si se consideran aspectos de la historia de vida de las especies que las hacen particularmente vulnerables a las variaciones climáticas (Jones *et al.* 2009), tales como su distribución geográfica, hábitos alimenticios, uso de espacios y recursos y reproducción.

La reproducción en murciélagos involucra un conjunto de factores endógenos y exógenos (Mello *et al.* 2009). Con respecto a los factores endógenos, en las hembras, por ejemplo, las etapas de reproducción más exigentes se encuentran en el último periodo de gestación: la lactancia y el destete, por lo que la probabilidad de supervivencia de una hembra y su descendencia se maximiza, haciendo coincidir estas etapas con las condiciones ambientales óptimas (Racey y Entwistle 2000). En los machos, la reproducción está determinada por el ciclo reproductivo de las hembras, por lo que se considera que la ciclicidad reproductiva anual del macho probablemente sea paralela a la de la hembra, con una producción sincronizada de gametos (Krutzsch 2000).

Se ha demostrado que las variaciones de factores ambientales como la temperatura y precipitación, así como la disponibilidad de alimento y la pérdida de hábitat, pueden afectar el momento de la ovulación y la fertilización, las tasas de crecimiento posterior a la implantación, el momento del parto, las tasas reproductivas, la espermatogénesis y el recrudecimiento gonadal de los murciélagos (Heideman 2000; Arlettaz *et al.* 2001; Mello *et al.* 2004; Mello *et al.* 2009; Arandas *et al.* 2019; de Carvalho *et al.* 2019). Los murciélagos presentan diversas estrategias reproductivas, tales como estro postparto, regresión testicular, retraso en la ovulación, implantación y desarrollo embrionario, por mencionar algunas, por lo que es poco probable que los efectos del cambio climático en su reproducción sean iguales para todas las especies (Sherwin *et al.* 2013). En este trabajo, se presenta una revisión y análisis de los efectos de la variabilidad en la temperatura y la precipitación causadas por el cambio climático sobre los eventos reproductivos en los murciélagos a nivel global.

Se realizó una búsqueda de artículos escritos en el idioma inglés y publicados del 2000 al 2023, relacionados al estudio del efecto de la variabilidad climática causada por el cambio climático en la reproducción de murciélagos, en los buscadores Google Scholar, Elsevier Science Direct, Researchgate, BioOneComplete, Redalyc, National Center for Biotechnology Information (NCBI), Wiley Online Library y SciELO-Scientific Electronic Library Online. Se combinaron tres elementos clave de búsqueda, el primero refirió a la variable de cambio climático con las palabras: "climate change", "climate variables", "global warming", "precipitation", "temperature"; el segundo al objeto de estudio: "bat", "Chiroptera"; y el tercero al efecto sobre los eventos reproductivos: "reproduction", "timing reproduction", "reproductive patterns", "reproductive rates".

Para la selección de los artículos con los que se construyó esta revisión, se realizó un primer filtro mediante la revisión del título y resumen de cada uno de los artículos encontrados, excluyendo aquellos que no estudiaran efectos de variables climáticas y del cambio climático sobre los murciélagos. Posteriormente, se determinó cómo cada uno de los artículos que se seleccionaron abordaron de forma directa o indirecta (no es el objetivo primordial del estudio) los efectos del cambio climático y de las variables de temperatura y precipitación sobre los eventos reproductivos de los murciélagos. Se incluyeron artículos que involucraran a estudios locales, regionales y globales; artículos de revisión e investigación y estudios a nivel de especies, familia y orden. De cada uno de los artículos elegidos se extrajo información sobre las variables ambientales estudiadas, los eventos reproductivos de los murciélagos como preñez, época de nacimientos y lactancia, sobre los que influyen las variables ambientales y los efectos climáticos evaluados como sequías y aumento de temperatura.

Los artículos seleccionados abordaron diferentes temas, como proyecciones de escenarios futuros, evaluación de impactos climáticos y modificación en patrones de comportamiento de los murciélagos; todos ellos presentados bajo múltiples enfoques metodológicos, áreas geográficas y diferentes resultados, por lo que los estudios elegidos no fueron homogéneos y no se realizó una extracción de datos que permitieran realizar análisis cuantitativos, por lo que los hallazgos se reportan como una síntesis cualitativa (Festa *et al.* 2023).

Los hallazgos se vertieron en una base de datos de Excel, en la cual se dividió la información en dos grupos, uno que incluye los datos generales de las publicaciones tales como título, año, autores, país en el que se realizó el trabajo; y el otro que incluye información cualitativa referente al contenido, como el objetivo del estudio, variables ambientales, efectos climáticos y efectos reproductivos estudiados.

Se revisaron un total de 114 artículos y 3 capítulos de libros. De éstos, sólo 41 artículos y 3 capítulos de libros, provenientes de 15 países, abordaron el efecto de la variabilidad climática en la temperatura y precipitación causada por el cambio climático en la reproducción de murciélagos, por lo que fueron considerados en el estudio (Apéndice 1). La mayoría de estos estudios se realizaron en Estados Unidos (n = 18), el resto de los países tenían menos de 5 publicaciones. El número de estudios que abordan directamente los efectos de la variabilidad climática en la temperatura y precipitación causada por el cambio climático en la reproducción de murciélagos fue de 15.

Temperatura. Uno de los principales efectos del cambio climático es el incremento en la temperatura media anual, causado principalmente por las emisiones de gases de efecto invernadero de los sistemas naturales y por las actividades humanas, lo que ha provocado un incremento de 1 °C por encima del nivel preindustrial y es probable que alcance los 1.5 °C entre 2030 y 2052 (IPCC 2021).

Los murciélagos de zonas templadas presentan una extrema dependencia de las temperaturas externas (Jones *et al.* 2009), por lo que pueden ser más sensibles al aumento de la temperatura causado por el cambio climático que otros grupos de mamíferos. Loeb y Winters (2013) sugieren que, cuando no logran mitigar los efectos de las altas temperaturas, es probable que ocurran cambios en su rango de distribución, desplazándose hacia nuevas áreas desocupadas (Mollhagen y Bogan 1997; La Val 2004; Parris y Hazell 2005; Sachanowicz *et al.* 2006; Lundy *et al.* 2010; Rebelo *et al.* 2010), afectando significativamente su patrón reproductivo (Jones *et al.* 2009).

Existe evidencia anterior al año 2000 en la que se ha documentado cambios en los patrones reproductivos de algunas especies de murciélagos cuando cambian de latitud. En áreas altamente estacionales de Sudáfrica, la mayoría de las especies presentan monoestría estacional restringida, mientras que se han registrado hasta 5 patrones reproductivos diferentes más cerca del ecuador (Happold y Happold 1990). Bernard y Cumming (1997) observaron que, con un gradiente de latitud creciente, se presenta un cambio gradual de la poliestría a la monoestría. Los cambios en los patrones reproductivos con la latitud han sido reportados para los murciélagos de la familia Molossidae, presentando patrones reproductivos poliéstricos no estacionales en *Tadarida pumila* y *Molossus ater* (0º S, 3º S), poliestría estacional multimodal en *T. pumila* (9º S, 25º S), poliestría bimodal estacional en *Molossus fortis* (18º N), y monoestría estacional restringida para *Tadarida aegyptiaca* y *Mormopterus planiceps* (33º S, 36º S), lo cual evidencia que incluso la misma especie (*T. pumila*) puede presentar variaciones en su ciclo reproductivo con la variación de la latitud (Happold y Happold 1990; Racey y Entwistle 2000). En el género *Myotis* también son evidentes estas variaciones en los patrones reproductivos con la latitud. En los trópicos, los miembros de este género son poliéstricos, en zonas de latitud y/o climas intermedios se presenta poliestría en asociación con almacenamiento espermático, mientras que en latitudes templadas se presenta monoestría con almacenamiento espermático durante la hibernación invernal (Bernard 1982). Así también, se ha demostrado que una misma especie (*Sturnira lilium*) pasa de la poliestría bimodal a una monoestría cuando se distribuye en zonas más australes (Autino y Barquez 1994).

Los cambios de temperatura pueden tener diferentes efectos en las especies de murciélagos debido a las diferencias en los requisitos de alimentación, hábitat y reproducción (Sherwin *et al.* 2013). Sin embargo, las especies pueden adaptarse a los patrones climáticos cambiantes, mediante modificaciones en su fenología migratoria y reproductiva (Festa *et al.* 2023).

En esta revisión se ha documentado que murciélagos nectarívoros de bosques templados de México realizan migraciones altitudinales en busca de temperaturas ideales para reproducirse y favorecer el desarrollo embrionario de sus crías, mejorando así el éxito reproductivo (Saldaña-Vázquez *et al.* 2019). El cambio climático puede influir en el momento del parto al alterar la disponibilidad de alimento (Sherwin et al.2013). En murciélagos de zonas templadas, los climas más cálidos pueden inducir un parto más temprano y el destete de las crías, lo que les permite más tiempo para aparearse y almacenar reservas de grasa en preparación para la hibernación, además que la gestación y el parto más tempranos proporcionan a los juveniles un período de crecimiento más largo antes de la temporada de reproducción (Burles *et al.* 2009; Jones *et al.* 2009). Lundy *et al.* (2010) examinaron el efecto del cambio climático en el murciélago insectívoro *Pipistrellus nathusii* y observaron que el momento del parto ha cambiado en áreas donde la temperatura ambiental se ha incrementado, esto probablemente se deba al hecho de que, a medida que las temperaturas aumentan, los insectos emergen antes en el año, lo que significa que los murciélagos pueden encontrar comida antes y, por lo tanto, parir antes, ya que los murciélagos necesitan tener acceso a una fuente de alimento confiable para criar a sus crías con éxito. Sin embargo, estas acciones podrían resultar en un aumento del tamaño de la población y, por lo tanto, en una competencia intra e interespecífica intensificada por el alimento y los sitios de descanso (Sherwin et al.2013).

Por otra parte, las olas de calor han afectado gravemente a la demografía de zorros voladores *Pteropus* spp. resultando en mayor mortalidad entre juveniles y hembras lactantes, siendo este último grupo uno de los más vulnerables ante las temperaturas extremas, ya que la lactancia provoca una elevación de la tasa metabólica basal y un aumento de las necesidades de termorregulación (Welbergen *et al.* 2008).

Precipitación. El calentamiento observado durante varias décadas, ha sido vinculado a cambios experimentados por el ciclo hidrológico en gran escala. Según las proyecciones, la intensidad y variabilidad crecientes de la precipitación agravarían el riesgo de inundaciones y sequías en numerosas áreas (Serdá y Quiroga 2020). La frecuencia de episodios de precipitación intensa aumentará muy probablemente en la mayoría de las áreas y al mismo tiempo, aumentará la proporción de superficie terrestre que padece sequía extrema y se manifestará una tendencia a la sequía en el interior de los continentes durante el verano, particularmente en las regiones subtropicales de latitudes bajas y medias (Bates *et al.* 2008).

En publicaciones anteriores al año 2000, se ha demostrado que la precipitación es una variable climática con gran influencia en los patrones reproductivos de los murciélagos. En algunas zonas tropicales, en las que la disponibilidad de alimento parece ser abundante todo el año y las variaciones estacionales de temperatura pueden no ser extremas, especies poliéstricas pueden experimentar un mayor o menor grado de estacionalidad reproductiva asociado a los patrones de lluvia, por lo que el parto generalmente tiene lugar al inicio de la temporada de lluvias, y la lactancia durante el pico de esta temporada (Racey y Entwistle 2000). En el murciélago vampiro común *Desmodus rotundus*, una especie poliéstrica continua, con una fuente de alimento constante al alimentarse del ganado, se ha documentado un incremento de nacimientos y hembras lactantes durante la época de lluvias, por lo que, Turner (1975) y Lord (1992) consideran que la precipitación puede ser un factor climático que influye en el nacimiento de sus crías, que al verse alterado por el cambio climático puede impactar en su patrón reproductivo.

Para Happold y Happold (1990), los patrones de lluvia y la severidad de las estaciones secas en diferentes regiones geográficas son la base de los patrones reproductivos encontrados en los murciélagos. Se ha demostrado que existen claras relaciones entre lluvias bimodales y nacimientos bimodales (*e.g.*, *Micropteropus pusillus*, Thomas y Marshall 1984), monoestría en lluvias unimodales cortas (*e. g.*, *Pipistrellus nanus*; Happold y Happold 1990) y la poliestría bimodal o multimodal programada para que ambos periodos de lactancia ocurran durante la temporada de lluvias (*e. g.*, *Epomops buettikoferi*; Kofron y Chapman 1994).

En esta revisión, se evidencian los efectos de la variabilidad de la precipitación en la reproducción de los murciélagos. O'Shea *et al.* (2011), estudiaron las diferencias en la reproducción de murciélagos entre un año con una primavera seca y el siguiente con una primavera húmeda en el Parque Nacional Mesa Verde, Colorado, USA, observando que los aumentos de precipitación dieron como resultado condiciones más favorables para la reproducción. En un estudio sobre los factores que influyen en las tasas reproductivas de los murciélagos frugívoros en el bosque Atlántico Brasileño, de Carvalho *et al.* (2019) observaron que las tasas de reproducción eran más altas en la estación de lluvias que en la estación de seca, sugiriendo que estos hallazgos probablemente se deban a la disponibilidad de alimentos y otros recursos.

Como parte de los efectos del cambio climático se esperan aumentos en la frecuencia y severidad de las sequías en diferentes regiones del mundo, teniendo un impacto negativo en los eventos reproductivos, provocando disminución de las poblaciones debido a fallas reproductivas recurrentes (Amorim *et al.* 2015); además, debido a que las hembras lactantes requieren altas tasas de consumo de agua (Adams y Hayes 2008), la reducción en su disponibilidad disminuye su éxito reproductivo (Adams 2010). O'Shea *et al.* (2010) observaron una menor supervivencia de crías durante el primer año en murciélagos nacidos durante un año de sequía. Amorim *et al.* (2015) evaluaron el impacto de un evento severo de sequía sobre el éxito reproductivo de *Tadarida teniotis*, observaron que las hembras gestantes o lactantes y la proporción de juveniles fueron significativamente menores bajo esas condiciones, sugiriendo que la sequía puede perjudicar la reproducción de *T. teniotis* al reducir los recursos alimentarios durante la pre-reproducción.

Temperatura y precipitación. A medida que cambia el clima, es probable que los murciélagos se vean afectados por los cambios en la temperatura y precipitación. Estos cambios podrían conducir a una disminución en la cantidad de murciélagos que pueden reproducirse, lo que podría tener un impacto negativo en sus poblaciones (O'Shea *et al.* 2011). En murciélagos insectívoros, cuando las condiciones ambientales eran más cálidas y secas que el promedio de la región Occidental de Norteamérica, se observó reducción de la fertilidad, mayor mortalidad, reproducción retrasada y tasas de natalidad más bajas (Adams 2010). Por otra parte, en el murciélago insectívoro *Myotis daubentonii*, Lucân *et al.* (2013) identificaron que el éxito reproductivo disminuyó en años con mayores precipitaciones y que el aumento de las temperaturas en primavera puede tener una influencia beneficiosa en la dinámica de sus poblaciones, ya que los partos más tempranos se relacionaron positivamente con la supervivencia de los murciélagos juveniles, aunque la mayor incidencia de los climas extremos, como lluvias excesivas en verano, puede disminuir en gran medida este efecto.

Burles *et al.* (2009) en el noroeste del Pacífico de Canadá, estudiaron los efectos del fenómeno meteorológico El Niño-La Niña, que dio lugar a climas contrastantes en dos años seguidos en los murciélagos *Myotis lucifugus* y *Myotis keenii*. Se observó que las bajas temperaturas y alta humedad dieron lugar a gestaciones prolongadas, retraso en el nacimiento de crías y disminución en los eventos reproductivos en *M. lucifugus*; por otra parte, *M. keenii* presentó gestaciones más cortas, nacimiento más temprano de las crías y sus eventos reproductivos no se vieron alterados.

Conclusiones. Es difícil generalizar los efectos de la variabilidad de temperatura y precipitación causadas por el cambio climático sobre la reproducción de los murciélagos, ya que éstos presentan una biología reproductiva muy diversa, sus ciclos reproductivos están influenciados por diferentes factores ambientales, de tal forma que la presentación de un ciclo reproductivo en una determinada especie puede variar según las condiciones ambientales (Zortéa 2003; Reusch *et al.* 2019; Linton y Macdonald 2020). Además, son capaces de detener, retrasar o acelerar eventos reproductivos en respuesta a la disponibilidad de alimento y variables climáticas.

En esta revisión, se evidencia la capacidad de algunas especies de murciélagos para modificar su patrón reproductivo en respuesta a diferentes condiciones climáticas, por lo que pudieran ser considerados como indicadores de los efectos del cambio climático (Russo *et al.* 2021); sin embargo, no se pueden hacer generalizaciones, ya que se han demostrado diferencias intra e interespecíficas en la capacidad para maximizar su éxito reproductivo. Se requiere de mayor investigación que aborde de manera directa los efectos de las variables climáticas sobre los eventos reproductivos en las especies tanto de zonas tropicales como templadas, debido a la gran diversidad de especies del orden Chiroptera, así como la diversidad en su biología reproductiva y la capacidad que tienen para adaptarse a diferentes condiciones ambientales.

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Apéndice 1

Literatura adicional que aborda el efecto de la variabilidad climática en la temperatura y precipitación causada por el cambio climático en la reproducción de murciélagos y que fue considerada en el estudio.

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Evaluación multicriterio y los modelos de distribución potencial: Herramientas clave para la mitigación del cambio climático y la conservación del jaguar (*Panthera onca*) en el noreste de México y sur de EUA

Multi-criteria assessment and potential distribution models: Key tools for climate change mitigation and jaguar (*Panthera onca*) conservation in northeastern Mexico and southern USA

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Para llevar a cabo protocolos de conservación del jaguar (*Panthera onca*) es indispensable determinar la idoneidad de hábitat de la especie por lo que, el objetivo de este trabajo es el análisis de idoneidad espacial para la conservación *de Panthera onca* para el noreste de México y sur de Estados Unidos como medida para mitigar el efecto del cambio climático. La evaluación de la idoneidad espacial del hábitat del jaguar en el noreste de México y el sur de Estados Unidos ayudará a implementar medidas de conservación para mitigar el impacto del cambio climático en la especie. Lo que conlleva a responder la pregunta ¿Cuál es el hábitat optimo del jaguar en el área seleccionada, y cómo se puede utilizar esta información para mitigar los efectos del cambio climático a través de medidas de conservación? Se utilizó un modelo de distribución potencial y una evaluación multicriterio. El AUC de entrenamiento promedio para los modelos corridos es 0.86. Por otra parte, el método de evaluación multicriterio es consistente (CR = 0.0725) por lo que los criterios seleccionados para el hábitat del jaguar son adecuados y favorables. En el área de estudio hay 1,257,650 ha que reúnen las condiciones de hábitat idóneo casi continuo para el jaguar tanto en México como EUA que no están consideradas para conservación de este felino en ambos países. Estas técnicas generan cartografía que puede auxiliar en la toma de decisiones de conservación, preservación, reintroducción y manejo de este felino ante el cambio climático.

Palabras clave: Distribución geográfica; especies bandera; modelo biogeográfico.

To carry out jaguar (*Panthera onca*) conservation protocols, it is essential to determine the species' habitat suitability. Therefore, the objective of this study is to analyze the spatial suitability for the conservation of *Panthera onca* in the northeast of México and the southern United States as a measure to mitigate the effects of climate change. Evaluating the spatial suitability of jaguar habitat in these regions will help implement conservation measures to mitigate the impact of climate change on the species. This leads to answering the question: What is the optimal jaguar habitat in the selected area, and how can this information be used to mitigate the effects of climate change through conservation measures? A potential distribution model and a multicriteria evaluation were used. The average training AUC for the models run is 0.86. Additionally, the multicriteria evaluation method is consistent (CR = 0.0725), indicating that the criteria selected for the jaguar's habitat are appropriate and favorable. In the study area, there are 1,257,650 ha that meet the conditions of almost continuous suitable habitat for the jaguar, both in México and the USA, which are not currently considered for conservation of this feline in either country. These techniques generate cartography that can assist in making decisions regarding conservation, preservation, reintroduction, and management of this feline in the face of climate change.

Key words: Biogeographic model; geographic distribution; sentinel species.

La distribución histórica del jaguar (*Panthera onca*) abarcaba desde el suroeste de Estados Unidos hasta río Negro, Argentina (McCain y Childs 2008; Di Bitetti *et al.* 2016; Sanderson *et al.* 2021). Actualmente, solo se localiza en un área de 9.02 millones de km², ocupando el 51 % de dicha distribución histórica (Quigley *et al.* 2017). Si bien su hábitat se caracteriza por una cobertura forestal densa, también se puede encontrar en selvas perennifolias, pantanos, pastizales, matorrales y selvas secas (Sanderson *et al.* 2021). El jaguar es una especie casi amenazada; sus poblaciones están decreciendo y su hábitat se encuentra altamente fragmentado por la actividad antropogénica (Quigley *et al.* 2017). En Arizona y Nuevo México, Estados Unidos, el jaguar ha sido eliminado (Johnson y Van Pelt 2016), mientras que en México ha perdido más del 60 % de su distribución (Chávez y Ceballos 2006), y se ha estimado su densidad poblacional en hasta 6 adultos por 100 km² (Chávez y Ceballos 2006; Ceballos *et al.* 2021).

El modelado de la distribución espacial de especies es una herramienta importante para la conservación de la vida silvestre. Permite no solo identificar los sitios que poseen las condiciones bióticas y abióticas necesarias para la alimentación, desarrollo y reproducción de las especies, sino también comprender los factores que impulsan dicha distribución (Rodríguez-Bustamante *et al.* 2019; López-González y Brown 2002). Para modelar la distribución potencial de una especie, se utilizan algoritmos como MaxEnt, GARP, BIOCLIM, DOMAIN, Mahalanobis y ENFA (Rodríguez-Bustamante *et al.* 2019; López-González y Brown 2002). Estas aplicaciones, en conjunto con técnicas de sistemas de información geográfica, se han utilizado recientemente para evaluar el impacto del cambio climático y la conservación de las especies. Un ejemplo de ello es la evaluación multicriterio, una técnica utilizada para evaluar opciones de manejo, gestión y conservación de especies. Al elegir la mejor estrategia de conservación, se toman en cuenta la viabilidad de la población, la conectividad del hábitat, la mitigación del cambio climático, el costo, la efectividad de la estrategia y la aceptación social (Niño *et al.* 2023). El combinar MaxEnt y evaluación multicriterio tiene múltiples beneficios para el manejo y conservación de las especies, posibilita una evaluación exhaustiva de las amenazas que enfrentan, simplifica la identificación de las acciones adecuadas para su conservación, mitigación ante el cambio climático y contribuye a una distribución más eficiente de los recursos destinados. Por tal motivo, se estimó la distribución potencial actual del jaguar (*P. onca*) en el noreste de México y sur de Estados Unidos, mediante MaxEnt y la evaluación multicriterio para identificar áreas de idoneidad espacial de hábitat.

Área de estudio: El estudio se llevó a cabo en un área de 78,7620.4398 km² entre Arizona, al suroeste de Estados Unidos, y Sonora, Chihuahua y Sinaloa, al noroeste de México. Esta área comprende 5 de las 15 ecorregiones (nivel I) de América del Norte: Desiertos de Norteamérica, Elevaciones Semiáridas Meridionales, Sierras Templadas, Selvas Cálido-Húmedo y Selvas Cálido-Secas (Figura 1a), las cuales presentan similitudes en términos ecológicos y en el tipo, aptitud y cantidad de recursos ambientales (CCA 2021). El área de modelación, M, es el espacio geográfico y ambiental donde se ha registrado la presencia de jaguares y se delimitó de acuerdo con el conocimiento biológico de la especie (Soberón y Townsend Peterson 2005).

Bases de datos y procedimiento. Para la elaboración del modelo de distribución, se descargaron 68 registros de ocurrencia de *Panthera onca* de la base de datos "jaguar observations database" (https://jaguardata.info/; Figura 1a). Se delimitó un área M correspondiente al área de distribución geográfica de Arizona en Estados Unidos y el noreste de México. Se obtuvieron 19 variables bioclimáticas de la página de WorldClim (https://www.worldclim.org/data/worldclim21.html), las cuales incluyen información sobre la temperatura mensual y la precipitación. Estas variables proporcionan una mayor explicación, ya que incorporan tendencias anualizadas y elementos limitantes para la distribución de las especies. La resolución de estas variables es de 30 segundos de arco (~1 km) y están disponibles en la base de datos global de superficies climáticas de WorldClim (Fick y Hijmans 2017).

Las variables climáticas en formato ASCII se homogenizaron por columnas y renglones para ajustar su resolución espacial y se recortaron al área de estudio (Apéndice 1; Pradhan 2016). A continuación, se analizó la correlación espacial de las 19 variables utilizando la correlación de Spearman entre pares de variables. Se eliminaron aquellas con valores de correlación igual o superior a 0.75 (valores entre 0.5 y 0.7 tienden a ser significativos en muestras pequeñas; Morales y Fernández 2020). Además, se realizó un remuestreo bootstrap con 1,000 reproducciones. Las covariables independientes estuvieron presentes en la mayoría de las muestras, mientras que las variables de ruido se encontraron en un menor número de muestras. Se calculó la desviación estándar y el sesgo, con un intervalo de confianza del 95 %, utilizando IBM SPSS Statistics v20.0™ para obtener variables representativas para el área de interés (Torres-Olave *et al.* 2020).

Modelo de distribución potencial. Se utilizó el algoritmo MaxEnt, el cual ha demostrado buenos resultados incluso con pocos datos disponibles (Elith *et al.* 2011). Regularmente, en MaxEnt, los datos se dividen en dos conjuntos, uno para entrenar el modelo y otro para validación. Sin embargo, en casos con tamaños pequeños de muestra, esto no es factible ya que se pierde información significativa (Yackulic *et al.* 2013). Para remediar esto, se realizaron 50 réplicas utilizando bootstrapping. En cada replicación, se generaron particiones al azar de los datos y cada modelo se validó utilizando un porcentaje del 50 % (Moo-Llanes 2021). Con el fin de identificar las variables más relevantes en el modelo, se llevó a cabo una prueba Jackknife (Jain *et al.* 2021).

Se eligió utilizar la salida logística del modelo, donde los valores se interpretan como probabilidades, oscilando entre 0 (ausencia de la especie) y 1.0 (probabilidad de presencia; Norallahi y Kaboli 2021). La evaluación se realizó a través de la curva de Característica Operativa del Receptor (ROC) calculando el área bajo la curva (AUC). Esta medida compara la proporción de falsos y verdaderos positivos. La curva ROC se despliega en dos ejes, X e Y, donde el eje X representa la proporción de falsos positivos (1-especificidad) y el eje Y representa la proporción de verdaderos positivos, también conocida como sensibilidad (Phillips y Dudík 2008).

Después de generar las 50 réplicas, se seleccionó el mejor modelo promediando los valores obtenidos. Se realizó una categorización de los valores utilizando el umbral establecido por MaxEnt: Equate entropy of thresholded and original distributions area (0.9726). Este umbral se utilizó debido a su capacidad para delimitar la idoneidad ambiental en especies de amplia distribución (Merow *et al.* 2013). Además, se calculó el AUC parcial (AUCp) utilizando el paquete ntbox de R, con 1,000 réplicas y un valor de E = 0.05 % (Qiao *et al.* 2019). Las probabilidades por debajo del umbral se transformaron a 0, indicando la ausencia de jaguares, mientras que las probabilidades por encima del umbral se transformaron a 1, representando la presencia de la especie (da Silva *et al.* 2018). Estas transformaciones se llevaron a cabo utilizando el software ArcGIS 10.7.1 de ESRI.

Análisis multicriterio (EMC). La ponderación de criterios se realizó utilizando el método AHP (Saaty 1987). Esta técnica permite asignar pesos a los criterios mediante la comparación de matrices de comparación por pares (Sari 2021). La ponderación muestra la importancia relativa de todos los factores y regula la compensación entre ellos. El propósito de las ponderaciones es expresar la importancia o preferencia de cada criterio en relación con otros criterios (Gkeka-Serpetsidaki y Tsoutsos 2021).

La identificación de criterios y restricciones (Apéndice 2) se basó en teoría, investigación empírica y sentido común. En este caso, los criterios considerados fueron la distancia a ríos y vegetación, mientras que las restricciones fueron la densidad poblacional y la altitud (McCain y Childs 2008; U. S. Fish and Wildlife Service 2016). Para asignar pesos a los criterios, se utilizó el método de la jerarquía analítica (AHP) propuesto por Saaty en 1987. Este método establece una matriz cuadrada en la cual el número de filas y columnas está determinado por el número de criterios a ponderar. Se compara la importancia de cada criterio con respecto a los demás, utilizando una escala de ponderaciones que va de 1/9 a 9 (Apéndice 3).

Con el fin de estandarizar los valores, se convirtieron a una escala que expresa cierto grado de idoneidad, clasificándolos en una escala de 0 a 1. En esta escala, 0 representa nula aptitud y 1 representa máxima aptitud. De esta manera, se pudieron identificar zonas donde los valores son aptos para desempeñar una actividad (Andrus *et al.* 2021). Se utilizó el método de suma ponderada lineal (Cartuche *et al.* 2018), el cual es una operación aritmética simple de tipo compensatorio aditivo. Este método consiste en multiplicar el valor de cada criterio por su peso:

$$r_i = \sum_{i=1}^{n} (w_i \, e_{ij})$$

Donde, r_i es la aptitud de la alternativa i; los valores más altos representan los sitios con mayor aptitud, w_j el peso del criterio j y e_ij es el valor ponderado de la alternativa i en el criterio j.

Para determinar si la matriz es dura, se calcula el λmax = ∑λi, y si este valor es cercano al número de variables independientes (n), la matriz, es consistente. A continuación, se estableció el índice de consistencia (CI), que determina la desviación del vector λmax respecto a n.

También, se calculó el índice de consistencia aleatorio (RCI) λmax - n 1.98*(n - 2), CI = RCI = n -1 n. Y se calculó la relación de consistencia, CR = CI / RCI, en donde, mientras menor sea la relación de consistencia CR, más consistentes son los criterios dados por los expertos. Si CR, es mayor a 0.10 los criterios son inconsistentes (Amarante *et al.* 2021; Apéndice 3). Finalmente, se superpusieron los mapas de los criterios y restricciones a través de la sumatoria lineal ponderada con la herramienta de Spatial Analyst con el módulo de Weighted Overlay en el software ArcGis 10.7.1v de ESRI.

Idoneidad espacial de hábitat. La idoneidad se refiere a la correspondencia matemática o estadística entre la distribución potencial de una especie y un conjunto de factores independientes utilizados como indicadores, en este caso, la evaluación multicriterio (Manzanilla Quiñones *et al.* 2019). Estos factores pueden ser topogeológicos, climáticos, actividades humanas, entre otros, y se espera que algunos de ellos, ya sea de forma individual o en combinación, definan las variables que determinan los ambientes favorables para la presencia de la especie (Chávez Carreto y Serrano 2019).

En este trabajo, se realizó la multiplicación del modelo de distribución potencial por el resultado de la evaluación multicriterio utilizando el álgebra de mapas (Takahashi *et al.* 2020). Se utilizaron shapefiles de las áreas naturales protegidas (ANPs) en México descargados del portal de CONABIO (http://www.conabio.gob.mx/informacion/gis/) y se obtuvo información sobre el hábitat crítico para el jaguar del portal de ECOS Environmental Conservation Online System (U. S. Fish and Wildlife Service 2021; https://ecos.fws.gov/ecp/report/table/critical-habitat.html). Esta información se utilizó para cuantificar la idoneidad espacial del hábitat en estas áreas protegidas y en áreas fuera de ellas en ambos países.

Los modelos se basaron en subconjuntos aleatorios para predecir la distribución de *P. onca*. El valor promedio del área bajo la curva (AUC) para el conjunto de entrenamiento fue de 0.86 (AUCp = 0.8), lo que indica que la capacidad del modelo para clasificar las presencias fue buena. Estos resultados son considerados aceptables y más precisos que un modelo obtenido al azar. Además, la alta AUCp sugiere una

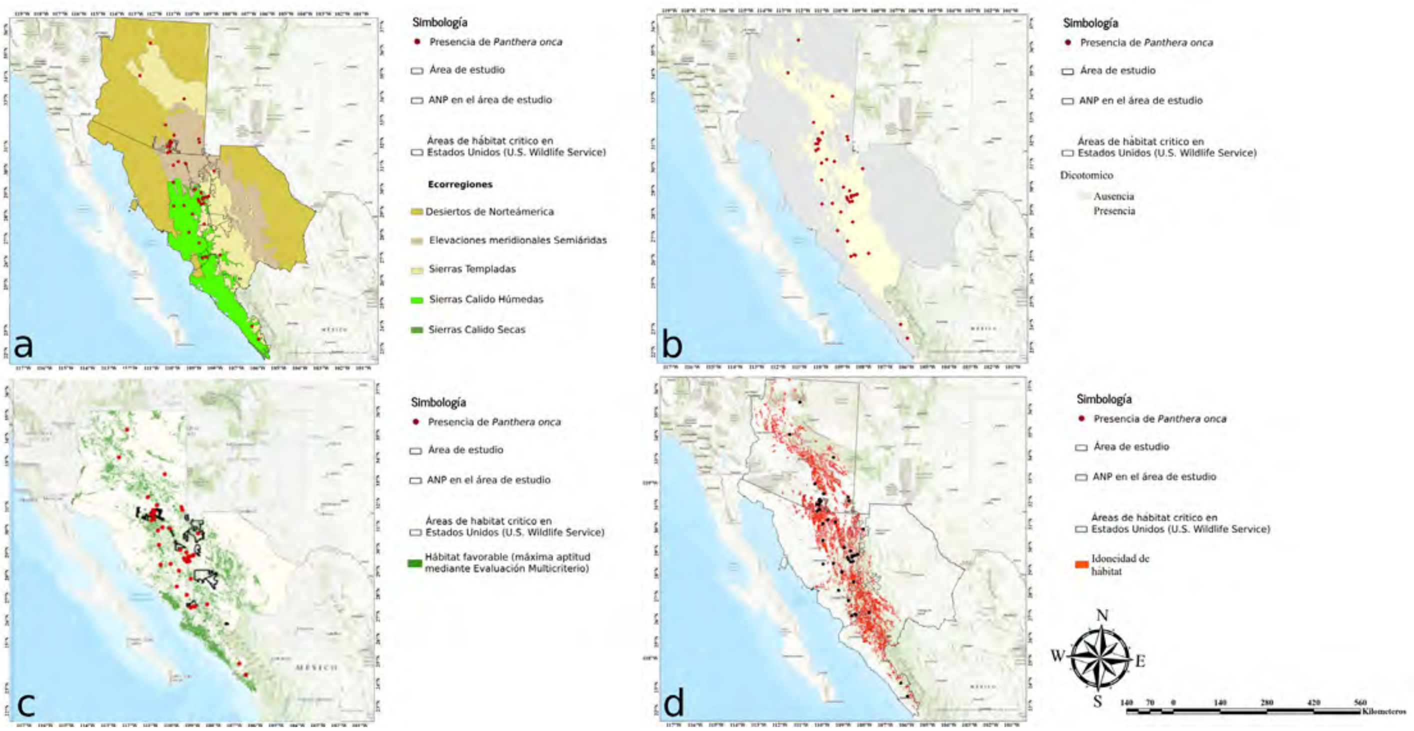

Figura 1. a). Área de estudio. Comprende Arizona en Estados Unidos de América y en México los estados norteños de Chihuahua, Sonora y Sinaloa. Los puntos rojos indican presencia de *Panthera onca*. Fuente: Elaboración propia. b) Modelo de distribución potencial de *Panthera onca* en el área de estudio, el color gris indica ausencia y el amarillo presencia de la especie; los puntos rojos son ocurrencias de la especie. Fuente: Elaboración propia. c) Evaluación multicriterio. Se muestra en color verde el hábitat favorable (máxima aptitud) para *Panthera onca*. Los puntos rojos son ocurrencias del jaguar en el área de estudio. Fuente: Elaboración propia. d) Mapa de idoneidad de hábitat para *Panthera onca*. Muestra el resultado del álgebra de mapas del modelo de distribución potencial y la evaluación multicriterio. Los puntos verdes muestran la presencia de jaguar en el área de estudio, en negro se observa las áreas destinadas para protección de flora y fauna en ambos países. Fuente: Elaboración propia.

correlación entre los registros de la especie y las variables climáticas utilizadas.

En cuanto al mapa binario de distribución potencial (Figura 1b), la cartografía resultante puede interpretarse como áreas de presencia y ausencia (con valores de 0 y 1) en: Arizona, EUA, en los condados de: Mohave, Coconino, Yabapai, Maricopa, Pinal, Gila, Navajo, Graham, Pima, Greenle, Santa Cruz y Cochise; y en México en el estado de Sonora en los municipios de: General Plutarco Elías Calles, Caborca, Altar, Pitiquito, Oquitoa, Tubutama, Sáric, Nogales, Imuris, Magdalena, Santa Ana, Cucurpe, Arizpe, Banámichi, Opodepe, Carbó, Rayón, Ures, Mazatán, Villa Pesqueíra, La Colorada, San Javier, Soyopa, Onavas, Rosario, Cajeme, Suaqui Grande, Guaymas, Empalme, Bácum, Quiriego, Álamos, Yécora, Bacanora, Sahuaripa, Arivechi, Tepache, Divisaderos, Bacadeuáchi, Huásabas, Aconchi, Huepac, San Felipe de Jesús, Moctezuma, Granados, Nácori Chico, Huachinera, Villa Hidalgo, Banámichi, Cumpas, Nacozari de García, Bacerac, Bacoachi, Fronteras, Cananea, Agua Prieta, Bavispe, Naco, Agua Prieta; al oeste de Chihuahua en los municipios de Janos, Casas Grandes, Madera, Temósachi, Moris, Ocampo, Guerrero, Uruachi, Maguarichi, Bocoyna, Chinipas, Guazapares, Urique, Batopilas, Guachochi, Balleza, Guadalupe y Calvo y Morelos; y para el estado de Sinaloa en los municipios de: Choix, El Fuerte, Sinaloa, Badiguarato, Mocorito, Culiacán, Cosalá, Elota, San Ignacio, Mazatlán, Concórdia, Rosario y Escuinapa.

El análisis Jackknife indica que la variable que contribuye más al modelo es la precipitación del cuarto más frío (Bio19), con una contribución porcentual del 63.8 %. Por otra parte, el método de evaluación multicriterio es consistente (CR = 0.0725), lo que indica que los criterios seleccionados para el hábitat del jaguar son adecuados y favorables. El mapa resultante de la sumatoria lineal ponderada (en este caso, los criterios fueron distancia a ríos y vegetación, y las restricciones fueron densidad poblacional y altitud) coincide en su mayor parte con los resultados de la distribución potencial.

La cartografía de idoneidad espacial de hábitat muestra un total de 3,008,179 ha. Las zonas con algún tipo de protección y/o conservación para *P. onca* en ambos países suman un área de 1,750,529 ha, lo que representa el 58.2 % del territorio dedicado a la protección de este felino. Quedan 1,257,650 ha que presentan las condiciones ambientales y físicas para ser consideradas hábitat idóneo casi continuo para el jaguar, tanto en México como en Estados Unidos (Apéndice 4), pero no están incluidas en las áreas de conservación designadas para esta especie en ambos países.

Los pronósticos de los modelos de distribución potencial se consideran indicadores ambientales y proporcionan información sobre el rendimiento de las especies, sus requisitos ecológicos y las condiciones ambientales necesarias para su supervivencia. También son herramientas excelentes para comprender los factores que afectan la distribución potencial de la vida silvestre a diferentes escalas (Tôrres *et al.* 2012; Serna-Lagunes *et al.* 2017).

El modelo generado por MaxEnt fue altamente predictivo de las presencias del jaguar y mostró robustez, siendo considerado aceptable y más preciso que un modelo generado al azar (AUC 0.86; Low *et al.* 2021). En cuanto a la precipitación del cuarto más frío (Bio19), que fue la variable que contribuyó más al modelo, su importancia se puede explicar por su relación con la vegetación. Esta variable influye en la abundancia y distribución de las presas del jaguar, ya que las presas dependen de los diferentes tipos de flora presentes en las áreas predichas por el modelo (De la Torre y Torres-Knoop 2014).

Las valoraciones en la construcción de la evaluación multicriterio fueron buenas, con un índice de consistencia de 0.0725, el cual se encuentra dentro del límite óptimo (Saaty 1987). Este análisis facilita los procesos de toma de decisiones en situaciones que implican juicios y dificultades particulares. Sin embargo, es importante que los expertos compartan opiniones sobre los factores ambientales y criterios más relevantes en la distribución del jaguar, y que se minimicen los valores y pesos derivados para obtener una aproximación más precisa de la disponibilidad de hábitat para la especie. Los resultados de la evaluación multicriterio brindan información fundamental para identificar áreas con probabilidad de presencia de esta especie en el corredor mesoamericano, así como para proponer nuevas áreas prioritarias de conservación (Guerra-Coss *et al.* 2021).

La coincidencia espacial resultante del álgebra de mapas indica la idoneidad del hábitat, es decir, los lugares donde el nicho del jaguar, las condiciones físicas adecuadas y los factores antropogénicos concuerdan, proporcionando un hábitat óptimo para su conservación y preservación. Los modelos y mapas derivados de este tipo de estudios son útiles en la investigación, gestión y desarrollo de estrategias más efectivas para la conservación en áreas de gran extensión (> 100 km; Zharikov *et al.* 2005), lo cual es necesario para mantener poblaciones saludables y sostenibles de este felino (Ceballos *et al.* 2021; Sanderson *et al.* 2021).

Los modelos basados en la distribución potencial y la evaluación multicriterio son herramientas efectivas para abordar los desafíos asociados con las áreas de conservación del jaguar. Estos modelos pueden reducir el esfuerzo de muestreo en campo en zonas inaccesibles o con características específicas de cobertura. La combinación de ambos puede proporcionar una imagen más completa de las áreas idóneas potenciales. Esto puede ayudar a los administradores e investigadores a tomar decisiones informadas sobre la protección de este felino y los ecosistemas que sustentan. En el contexto del cambio climático, estas herramientas pueden ser aún más importantes ya que el cambio climático está alterando los patrones de distribución de las especies, por lo que es fundamental identificar nuevas áreas que proporcionen cobijo a estas especies en un futuro cercano y que permitan la permanencia de poblaciones saludables y permanentes.

Es fundamental recordar que el jaguar está estrechamente vinculado a su entorno y que una evaluación objetiva de su estado de conservación requiere considerar datos ambientales a microescala, como la vegetación y el análisis del paisaje, para predecir su abundancia. Asimismo, es necesario tener en cuenta la biología y ecología del jaguar, ya que desempeña un papel clave como depredador en el control de otras especies y en la dinámica de los ecosistemas. Su presencia es un indicador de la salud del ecosistema y su conservación es esencial para mantener la biodiversidad.

Este enfoque se basó en 3 elementos clave: el uso de insumos públicos para sistemas de información geográfica, el conocimiento experto y la competencia general en el uso de software SIG. Por lo tanto, puede ser fácilmente aplicado por gestores e investigadores dedicados al estudio de fauna silvestre.

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Apéndice 1

Listado de variables climáticas utilizadas en el modelo de distribución potencial. **Variables que se usaron para el modelado de distribución de *Panthera onca*. Spearman (2 tiles), Bootstrap (1000, 95 %) * > 0.70 (no usar).

Código	**Variables ambientales**
BIO1	Temperatura media anual
BIO2	Rango de temperatura media mensual**
BIO3	Isotermalidad (P2/P7) (*100)
BIO4	Estacionalidad de la temperatura (desviación estándar *100)*
BIO5	Temperatura máxima del mes más cálido
BIO6	Temperatura mínima del mes más frío**
BIO7	Rango anual de temperatura (P5-P6)
BIO8	Temperatura media del trimestre más húmedo
BIO9	Temperatura media del trimestre más cálido
BIO10	Temperatura media del trimestre más cálido
BIO11	Temperatura media del trimestre más frío
BIO12	Precipitación anual
BIO13	Precipitación del mes más húmedo
BIO14	Precipitación del mes más seco
BIO15	Estacionalidad de la precipitación (coeficiente de variación)
BIO16	Precipitación del trimestre más húmedo
BIO17	Precipitación del trimestre más seco
BIO18	Precipitación del trimestre más cálido
BIO19	Precipitación del trimestre más frío**

Apéndice 2

Variables usadas para la identificación de idoneidad de hábitat para el jaguar a través del análisis multicriterio.

Variables	Fuente	Importancia (Saaty 1987)	Peso	Criterio para reclasificación
Distancia a ríos	GloRiC proporciona una subclasificación hidrológica, fisioclimática y geomórfica. Ouellet Dallaire, C., Lehner, B., Sayre, R., Thieme, M. (2018): A multidisciplinary framework to derive global river reach classifications at high spatial resolution. Environmental Research Letters. doi: 10.1088/1748-9326/aad8e9 (open access) https://www.hydrosheds.org/page/gloric	8	0.12	Los hábitats cercanos a los cuerpos de agua son más aptos para *Panthera onca*. Prioridad alta en zona de influencia (10 km).
Densidad de población 2020	Gridded Population of the World, Version 4 (GPWv4): Densidad de población, Revisión 11 consiste en estimaciones de la densidad de población humana (número de personas por kilómetro cuadrado) con censos nacionales y registros de población, para los años 2000, 2005 ,2010, 2015 y 2020. Gridded Population of the World, Version 4 (GPWv4): Population Density, Revision 11 https://doi.org/10.7927/H49C6VHW. Accessed DAY MONTH YEAR. https://sedac.ciesin.columbia.edu/data/set/gpw-v4-population-density-rev11	6	0.12	El hábitat que presenta una mayor densidad de poblados son menos aptos para *Panthera onca*; Densidad de población humana mínima o nula
Vegetación	12 clases de cobertura terrestre con una resolución de 1 km. Tuanmu, M.-N. and W. Jetz. 2014. A global 1-km consensus land-cover product for biodiversity and ecosystem modeling. Global Ecology and Biogeography 23(9): 1031-1045. http://www.earthenv.org/landcover	9	0.68	Áreas de bosques y pastizales/arbustos tienen una mayor aptitud para ser consideradas hábitat potencial
Altitud	Se utilizó el GTOPO30 (USGS, 1996) Elevación a 1-km. Fick, S.E. and R.J. Hijmans, 2017. WorldClim 2: new 1km spatial resolution climate surfaces for global land areas. International Journal of Climatology 37 (12): 4302-4315. https://worldclim.org/data/worldclim21.html	6	0.08	Los hábitats localizados en bajas elevaciones son más aptos para *Panthera onca*

Apéndice 3

Ponderación de criterios y determinación de pesos por el método de Saaty (EMC).

	Vegetación	Distancia a ríos	Densidad Humana	Elevación	Wi	Ci	Lambda i
Vegetación	1.00	8	6	6	4.12	0.68	1.00
Distancia a río	1/8	1.00	2	1	0.71	0.12	1.23
Densidad Humana	1/6	1/2	1.00	3	0.71	0.12	1.10
Elevación	1/6	1	1/3	1.00	0.49	0.08	0.89

Apéndice 4

Total de hectáreas en zonas con algún tipo de protección para jaguar en México/EUA.

Nombre	**Área/Has**	**Total, en hectáreas**	**País**
Atascosa	53,127	280,093	EUA
Baboquivari	23,121		
Patagonia	128,827		
Peloncillo	37,673		
San Luis	2,831		
Whetstone	34,514		
Campo Verde	98,829	1470,436	México
Cascada de Bassaseachic	5,370		
Janos	478,609		
Papigochic	205,920		
Sierra de Álamos-Río Cuchujaqui	86,690		
Tutuaca	403,036		
Cerro Mohinora	8,592		
Bavispe	183,390		
Gran total		1750,529	

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Noteworthy record of *Puma yagouaroundi*'s elevational distribution

Registro notable en la distribución altitudinal del *Puma yagouaroundi*

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Despite the wide distribution of the jaguarundi (*Puma yagouaroundi*) in America, it is considered a rare and elusive species from which little is known throughout its distributional range. Its altitudinal distribution ranges from sea level to around 3,200 m, but it generally occurs below 500 m. A direct encounter with a jaguarundi was documented during a routine walk in the Sierra de los Cuchumatanes (Huehuetenango, Guatemala) and specific data on the location, time of day, and behavior of the individual were recorded. We observed and photographed an adult male at 3,559 m in the Parque Regional Municipal Todos Santos Cuchumatán. This is the highest altitudinal record for the species and reflects its plasticity to inhabit in a great variety of ecosystems and climatic conditions.

Key words: Elevation profile; Guatemala; jaguarundi; Sierra de los Cuchumatanes.

A pesar de la amplia distribución del jaguarundi (*Puma yagouaroundi*) en América, es considerada una especie rara y elusiva, de la cual se conoce poco a lo largo de su rango de distribución. El intervalo de su distribución altitudinal es desde el nivel del mar hasta alrededor de los 3,200 m, pero generalmente se encuentra por debajo de los 500 m. Durante una caminata rutinaria en la Sierra de los Cuchumatanes (Huehuetenango, Guatemala), se documentó un encuentro directo con un jaguarundi y se registraron datos específicos sobre la ubicación, la hora del día y el comportamiento del individuo. Observamos y fotografiamos un macho adulto a 3,559 m en el Parque Regional Municipal Todos Santos Cuchumatán. Este es el registro a mayor altitud para la especie y refleja su plasticidad para habitar en una amplia variedad de ecosistemas y condiciones climáticas.

Palabras clave: Guatemala; jaguarundi; perfil altitudinal; Sierra de los Cuchumatanes.

The jaguarundi *Puma yagouaroundi* is a medium-sized carnivore species widely distributed in America. Its distribution ranges from southern United States, throughout México and Central America, to Southern Argentina (de Oliveira 1998; Herrera-Montes *et al.* 2008; Caso *et al.* 2015). It occurs in an altitudinal range varying from sea level to around 3,200 m and in several ecosystems such as arid, dry, tropical, montane, moist and pine-oak forests, swamps, savannas, dry shrubs, grasslands, riparian areas, and subalpine paramos (Cuervo *et al.* 1986; de Oliveira 1998; Herrera-Montes *et al.* 2008; Reid 2009; Solari *et al.* 2013; Caso *et al.* 2015; Nascimento and Lima 2016; Kasper *et al.* 2017; Mármol-Kattán *et al.* 2019).

In contrast to other felids with which jaguarundi coexists, this species has a predominantly diurnal behavior, hunting mainly during the daytime and during the evenings (*e.g.*, jaguar, ocelot, puma). Furthermore, individuals are sparsely distributed and make use of large home ranges (Crawshaw 1995; Michalski *et al.* 2006; de Oliveira *et al.* 2010; Di Bitetti *et al.* 2010; Monterrubio-Rico *et al.* 2012; Nascimento and Lima 2016; Kasper *et al.* 2017). Although they are agile while moving in trees and skillful swimmers, they are considered mainly terrestrial where they hunt a great variety of small vertebrates such as rodents, opossums, rabbits, birds, and lizards (McCarthy 1992; de Oliveira 1998; Tófoli *et al.* 2009; Giordano 2015; Nascimento and Lima 2016; Kasper *et al.* 2017; Escobar-Anleu *et al.* 2020).

The jaguarundi also occurs in disturbed and fragmented habitats including agricultural lands, secondary vegetation near water, and even in secondary forests near great populated areas where they have been observed crossing roads (Guix 1997; Trovati 2004; Lyra-Jorge *et al.* 2007; Tófoli *et al.* 2009; de Oliveira *et al.* 2010; Giordano 2015; Escobar-Anleu *et al.* 2017; González *et al.* 2021). The species is listed as Least Concern in the Red List of Threatened Species of the

International Union for Conservation of Nature (IUCN); however, the current population trend appears to be decreasing (Caso *et al.* 2015). Habitat loss and fragmentation are the major threats for the species, but jaguarundis are also threatened by hunting, road kills and human vandalism (Herrera-Montes *et al.* 2008; Caso *et al.* 2015).

The primary objective of this contribution is to report the highest elevation record for the jaguarundi, exceeding 3,500 m and to document the first observation of the species within the Parque Regional Municipal Todos Santos Cuchumatán, located in the Sierra de los Cuchumatanes, Huehuetenango, Guatemala. Furthermore, this contribution assesses the elevational distribution of the species to better understand the implication of the new record.

The Parque Regional Municipal Todos Santos Cuchumatán is located in the Sierra de los Cuchumatanes, which is located at Todos Santos Cuchumatán municipality, Huehuetenango department, northwestern Guatemala (Figure 1; CONAP 2016). The Sierra de los Cuchumatanes is the highest and largest non-volcanic mountain complex in Northern Central America, as well as the most diverse geological unit in the region, with altitudes ranging from 500 to about 3,900 m (Savage 1982; Donnelly 1989; Donnelly *et al.* 1990). The geological diversity and the broad altitudinal range are reflected in a great variety of ecosystems, such as mountain forest, subtropical pluvial forests, pine-oak forests, coniferous moist forest and subalpine grassland and shrublands (Matson *et al.* 2012; CONAP 2016).

In order to contextualize our observation and to better understand the elevational distribution of the jaguarundi, we performed an elevation profile using the information available in the Global Biodiversity Information Facility dataset (GBIF.org 2023). We downloaded data under the search terms "*Puma yagouaroundi*" and "*Herpailurus yagouaroundi*". Only records with geographic coordinates that could be attributed to a particular collection specimen, photograph, or observation were considered in this study. In total, we found 2,797 specimens and occurrence points.

On April 7, 2022, at 12:38 hr, we observed and photographed an adult male of *P. yagouaroundi* on the northwestern slope of the Parque Regional Municipal Todos Santos Cuchumatán. The observation was made in the subalpine grasslands and shrublands (15° 33′ 35″ N, 91° 35′ 34″ W, WGS84; 3,559 m; Figure 2). We deposited the photograph in the USAC Photographic Mammal Collection (USACF) under collection number USACF00016.

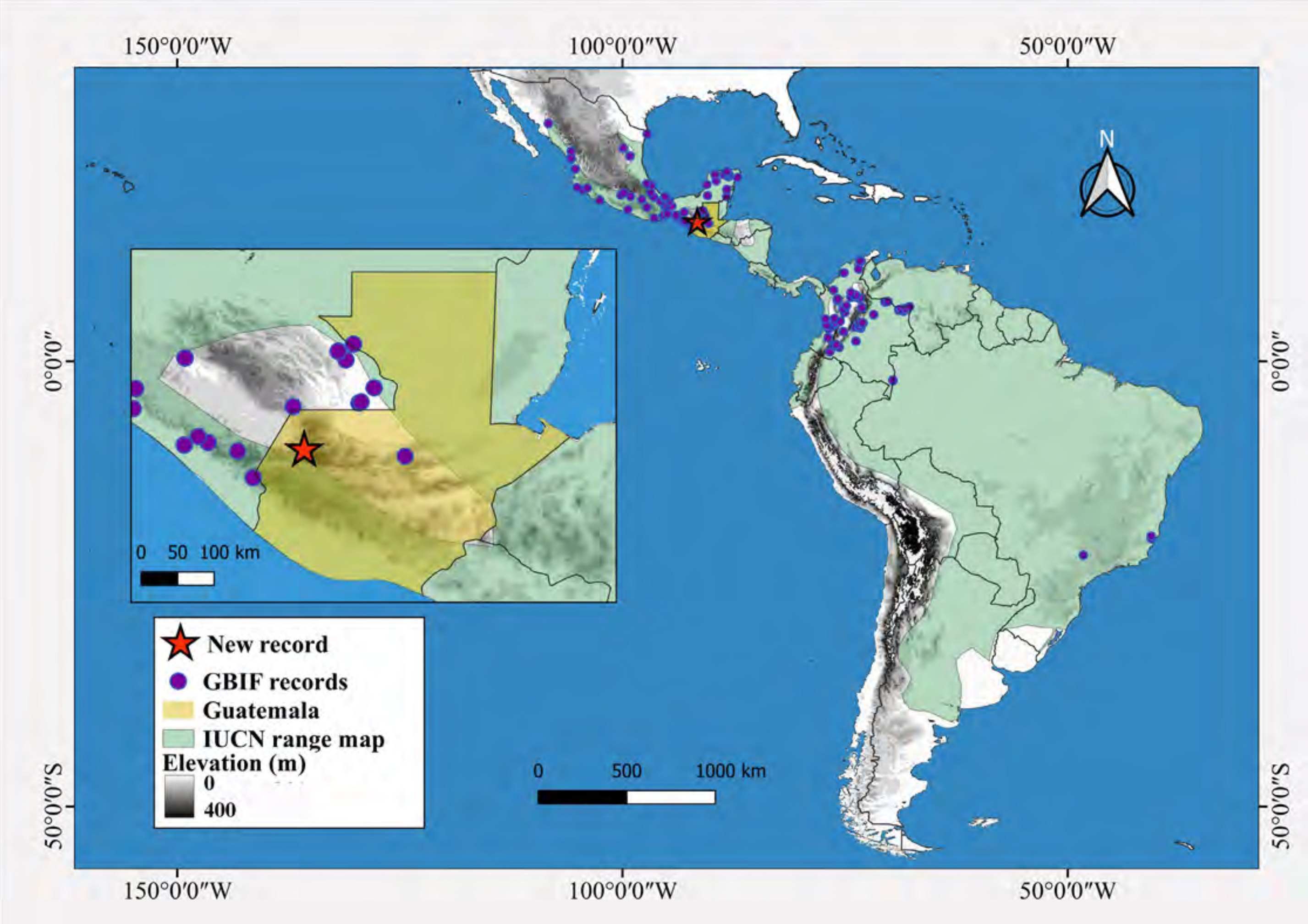

Figure 1. Distribution polygon of *Puma yagouaroundi* in the Americas according to the IUCN (Caso *et al.* 2015). Red star indicates the new record, and blue dots the previous records or collection localities (GBIF.org).

Figure 2. Adult male of *Puma yagouaroundi* in the Parque Regional Municipal Todos Santos Cuchumatán, Sierra de los Cuchumatanes, Huehuetenango, Guatemala. Photograph: E. Matías-Ramos.

Based on the elevation profile, we observed that the 73 % of records along the continent are below 500 m, with the 98.5 % below 2,500 m (Figure 3). To our knowledge, previous to this report the highest elevation record that could be assigned to a museum specimen, or a particular photograph or observation, was at 3,142 m, in Cauca department, Colombia (GBIF.org 2023).

The jaguarundi has a wide altitudinal range distribution with records ranging from 0 to 3,200 m (Cuervo *et al.* 1986; de Oliveira 1994, 1998; Herrera-Montes *et al.* 2008; Solari *et al.* 2013; Caso *et al.* 2015). Cuervo *et al.* (1986) mentioned that in Colombia the species is distributed in moist forest up to around 3,200 m; however, it is important to clarify that the elevation limit is not associated with a particular

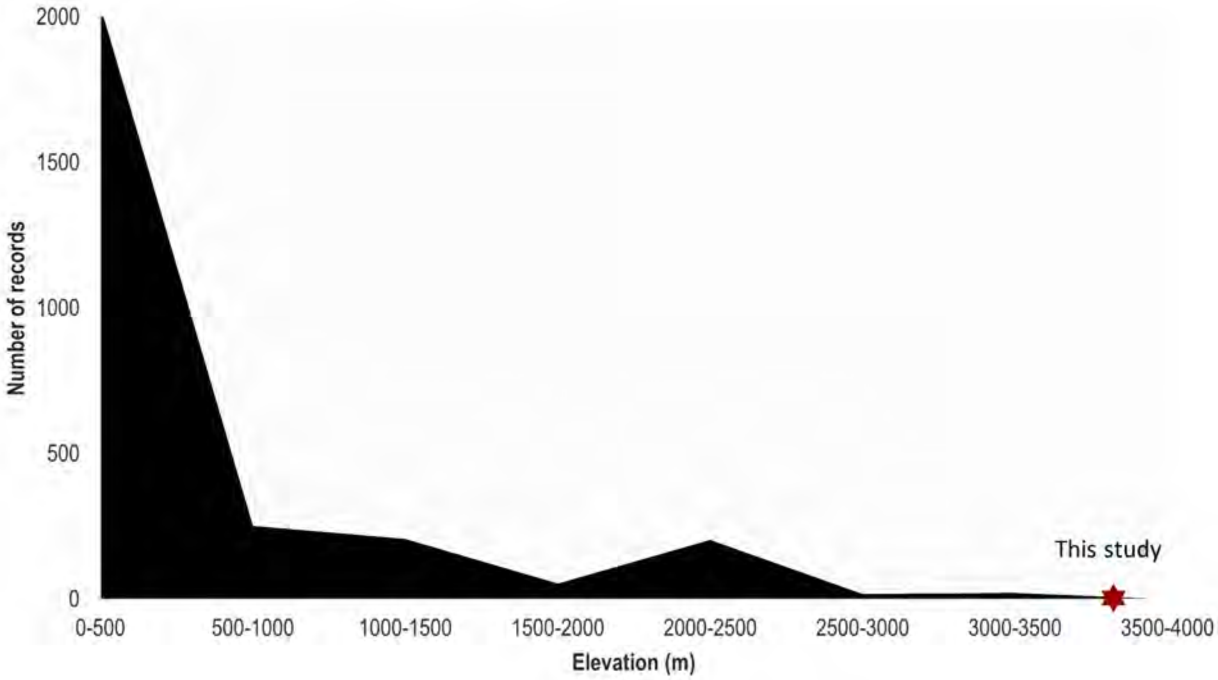

Figure 3. Elevation profile of *Puma yagouaroundi* across its distributional range, based on museum specimens, this study and occurrence records obtained from the Global Biodiversity Information Facility (GBIF).

record or locality. Since the highest altitudinal record was at 3,142 m (GBIF.org 2023), our record increased in 417 m the previously known elevation limit of the species.

Within the distribution range of jaguarundis, this elusive feline has been mostly reported or collected in lowland regions throughout the Americas, where tropical humid ecosystems are predominant. However, there are some jaguarundis reported at elevations above 3,000 m, particularly in Colombia (GBIF.org 2023). Remarkably, it has now been recorded for the first time at elevations above 3,500 m in Guatemala, indicating that the species may have a greater elevational and ecological range than previously thought.

This is the first time that the jaguarundi is recorded in the Sierra de los Cuchumatanes and represents the highest altitudinal record across the species' distributional range. These findings contribute to a better understanding of the ecological and biogeographical distribution of the jaguarundi, which is important for conservation efforts and the management of this species in the region. This study also highlights the importance of monitoring the wildlife of the Sierra de los Cuchumatanes in order to ensure the long-term conservation of its unique habitats.

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A visit to the Mountain of Guerrero; first records of medium and large mammals in Atlixtac, Guerrero, México

Una visita a la Montaña de Guerrero; primeros registros de los mamíferos medianos y grandes en Atlixtac, Guerrero, México

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The Guerrero state is an important area for its high diversity of mammals. However, there are few studies documenting this diversity in the state. Due to the above, the diversity of terrestrial mammals in the Mountain region of the Atlixtac, Guerrero was analyzed. During September 2021 to March 2022 the community of Atlixtac, Guerrero was visited, camera-traps were placed, and walks were conducted. The information obtained was organized and analyzed for abundance and diversity. Fifteen species distributed in 10 families were recorded; of these, 2 species are under protection in the NOM-059-SEMARNAT-2010; *Leopardus wiedii* by photo-trapping (n = 3) and *Herpailurus yagouaroundi* (n = 1) by hunting report. The study area is important for mammals in the Guerrero state, the distribution and knowledge of species such as *L. wiedii*, *H. yagouaroundi* and *S. angustifrons* are expanded. It is important to increase monitoring in the Mountain region of Guerrero, the results obtained indicate a high probability of increasing the number of species in the state. The study area is of ecological importance because it is located within the Sierra Madre del Sur and connects with the Balsas Basin and serving as a biological corridor for various species of mammals.

Key words: Conservation; diversity; *Leopardus wiedii;* mammals*; Spilogale angustifrons*.

El estado de Guerrero es un área importante por su alta diversidad de mamíferos. Sin embargo, pocos estudios documentan esta diversidad de mamíferos en el estado. Debido a lo anterior, en este estudio se analizó la diversidad de mamíferos terrestres la región de Montaña de Atlixtac, Guerrero. Durante septiembre 2021 a marzo 2022 se visitó la comunidad de Atlixtac, Guerrero, se colocaron cámaras-trampa y se realizaron recorridos. La información obtenida se organizó y se analizó la abundancia y la diversidad. Se registraron 15 especies distribuidas en 10 familias; de éstas, 2 especies se encuentran bajo protección en la NOM 059 SEMARNAT; *Leopardus wiedii* mediante foto trampeo (n = 3) y *Herpailurus yagouaroundi* (n = 1) mediante reporte de caza. La zona de estudio es importante para los mamíferos del estado de Guerrero, se amplía la distribución y el conocimiento de especies como *L. wiedii*, *H. yagouaroundi* y *S. angustifrons*. Es importante incrementar el monitoreo en la región de montaña de Guerrero, los resultados obtenidos indican una alta probabilidad de aumentar el número de especies en el estado. El área de estudio es importante ecológicamente porque se encuentra dentro de la Sierra Madre del Sur, conecta con la Cuenca del Balsas y sirve de corredor biológico para varias especies de mamíferos.

Palabras clave: Conservación; diversidad; *Leopardus wiedii*; mamíferos; *Spilogale angustifrons*.

Guerrero, located in southern México, is an important area for wild land mammals. The state possesses a diversity of 71 species of mammals (Flores-Villela and Fernández 1994; Espinosa-Martínez *et al.* 2017). Mammals are important in the dynamics of ecosystems because they participate in processes and interactions that shape their structure and function (Sato *et al.* 2019; Miller and Rabinowitz 2002). In addition, the richness and abundance of wild mammals are frequently used as indicators of the state of conservation of ecosystems (Galetti *et al.* 2015; Macario-Cueyactle *et al.* 2019; Pozo-Montuy *et al.* 2019).

Currently, studies of the diversity of mammals in the Guerrero state have been carried out mainly in the Coastal, Central, and Northern regions of the state (León-Paniagua and Romo-Vázquez 1993; Ramírez-Pulido *et al.* 1977; Almazán-Catalán *et al.* 2005, 2013, 2015; Marín *et al.* 2016; Ruiz-Gutiérrez *et al.* 2020; Briseño-Hernández and Naranjo 2021; Osorio-Rodríguez *et al.* 2021), and particularly for the Mountain region they are scarce (Almazán-Catalán *et al.* 2013; Ruiz-Gutiérrez *et al.* 2020). Due to the above, the objective of this study was to know the diversity and abundance of medium and large wild mammals in the Mountain region of Atlixtac, Guerrero.

The study area is located northwest of the municipality of Atlixtac, Guerrero (17° 37' 52.37" N, 98° 56' 14.15" W), in the geo-cultural region known as La Montaña. It is located at the intersection of the Sierra Madre del Sur and the Balsas Basin. La Montaña region presents rugged orography with vegetation composed mainly of pine-oak in areas > 1,500 m and deciduous forest in areas of lower altitude (Figure 1).

From September 2021 to March 2022, 10 stations (camera traps) were placed at a minimum distance of 800 m and a maximum distance of 4 km between cameras, in an altitude range of 1,400 to 1,812 m. The sampling design was adjusted according to the site conditions following the suggestion of Chávez *et al.* (2013), the camera traps were located near roads, trails, paths and water bodies (Figure 1). The cameras were programmed to obtain day and night photographic records. The photographic records were analyzed according to specialized literature (Ramírez-Pulido *et al.* 2014). Sampling effort was calculated by multiplying the days of camera activity by the number of camera traps. Those individuals registered with 24 hr time gap between them were treated as independent records. The index of relative abundance (IAR) was calculated by dividing the number of photographic records (independent) by the sampling effort (measured in days-trap) and then multiplying by 100 (O'Brien *et al.* 2003; Monroy-Vilchis *et al.* 2011). For *Leopardus wiedii*, individuals were identified based on their pattern of spots on the skin.

Species richness and sampling effort were analyzed with 2 non-parametric estimators (Bootstrap, ACE) using the EstimateS version 9.1.0 program (Colwell 2013). These estimators are intended to reduce the effect of under sampling, which inevitably biases the observed species count. For this purpose, a matrix was created with the number of species as rows and the sampling months as columns; 1,000 randomizations were then run using a bootstrap process. The species accumulation curve was generated from the expected richness (number of species) per month elapsed

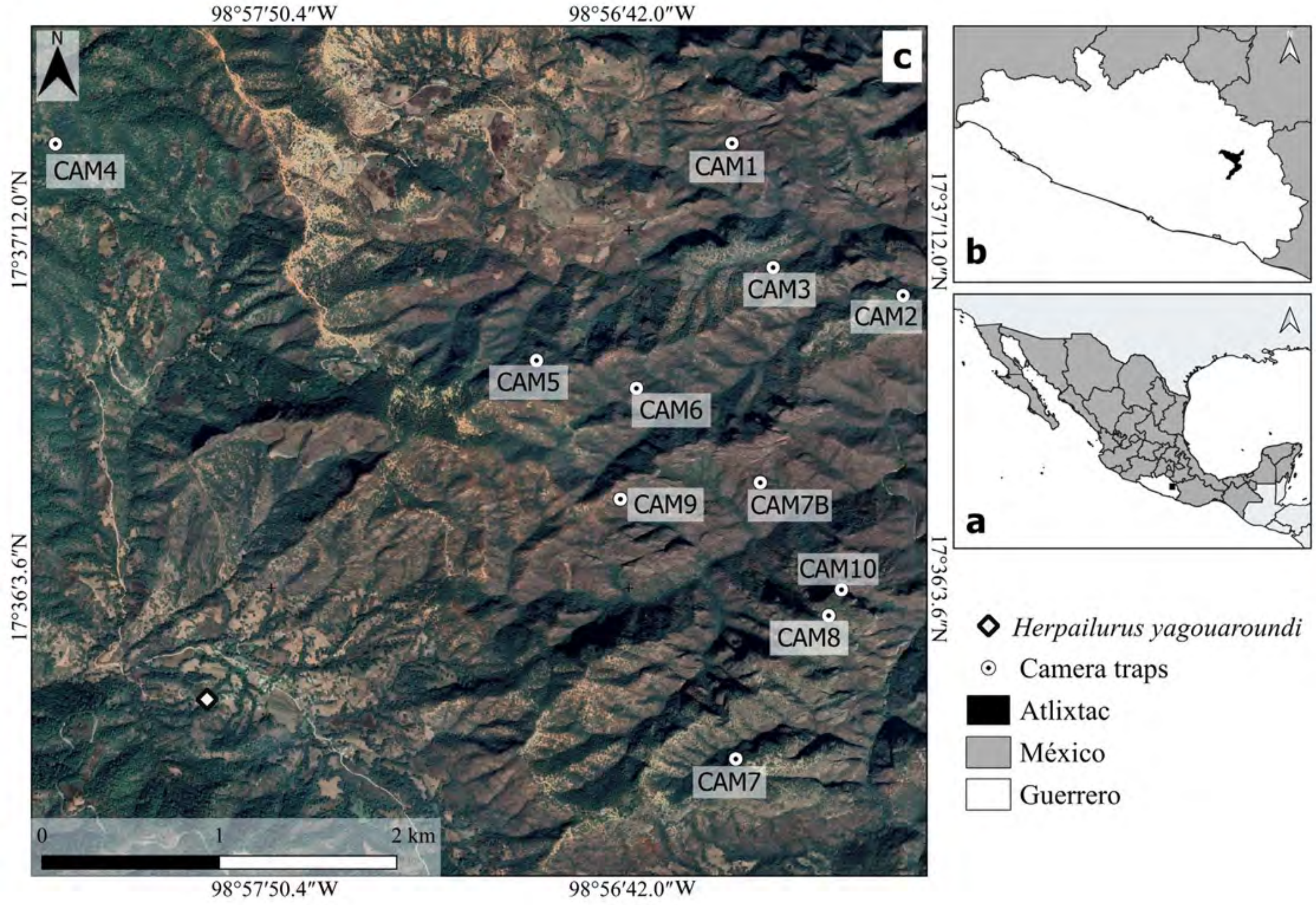

Figure 1. Study area. The map of the sampled area is presented in Atlixtac, Guerrero, México. a) the national location; b) state location; c) location of each camera trap and *Herpailurus yagouaroundi* (in diamond).

in the sampling (Escalante and Morrone 2002). During the first month of sampling, CAM8 was lost and later, in December 2021 CAM10 was missing as well. For this reason, the information was analyzed with the remaining 8. Besides, CAM7 was moved from its original location (CAM7B; Figure 1). A month after the camera traps were removed, a phone call was received notifying us about that a specimen of *Herpailurus yagouaroundi* had been hunted in Ahuitla, an adjacent area to the sampling site, it was added as an additional record in this study.

A sampling effort of 1,504 days-trap was applied, 1,028 photographic records were analyzed, of these, 171 were independent records. Fourteen medium and large sized mammal species distributed in 10 families and 6 orders were recorded, and 1 additional species was recorded with a specimen in the possession of a local inhabitant (*n* = 15; Table 1).

The species accumulation curve did not show a defined asymptote, presenting a high initial growth for the ACE estimator. A richness of 18 species (83 % efficiency) is predicted, so it is likely that additional species will be recorded in the area in the future (Figure 2). Two species under some status protection were registered (SEMARNAT 2010): *L. wiedii* (endangered) and *H. yagouaroundi* (threatened; Figure 3). In the case of *L. wiedii*, 2 different individuals were identified according to their spotting pattern.

The species with highest IAR were: *Nasua narica* (IAR = 4.0) followed by *Odocoileus virginianus* (IAR = 2.8), recorded in all cameras. The species with the lowest records were *Mephitis macroura* (IAR = 0.06) and *Spilogale angustifrons* (IAR = 0.06), with 1 record for each species in CAM6 and CAM7B, respectively (Table 1).

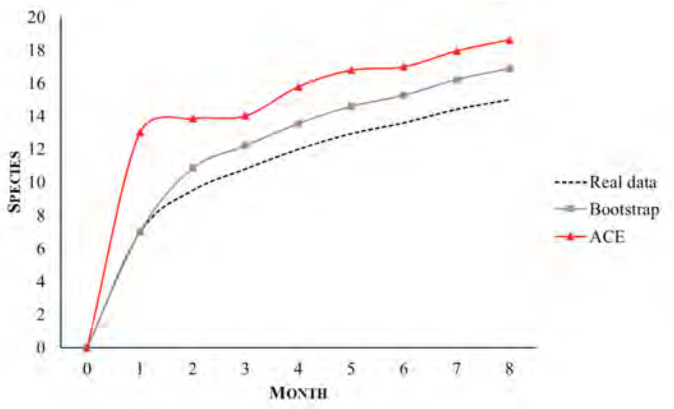

Figure 2. Cumulative curve of mammal species recorded during the period September 2021 to March 2022. The black line represents the non-parametric ACE estimator, the gray line represents the non-parametric Bootstrap estimator, and the dotted line represents the actual values obtained.

The 15 wild terrestrial mammal's species reported here, represent 21 % of the terrestrial mammals reported previously for Guerrero (Espinosa-Martínez *et al.* 2017). Particularly, the records of *Bassariscus astutus* and *S. angustifrons*, for the Guerrero state are scarce (León-Paniagua and Romo-Vázquez 1993; Almazán-Catalán *et al.* 2015; Espinosa-Martínez *et al.* 2017), with this study, both species expand its distribution towards the mountain region of the northeast of the state. Although, the Guerrero state is recognized as a distribution area for *S. angustifrons*, there is not enough information on its abundance and local distribution. Therefore, these first records are relevant in broadening the knowledge of its distribution in Guerrero.

Carnivore species richness (*n* = 9) was higher than that obtained by Pérez-Irineo and Santos-Moreno (2012) in a semi-deciduous forest in northeastern Oaxaca; this suggests the importance of the southern Mexican mountain region, where oak forest and low deciduous forest converge (Altamirano Álvarez *et al.* 2009; Ruiz-Gutiérrez *et al.* 2020).

The abundance data indicates that *N. narica* is the dominant species in the study area; similar values were reported

Table 1. Mammals of Atlixtac Guerrero. Taxonomic list based on the proposal of Ramírez-Pulido *et al.* (2014). Mammals recorded, chamber in which the species was recorded (CAM), independent records (RI) and index of relative abundance (IAR) are presented.

Order	**Family**	**Species**	**CAM**	**RI**	**IAR**
Carnivora	Mephitidae	*Mephitis macroura*	6	1	0.06
		Spilogale angustifrons	7B	1	0.06
	Canidae	*Canis latrans*	2, 4, 5, 6	11	0.73
		Urocyon cinereoargenteus	4, 5, 6, 7	13	0.86
	Felidae	*Leopardus wiedii*	10, 5	3	0.49
		Herpailurus yagouaroundi		1	
	Procyonidae	*Bassariscus astutus*	2, 7	2	0.49
		Procyon lotor	2	3	0.49
		Nasua narica	1, 2, 3, 4, 5, 6, 7,7B, 9, 10	61	4.06
Rodentia	Sciuridae	*Sciurus aureogaster*	3. 7, 9	7	0.46
	Cricetidae	*Peromyscus* sp.	7B	1	0.06
Didelphimorphia	Didelphidae	*Didelphis virginiana*	1, 7B, 9	3	0.19
Lagomorpha	Leporidae	*Sylvilagus cunicularius*	4	6	0.39
Cingulata	Dasypodidae	*Dasypus novemcinctus*	1, 5, 6, 7, 7B, 10	16	1.06
Cetartiodactyla	Cervidae	*Odocoileus virginianus*	1, 2, 3, 4, 5, 6, 7, 7B, 9, 10	43	2.86

Figure 3. Photographic records obtained by camera trapping of *Nasua narica* (a), *Odocoileus virginianus* (b), *Bassariscus astutus* (c), *Leopardus wiedii* (d), *Spilogale angustifrons* (e) and *Herpailurus yagouaroundi* (f) in the community of Ahuitla belonging to the agrarian nucleus of Atlixtac, Guerrero, México.

for Oaxaca (Pérez-Irineo and Santos-Moreno 2010), it is worth noting that none of these study areas in Oaxaca and the present have records of large carnivores, which may explain that the abundance of *N. narica* and *O. virginianus* was influenced by the scarcity of larger predators such as *Puma concolor* (Núñez *et al.* 2000; Hernández 2008). In addition, *N. narica* is an omnivorous species with generalist habits, and in general, both species are tolerant to human activities as long as there are habitat relicts that provide food, water and vegetation cover enough (Mandujano 2004; Torres 2006).

Three records of *L. wiedii* were obtained, these corresponding to 2 different individuals, obtained in low deciduous forest in CAM10 (*n* = 1) and CAM5 (*n* = 2), which were separated by 2.18 km (Figure 1). Previously, *L. wiedii* had been recorded towards the centre of the state (Almazán-Catalán *et al.* 2013; Briseño-Hernández and Naranjo 2021). However, there was no information for the Mountain region.

Species richness in Atlixtac was in the average richness reported by Ruiz-Gutiérrez *et al.* (2020) for landscapes of the Sierra Madre del Sur in Guerrero. However, it is essential to increase sampling efforts in the Mountain Guerrero region. The recorded number of species could potentially increase as residents provide us inputs regarding the presence of other larger carnivores, such as the puma (*P. concolor*) and the wild cat (*Lynx rufus*). Additionally, Almazán-Catalán *et al.* (2013) had documented their presence in La Montaña region through fur records showed by local people.

The finding of *H. yagouaroundi* confirms that a greater sampling effort is required in the study area. Since its conservation status in the state of Guerrero is unknown, and only few records from the coast and centre of the state are known (Ramírez-Pulido *et al.* 1977; Almazán-Catalán *et al.* 2013; Briseño-Hernández and Naranjo 2021), our registry adds information for the northeastern.

This study contributes to the knowledge about the distribution of mammals in the Sierra Madre del Sur, Mountain region in the state of Guerrero, providing the first records of the mammal species for the area. La Montaña region is a great biological area because of its location within the Sierra Madre del Sur and its conection with the Balsas Basin, serving as a biological corridor for mammals' species (Rodríguez-Soto *et al.* 2013; Ruiz-Gutierrez *et al.* 2020).

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Medium-sized mammals in an urban park of Xalapa, Veracruz, México and local knowledge about wildlife

Mamíferos medianos en un parque urbano de Xalapa, Veracruz, México y conocimiento local sobre la fauna silvestre

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Wildlife inventories are key elements for the study of biological diversity and useful tools to increase public awareness on environmental topics. This study provides insights into the medium mammals that roam the Jardín de las Esculturas, a 2 ha park located in the capital of the state of Veracruz, México, in which no previous work on mammals has been conducted. Data was obtained as part of an environmental education-focused project, through camera-trapping stations and informal interviews with park employees. We report as the first time an inventory of medium-sized mammals for this site. A total of 5 orders were registered, 7 families and 10 species, 8 of which are local fauna. None of these species are under any risk category, although the loss of greenspaces and socio-environmental conflicts could eventually lead to their extirpation and local extinction, along with their ecological roles. Employees noted that the human influence of nearby settlements has had several adverse effects on local wildlife. We highlight the importance of this area as a part of the larger archipelago of forests fragments and greenspaces of Xalapa, while also mentioning the relevance of designing environmental education programs to increase public knowledge of local wildlife, their biology and conservation.

Key words: Camera-trapping; greenspaces; species checklist; urban ecology; urban wildlife.

Los inventarios de vida silvestre son herramientas para la investigación biológica que pueden fomentar la conciencia pública sobre temas ambientales. Este estudio proporciona información sobre los mamíferos medianos que deambulan por el Jardín de las Esculturas, un parque de 2 ha ubicado en la ciudad de Xalapa, Veracruz, México, en el que no se han llevado a cabo trabajos previos sobre mamíferos. Los datos se obtuvieron como parte de un proyecto de educación ambiental, a través de fototrampeo y entrevistas informales con los empleados del parque. Reportamos por primera vez un inventario de mamíferos medianos para este sitio. Se registraron un total de 5 órdenes, 7 familias y 10 especies, 8 de las cuales son fauna nativa. A pesar de no encontrarse en ninguna categoría de riesgo, la pérdida de áreas verdes y los conflictos socioambientales podrían eventualmente llevarlas a la extirpación, junto con sus funciones ecológicas. Los empleados reportaron diversos conflictos entre asentamientos humanos vecinos y las especies silvestres registradas. Nosotros destacamos la importancia de esta zona como parte del archipiélago de fragmentos de bosques de Xalapa, al tiempo que mencionamos la relevancia de diseñar programas de educación ambiental que tengan como fin el fomentar la conexión con las especies locales, la difusión de su biología y conservación.

Palabras clave: Áreas verdes; ecología urbana; fauna urbana; fototrampeo; inventario de especies.

Besides their ecological significance, wildlife inventories are useful tools to increase public awareness on environmental topics and establish links between the scientific community and the general public (Aranda 2000; Contreras-Hernández 2008). Providing such information to urban communities is important in regions of accelerated urban development, especially those with high biodiversity (González-García *et al.* 2014; MacGregor-Fors *et al.* 2016). Such is the case of Xalapa de Enríquez, Veracruz, México, a state capital, whose original vegetation was a mosaic composed mainly of cloud forests, as well as tropical dry forests, oak forests, coniferous forests and riparian vegetation (Castillo-Campos 1991; Lemoine-Rodríguez *et al.* 2019).

Xalapa de Enríquez is a city relatively abundant in vegetation (Von Thaden *et al.* 2021). However, disturbed patches of native vegetation are common, with 90 % of the municipality's surface being occupied by urban settlements, coffee plantations, cattle ranching, urban and periurban parks as well as isolated fragments of second-growth forests (Castillo-Campos 1991; Williams-Linera

1992; Williams-Linera *et al.* 2002; Lemoine-Rodríguez *et al.* 2019). The urbanization of this city and its associated reduction of habitat quality has had negative effects on the local fauna, reducing its diversity and increasing their exposure to human-made threats, such as road impacts (MacGregor-Fors *et al.* 2016; Von Thaden *et al.* 2021). In the case of mammals, historically their diversity in Xalapa de Enríquez has decreased by 54 % (from 57 mammal species reported since the end of the XIX century to 26 species) as reported by González-Romero and López-González (1993).

Urban parks are defined by Capitanachi and Amante (1995) as greenspaces surrounded by an urban matrix, with native and exotic vegetation. The role of these spaces as wildlife refuges has been consistently reported in recent years, as well as the negative ecological effects of urban growth (MacGregor-Fors 2010; Pineda-López *et al.* 2010; Bernardo and Melo 2013; MacGregor-Fors *et al.* 2016). One of Xalapa's largest urban greenspaces is the Tejar-Garnica, a 133 ha State Natural Protected Area, which includes on its zonification an urban park called the Parque Natura, and whose vegetation connects with that of adjacent properties and cultural spaces such as the Jardín de las Esculturas (referred to hereafter as JEX).

The dominant vegetation of the Tejar Garnica is represented by second-growth heavily-disturbed cloud forest with an influence of subtropical semi-deciduous forests (MacGregor-Fors *et al.* 2016). In contrast the JEX is a homogeneous greenspace, comprised of a mixture of native reintroduced trees such as sweetgums (*Liquidambar styraciflua*) and sycamores (*Platanus mexicana*), and a vast array of exotic species such as loquats (*Eriobotrya japonica*) and African tulips (*Spathodea campanulata*). Historically, this area had been dominated by agricultural zones, which heavily modified the original vegetation, mainly for the production of shade-grown coffee and secondly for sugar cane plantations and cattle ranching (Castillo-Campos 1991; Williams-Linera 1992; SDR and SEDEMA 2001). This area is considered as part of a broader Natural Protected Area, the Archipiélago de Bosques y Selvas de la Región Capital del Estado de Veracruz. This zone is a biological corridor of connected patches and vegetation islands (SEDEMA *et al.* 2017; Hensler and Merçon 2020).

Due to their background, several stages of ecological succession can be appreciated in both the JEX and the Tejar-Garnica, making them important shelters for urban wildlife (SDR and SEDEMA 2001). Despite this, few studies on medium-sized mammals have been conducted in the area. The most relevant was the management program for the Tejar-Garnica which identified 10 species (SDR and SEDEMA 2001); Mella-Méndez *et al.* (2019a) reports 12 species in 5 urban parks of Xalapa, reporting 7 for the Parque Natura (Mella-Méndez *et al.* 2019b). On a broader study of the suburban areas of Xalapa and Coatepec, González-Romero and López-González (1993) registered 27 species of mammals for the region, their abundance and notes on human-wildlife interactions as well as compiling a list of 57 species of mammal fauna historically reported for the region since the end of the 19th century.

The community of medium-sized mammals is comprised of species with a wide array of behavioral specializations and feeding guilds being best described as species weighting > 100 g, who are able to leave observable indirect evidence (Aranda 2000; García-Burgos *et al.* 2014; Ramírez-Bautista and Lavariega 2021). For México, this classification includes all the species in the orders Artiodactyla, Carnivora, Cingulata, Lagomorpha, Perissodactyla, Pilosa and Primates; and species in the families Agoutidae, Caluromyidae, Cuniculidae, Didelphidae (Order Didelphimorphia), Erethizontidae and Sciuridae (order Rodentia; Aranda 2000; Ramírez-Bautista and Lavariega 2021). Given the role of urban parks and greenspaces as shelters for wildlife, the objective of the present study was to compile for the first time an updated inventory of the medium-sized mammals inhabiting or moving through this space, to contribute to further develop environmental education activities that involve a conservation background.

This study was carried out in the Jardín de las Esculturas, a 2 ha cultural precinct/urban park located in the southeastern zone of Xalapa, which opened to the public in 1998 and is managed by a state dependency, the Instituto Veracruzano de la Cultura (IVEC). It adjoins a high-traffic road on its northwest side (Rafael Murillo Vidal avenue), a small urban settlement on its northeast (Campo Nuevo), and it has connectivity on its southeast and west side with the Tejar-Garnica natural protected area (Figure 1).

This research started on June 2020 as part of a multidisciplinary environmental-education oriented project titled "Flora y Fauna del Jardín", intending to share information about the biodiversity of the JEX and the city of Xalapa de Enríquez, Veracruz with a broader audience through art and science. While conducting a botanical survey, we noticed indirect evidence of mammals, such as feces and tracks. At the same time, testimonies of employees confirmed the presence of at least 4 different mammal species.

From June 2020 to March 2021, we installed 4 camera-trapping stations in patches of second-growth cloud forest, 2 baited with a mixture of sardines and chicken viscera (Orjuela and Jiménez 2004). Two camera traps (Bushnell Trophy Cam) were interchanged in these stations and set to trees at 30-40 cm above ground level, which were separated by 500 m on average on sites identified as possible corridors for mammals. Cameras were programmed to run for 24 hr on hybrid mode, with a delay of 4 sec between photographs and video. Additionally, we conducted 5 unstructured informal talks with 5 employees of the JEX (adults from 28 to 60 years old) to gather additional information on their experiences with local fauna and we presented the results to them to inquire about their knowledge of the listed species.

To identify the photographed species and catalogue their local status, we consulted the guides of Aranda (2000)

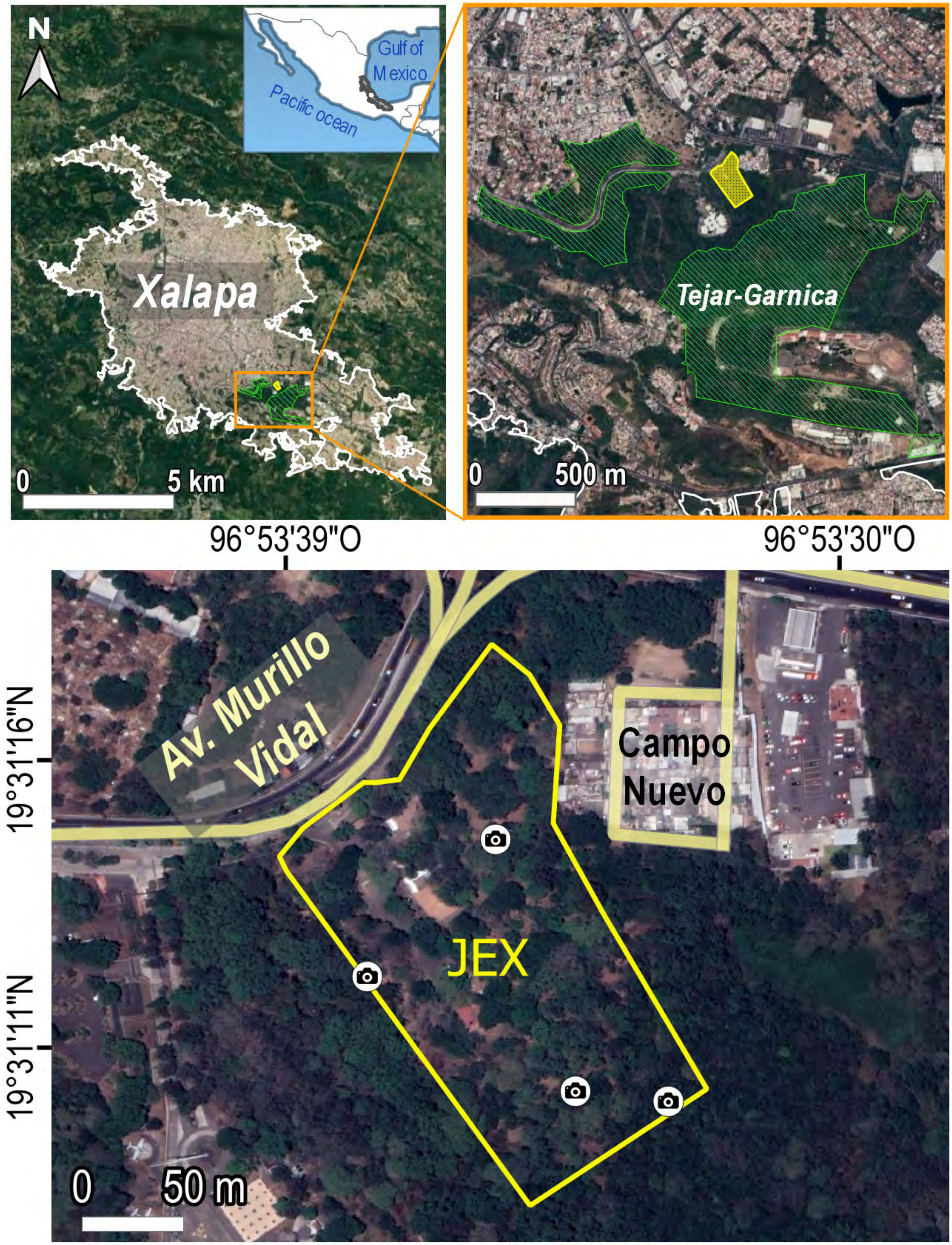

Figure 1. Geographical location of the Jardín de las Esculturas (JEX) in the metropolitan area of the city of Xalapa de Enríquez, in central Veracruz, México. Circles indicate the position of camera-trap stations.

and Reid (2006). Taxonomic nomenclature for the species list follows the proposal of Ramírez-Pulido *et al.* (2014). About their conservation status, we consulted the Mexican Official Norm NOM-059-ECOL-2010 (SEMARNAT 2010) and the red list of the International Union for the Conservation of Nature (IUCN 2019).

During the survey, we recorded 10 medium-sized mammal species, corresponding to 5 orders and 7 families (Table 1; Figure 2). None of the identified species are under any category of protection under Mexican Law nor globally. Two records are of domestic mammals, *Felis catus* and *Canis familiaris*, which roam the JEX at noon and nighttime (at least 3 different dogs were identified in the photographs). Little human activity was registered, mostly accounting to photographs of night guards, due to the space being closed to the public due to the COVID-19 pandemic.

Employees of the JEX recognized 5 out of the 8 native species reported in this study as part of the local fauna: *Dasypus novemcinctus*, *Didelphis* spp., *Sciurus aureogaster*, *Sylvilagus floridanus* and *Urocyon cinereoargenteus*. The other native species photographed (*Bassariscus astutus*, *Philander opossum* and *Procyon lotor*) surprised them, believing that such species were not distributed in this place. During the 5 informal interviews (2 females ages 32 and 67, and 3 males ages 28-55 were surveyed), personal interests, background knowledge of local wildlife and each informant's working schedule were relevant to the information provided. On the topic of human-wildlife interaction, 2-night guards mentioned that opossums (*Didelphis* spp.) are often seen during their work shifts, foraging from trees of guava (*Psidium guajava*), avocado (*Persea schiedeana*) and loquat (*Eriobotrya japonica*) when fruits are available. Armadillos (*D. novemcinctus*) and grey foxes (*U. cinereoargenteus*) are also frequent but harder to spot; cottontail rabbits (*Sylvilagus floridanus*), opossums (*Didelphis* spp.) and squirrels (*Sciurus aureogaster*) were the animals reportedly seen by all 5 of the employees during daytime and early morning after night shifts. The 8 native species registered (including those which caused surprise), were not perceived as negative by those interviewed. It was mentioned that individuals of *D. novemcinctus* were previously captured for consumption by a former employee. Activities such as logging, cattle ranching and hunting for armadillos and rabbits used to be common in the adjacent areas of the Tejar-Garnica during the past century. It was also mentioned that a pair of grey foxes (*U. cinereoargenteus*) were commonly seen in the JEX during the early 2000's, but they were poisoned by the inhabitants of the adjacent human settlement, as collateral damage on an attempt to poison feral dogs and cats.

Table 1. Species list of medium-sized mammals recorded with camera traps in 4 sites of the Jardín de las Esculturas de Xalapa, Veracruz, México. Conservation status according to the IUCN Red List (2019). IUCN categories: (LC) Least Concern.

Species list	Activity patterns	Ecological roles	Records	Conservation status IUCN	Local status
Carnivora					
Canidae					
Canis familiaris	Crepuscular		4		Exotic
Felidae					
Felis catus			2		Exotic
Procyonidae					
Bassariscus astutus		Seed dispersal	11	LC	Native
Procyon lotor		Seed dispersal	1	LC	Native
Urocyon cinereoargenteus		Predation; Seed dispersal	4	LC	Native
Cingulata					
Dasypodidae					
Dasypus novemcinctus	Nocturnal	Seed dispersal	1	LC	Native
Didelphimorphia					
Didelphidae					
Didelphis spp.	Nocturnal	Seed dispersal	75	LC	Native
Philander opossum	Nocturnal	Seed dispersal	13	LC	Native
Lagomorpha					
Leporidae					
Sylvilagus floridanus		Prey	9	LC	Native
Rodentia					
Sciuridae					
Sciurus aureogaster		Seed dispersal	7	LC	Native

The records of ringtails (*B. astutus*), gray four-eyed opossums (*P. opossum*) and raccoons (*P. lotor*; FIgure 2a, 2d, 2e) caused surprise during the interviews, with both ringtails and four-eyed opossums being unknown species to the 5 interviewed employees. The presence of free-ranging dogs had remained mostly unnoticed during the day (Figure 2i), while the presence of cats was reported as common (Figure 2j). In the case of cats, they probably come from an adjacent urban settlement, while dogs most likely live in conditions of abandonment in nearby greenspaces. Both cats and dogs are invasive carnivorous mammals which represent a threat to local fauna of urban and peri-urban greenspaces, affecting the richness, activity and abundance of medium-sized mammals as reported by Mella-Méndez *et al.* (2019b) in 5 urban parks and greenspaces of Xalapa de Enríquez. Such threats can be pointed out by the action of domestic species as predators, competitors and carriers of parasites and diseases (Creel and Christianson 2008; Mella-Méndez *et al.* 2019a, 2019b).

No previous work on mammals had been conducted at the JEX. Nevertheless, for the adjacent natural protected area, the Tejar-Garnica, 7 out of these 8 native species had been reported (SDR and SEDEMA 2001), with the exception of the gray fox (*Urocyon cinereoargenteus*) while for the Parque Natura, the results of this inventory are consistent with the findings reported by Mella-Méndez *et al.* (2019b). All of the recorded species were registered by González-Romero and López-González (1993) as part of the mastofauna of the Xalapa-Coatepec region.

Some of the native species registered in this study (such as opossums, raccoons, and grey foxes) are classified by McKinney (2002) as urban adapters. This group includes some medium-sized omnivores and carnivores, who take advantage of human-subsidized food and other resources in suburban spaces, forest fragments and surrounding greenspaces. Concerning their functional significance, these species play ecological roles such as seed dispersal in second degree forests and acting as prey and predators (Table 1; Chapman *et al.* 1980; Fritzell and Haroldson 1982; Castro-Arellano *et al.* 2000; Cortés-Marcial *et al.* 2014; Medrano Nájera *et al.* 2014; Villalobos Escalante *et al.* 2014; Koprowski *et al.* 2016).

The JEX is a space more widely known for its botanical diversity and cultural appeal, while fauna (in particular mammals) has largely been sidelined, due in part to visitor's difficulties to observe them. The use of camera traps allowed us to record evasive species of mainly nocturnal behavior. Due to the relatively small size of this park and its abundant open spaces, it might be inferred that most of these species do not inhabit directly in the area, but in neighboring grounds, as it occurs in coffee plantations, depending on each species requirements and home ranges (Gallina *et al.* 1996).

This research shows that even small greenspaces surrounded by urban areas can host or act as corridors for local wildlife. However, further studies are needed to gather additional insight into movement dynamics and behavioral patterns of native mammals inside the park and adjacent areas, as well as the human influence on their abundance and biomass. Depending on their roles and interactions, medium and large-sized mammals have the potential to be monitored as indicators of ecosystem health and connectivity (Dirzo *et al.* 2009). The JEX is a recreational space, whose public activities are conducted mostly during the day (on a schedule of Tuesday to Sunday from 10 to 18:00 hr); given the mostly nocturnal and crepuscular activity patterns of the species registered, a significant change on their behavior would not be expected as a result of the post-COVID-19 reopening of the precinct (Reilly *et al.* 2017; Mella-Méndez *et al.* 2019a, 2019b).

While none of the species registered are listed under any category of risk at a national or international level, the local survival of their populations is not guaranteed. Amongst the conservation challenges they face are the proximity to a high traffic road (which divides 2 large sectors of the Tejar-Garnica), the presence of free-ranging exotic species, the proximity to urban settlements and urban growth, which could eventually limit the terrestrial connection between these areas.

Informal interviews provided some insights into the relationship between the neighboring human community and local wildlife, which has mostly been neutral in recent years. Negative situations, such as logging, cattle ranching and poaching reportedly used to occur in the adjacent area of the Tejar-Garnica, with the JEX being undisturbed possibly due to its relatively small size and the presence of employees at all times. Regarding the consumption of mammals, only *S. floridanus* and *D. novemcinctus* were mentioned as prey, while previous reports for the region also mention *P. lotor* and *S. aureogaster* (González-Romero and López-González 1993), which were also recorded on the present study.

Previous studies have mentioned that poaching, cattle ranching, species extraction and logging are still common in the area and that such activities can accelerate local extinctions (SDR and SEDEMA 2001; Hensler and Merçon 2020). For these reasons, it is crucial to enforce and improve municipal and state-level management frameworks that involve different social actors to promote a healthy coexistence between human communities and wildlife (Collins *et al.* 2021). In Xalapa de Enríquez and the central region of Veracruz, advances have been made in participatory management schemes, such as the conservation actions of the Network of Custodians of the Natural Protected Area Archipiélago de Bosques y Selvas de Xalapa (Ayora Vázquez 2020; Hensler and Merçon 2020).

Finally, it is essential to improve conservation awareness amongst the general public, active programs of environmental education can be helpful not only to transmit knowledge and inform about socio environmental problems, but also to enhance public perceptions towards wildlife and the environment (Aranda 2000). As part of the mul-

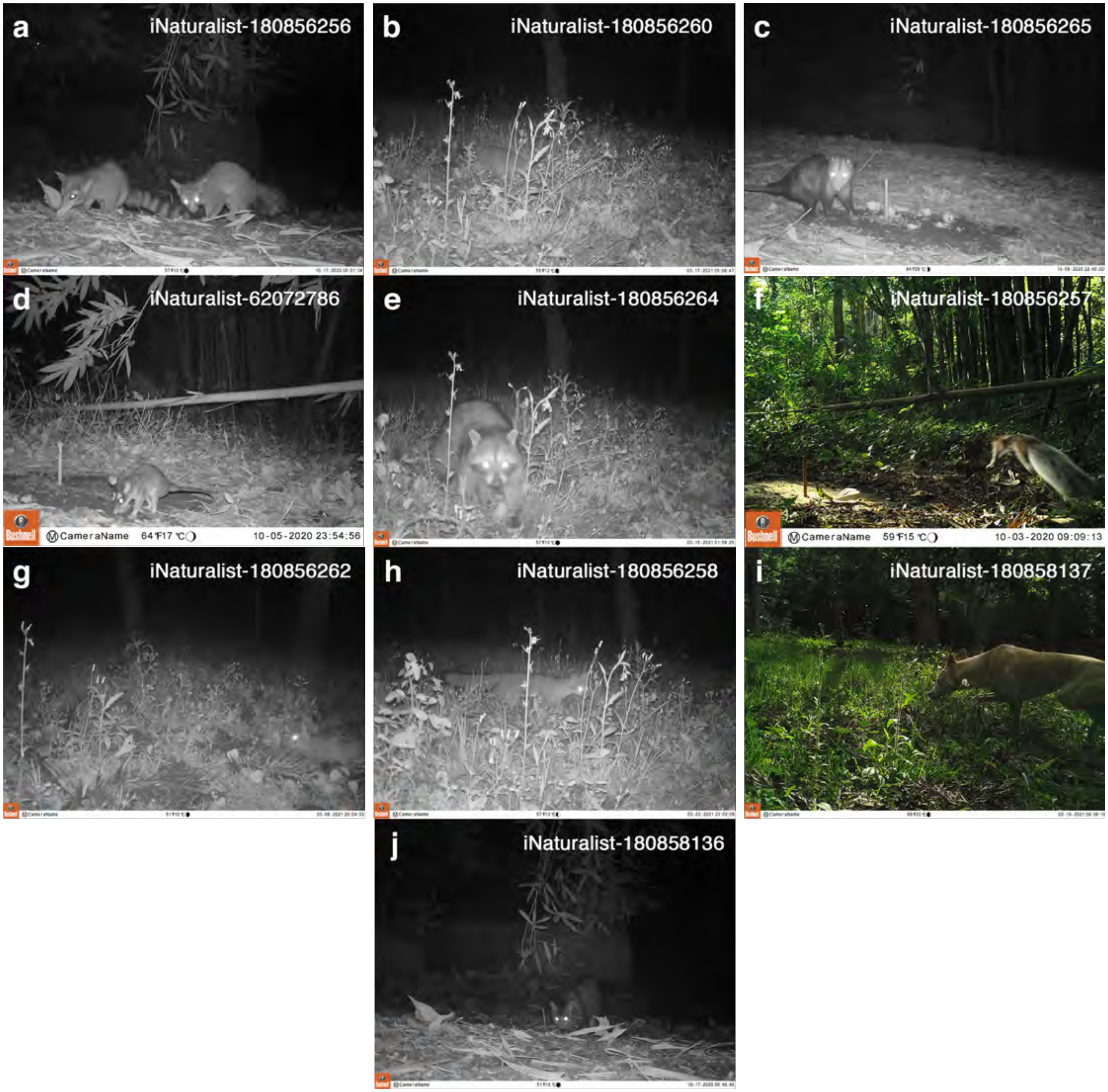

Figure 2. Evidence of medium-sized mammals of the Jardín de las Esculturas de Xalapa, Veracruz, México. Exotic species are i) and j). a) *Bassariscus astutus*, b) *Dasypus novemcinctus*, c) *Didelphis* spp., d) *Philander opossum*, e) *Procyon lotor*, f) *Sciurus aureogaster*, g) *Sylvilagus floridanus*, h) *Urocyon cinereoargenteus*, i) *Canis familiaris*, j) *Felis catus.*

tidisciplinary collaboration with the JEX, and regarding the wild mammal species, 1 children-oriented workshop was conducted and 2 scientific communication materials were produced by the IVEC: a printed guide to the mammals of the cultural precinct, illustrated by Mexican artists (http://www.ivec.gob.mx/jex/recursos/GUIA_DE_MAMIFEROS.pdf) and a short documentary film featuring the audiovisual materials generated through camera trapping (https://www.youtube.com/watch?v=M4nuyG2PhfU). Additionally, a citizen science project is being promoted on the iNaturalist plataform (https://www.naturalista.mx/projects/biodiversidad-del-jardin-de-las-esculturas) and for its 23rd anniversary, the JEX presented Caco, Miztli and Jex, a trio of character mascots inspired by the *B. astutus*, to accompany child-oriented activities and workshops, and as a flagship species to promote the protection of the precinct's greenspace and its wild inhabitants. We hope this study motivates local authorities and the civil society to get involved in active conservation actions.

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Predation of Sumichrast's vesper rat *Nyctomys sumichrasti* by the lizard *Basiliscus plumifrons*

Depredación de la rata vespertina de Sumichrast *Nyctomys sumichrasti* por la lagartija *Basiliscus plumifrons*

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There are 33 Cricetidae species in Costa Rica, including Sumichrast's vesper rat, *Nyctomys sumichrasti*. It is relatively uncommon but potentially locally common to abundant. In Costa Rica, it primarily inhabits the canopy and is rarely seen due to its nocturnal and arboreal habits. In México, it has been observed both in treetops and on the ground amidst dense vegetation and trees. During a tour at Selva Verde Lodge in northern Costa Rica, we observed a predation event. We took pictures of it from about 5 m avoiding disturb the predator. We identified the predator on site, and later we confirmed the prey identification reviewing our pictures and comparing them with other pictures and field guides and taxonomic keys. On March 19, 2023 at 17:28 hr we observed an adult female green basilisk (*Basiliscus plumifrons*) preying and consuming a Sumichrast's vesper rat. The basilisk chased the rat across the floor, grabbed it with its jaws, killed it and then swallow it. The whole process took about 40 min. *Nyctomys sumichrasti* visits buildings at Selva Verde where basilisks are always present. These basilisks are diurnal while *N. sumichrasti* is nocturnal, but they can coincide in activity and location. Recently, a female basilisk hunted a night lizard, and weeks earlier, a male of the same species consumed a young green iguana at the same area.

Key words: Basilisks; Costa Rica; humid forest; rodents; Selva Verde.

En Costa Rica hay 33 especies de Cricetidae, incluida *Nyctomys sumichrasti*, una rata relativamente poco común. En Costa Rica, habita principalmente en el dosel y rara vez se le ve debido a sus hábitos nocturnos y arbóreos. En México, se le ha observado tanto en las copas de los árboles como en el suelo en medio de vegetación densa y árboles. Durante una caminata en Selva Verde Lodge en el norte de Costa Rica, observamos un evento de depredación. Tomamos fotos desde aproximadamente 5 m para no perturbar al depredador. Identificamos al depredador en el lugar y luego confirmamos la identificación de la presa al comparar nuestras fotos con otras imágenes, guías de campo y claves taxonómicas. El 19 de marzo de 2023 a las 17:28 hr, observamos a una hembra adulta de basilisco verde (*Basiliscus plumifrons*) que depredó y consumió una *Nyctomys sumichrasti*. El basilisco persiguió a la rata por el suelo, la agarró con sus mandíbulas, la mató y luego la engulló. Todo el proceso duró aproximadamente 40 minutos. *Nyctomys sumichrasti* visita edificios en Selva Verde lodge donde siempre hay basiliscos. Estos son diurnos, mientras que *N. sumichrasti* es nocturna, pero pueden coincidir en actividad y ubicación. Recientemente, un basilisco verde hembra capturó una lagartija nocturna, y semanas antes, un macho de la misma especie consumió una cría de iguana verde en la misma área.

Palabras clave: Basiliscos; bosque húmedo; Costa Rica; roedores; Selva Verde.

There are 2,652 described species of rodents globally, constituting approximately 40 % of all mammals, thus making Rodentia the most diverse order within the class (ASM 2023). The diversity within this order is attributed to successive radiations, underscoring its adaptive capacity and expansion within the group (Auffray *et al.* 2009). Rodents exploit a vast array of foods and inhabit a wide variety of habitats (Espinoza Medinilla *et al.* 2006). While often considered pests due to their impact on agriculture and potential disease transmission (Mukherjee *et al.* 2004), rodents also serve a significant ecological role as prey for numerous small carnivores (Sillero-Zubiri and Gottelli 1995; Mukherjee *et al.* 2004).

Small rodents are the primary prey of specialized small mustelids (Norrdahl and Korpimaki 2000), while many raptors and predatory birds rely on rodents (Trejo and Guthmann 2003). Additionally, a substantial number of snakes feed on rodents (Zipkin *et al.* 2020). Despite this, only a few lizard species are known to prey on rodents. While collared lizards (*Crotaphytus* spp.; Crotaphytidae) primarily feed on arthropods, larger individuals also capture small vertebrates, including rodents (O'Shea 2021). The black iguana (*Ctenosaura similis*) has been reported as a predator of *Oryzomys*, *Scotinomys*, and *Sigmodon* (Fitch and Hackforth-Jones 1983). Notably, other large lizards such as Helodermids and especially Varanids are known to consume vertebrates, including rodents (Pianka and Vitt 2006; O'Shea 2021).

Cricetidae is the second most diverse family within Rodentia, containing 849 species (ASM 2023). Costa Rica harbors 33 Cricetidae species (Mora and Ruedas in press), including Sumichrast's vesper rat (*Nyctomys sumichrasti* Saussure, 1860). This species is found in lowland and lower montane forests, ranging from Jalisco and southern Veracruz, México to central Panamá, at elevations of 0 to 1,800 m (Musser and Carleton 2005; Reid 2009; Samudio *et al.* 2016).

In Costa Rica, Sumichrast's vesper rat inhabits various forest types, from evergreen to dry and cloud forests, as well as secondary and riverine forests. It's also found near clearings and agricultural areas, such as sugar cane fields (León-Paniagua 2017), throughout the country. Here, it mostly resides in the canopy and it is rarely seen due to its nocturnal and arboreal habits (León-Paniagua 2017). In México, it's been spotted in treetops and on the ground amidst dense vegetation and trees (León-Paniagua 2017). This rat's diet encompasses fruits, seeds, leaves, and insects (Hunt *et al.* 2004). Typically, it forages 3 m or more above ground (Reid 2009). This medium-sized rat measures 102-137 mm in head-body length and weighs 40-67 g (Reid 2009).

Some of the most captivating lizard species in Costa Rica are the basilisks, famously known as Jesus Christ lizards due to their remarkable ability to run on water (O'Shea 2021). Basilisks have been noted as participants in trophic relationships with other vertebrates (Quirós Rosales *et al.* 2023). While some of these predatory interactions might occur frequently, they are rarely observed. Recent reports detail 2 instances: a male green basilisk *Basiliscus plumifrons* Cope, 1875 preying on a young green iguana *Iguana rhinolopha*, Wiegemann, 1834 (Alvarado *et al.* 2022), and a female green basilisk preying on a yellow-spotted night lizard *Lepidophyma flavimaculatum* Dumeril, 1851; Quirós Rosales *et al.* 2023).

Green basilisk's diet primarily consists of arthropods, especially insects, particularly small juveniles (Hirth 1963). However, larger individuals incorporate a notable amount of flowers, seeds, fruits, and leaves into their diet (Hirth 1963; Savage 2002). Nonetheless, adult and sub-adult basilisks occasionally consume vertebrates. Instances include an individual reportedly eating a bat (Hirth 1963), a sub-adult consuming a frog (Cover 1986), and captive individuals consuming small fish (guppies; Kober 2012). Kober (2012) also documented that green basilisk forage in water.

Adult male green basilisks can exceed 900 mm in length, with tails representing 72-75 % of their total length. Males measure 122-250 mm in snout-vent length, while females range from 146-174 mm (Savage 2002; Leenders 2019). Sporting an emerald green color and striking yellow eyes, males exhibit prominent dorsal and tail crests, distinguishing them from smaller female and juvenile counterparts (Savage 2002; Leenders 2019).

Endemic to Middle America, green basilisk is found in humid lowlands at moderate elevations, ranging from sea level to 780 m (McCranie 2018; Leenders 2019). This diurnal species typically inhabits areas near streams, rivers, and along riverbanks, often perching on vegetation, logs, rocks, and bushes (Savage 2002; Leenders 2019). Adult basilisks are highly arboreal, adept at climbing and often found high up in trees (McCranie 2018; O'Shea 2021).

The role of predation is critical in structuring ecosystem function and structure (Berger *et al.* 2001; Kotrschal *et al.* 2017). Most species face the risk of predation at some point in their life (Kotrschal *et al.* 2017). As a result, predation plays a crucial role in establishing feeding connections between species, aiding in the understanding of significant patterns and dynamics within biological communities (Pimm *et al.* 1991; Hall and Raffaelli 1993).

Understanding predation is essential for comprehending animal ecology and behavior. Unfortunately, specific instances of predation, especially on tropical rodents, are scarce in the literature. In this context, we present the first documented case of an adult green basilisk preying on Sumichrast's vesper rat, a significant event given that this is only the second known instance of mammalian predation by this basilisk species, the first being a small bat.

Sarapiquí region, in the province of Heredia, northern Costa Rica, is well-known for its various ecotourism activities (Jones and Spadafora 2017). The region boasts several biological stations and reserves that attract numerous researchers and visitors, significantly contributing to the expansion of knowledge about its biodiversity (Butterfield 1994). During a visit to this region, we conducted a guided tour for general nature observation. While walking the trails of Selva Verde Lodge (10° 27' 03" N, 84° 04' 12" W; 78 m; Figure 1), we witnessed a predation event. We photographed the event from about 5 m avoiding to disturb the predator. We identified the predator on-site and subsequently confirmed the prey's identification by reviewing our pictures and comparing them with field guides and keys by Reid (2009) and Villalobos-Chaves *et al.* (2016).

Selva Verde Lodge is situated in the Tropical Wet Forest (TWF) life zone, which experiences an average annual rainfall of about 4,000 mm (Alvarado *et al.* 2022). The TWF is characterized by tall, multi-stratal, evergreen forest, with some canopy species briefly deciduous. Canopy trees grow to heights of 45–55 m, sporting round to umbrella-shaped crowns and unbranched trunks reaching up to 30 m and measuring 100–200 cm in diameter at breast height (dbh; Hartshorn 1983). The understory often showcases stilt-rooted palms, while the shrub layer stands 1.5–2.5 m tall, frequently with abundant dwarf palms; occasional unbranched treelets and large broad-leaved herbs are also present (Hartshorn 1983).

On March 19, 2023, at 17:28 hr, we observed an adult female green basilisk (*Basiliscus plumifrons*) preying on a Sumichrast's vesper rat at Selva Verde Lodge. The basilisk seized the rat near one of the lodge's buildings, chased it across the floor, captured it with its jaws, killed it, and swallow it (Figure 2). The ingestion of the rat started from the tail and rear, continuing in that direction, without the basilisk attempting to flip it. Thus, the head was the last part of the rat to be swallowed by the basilisk (Figure 2). The entire process took about 40 min, after which the basilisk darted

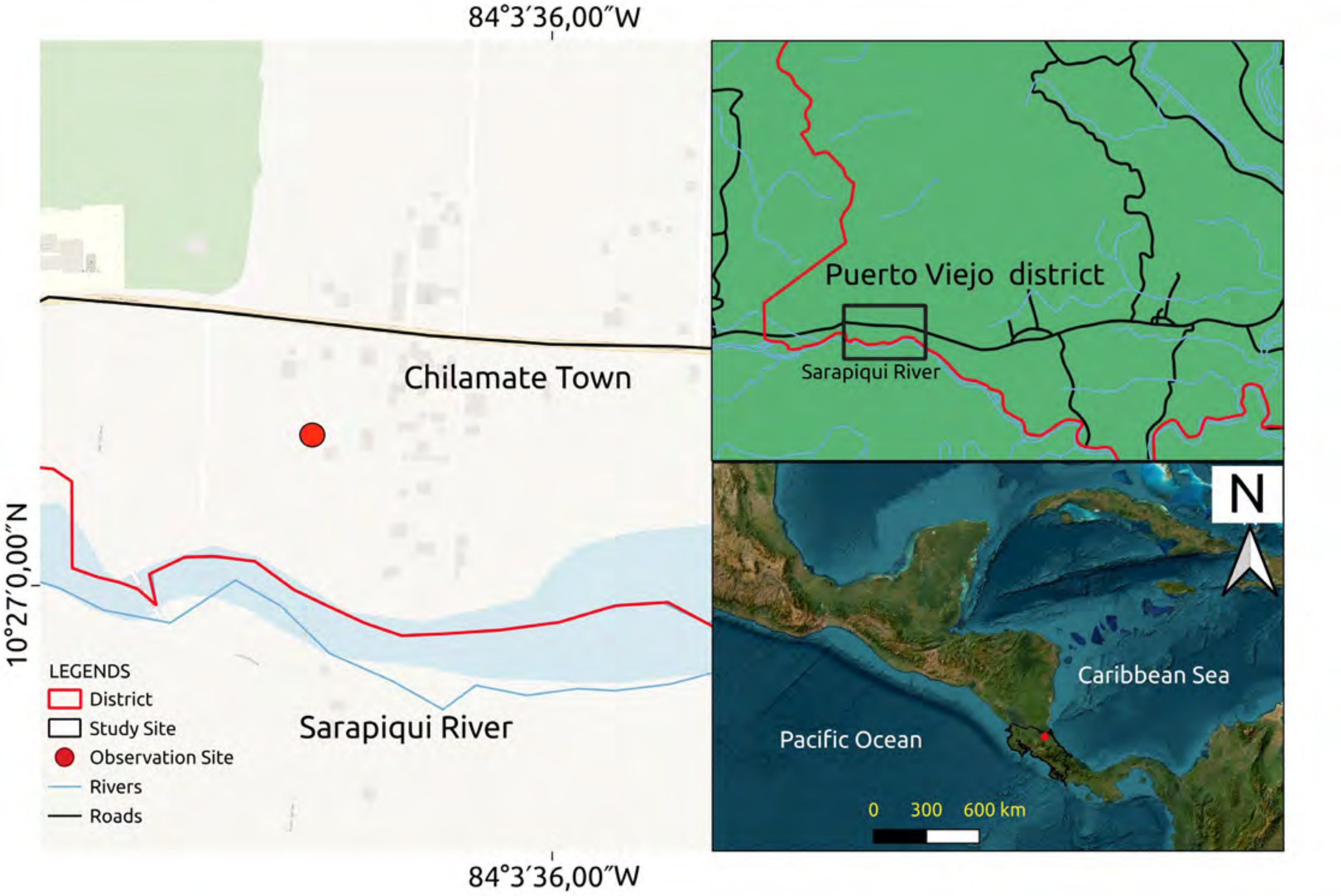

Figure 1. Site (red dot) where a Sumichrast's vesper rat *Nyctomys sumichrasti* was captured and ingested by an adult female green basilisk (*Basiliscus plumifrons*) at Selva Verde Lodge, Sarapiquí, Heredia, Costa Rica. Map by: G. Chaves.

away toward a nearby tree where it is often seen sleeping at night. The female basilisk we are reporting on spent the night in a small tree near one of the lodge buildings. The rat moved on a somewhat slippery, waxed cement floor with limited grip, which may have been a crucial factor in the predation event. The basilisk spotted the rat, which moved but not as quickly as required, allowing the basilisk to capture it. During the time of this event (17:30 hr), the basilisk was still active and vesper rats were commencing their nocturnal activity.

Some reptiles are frequently sighted in the vicinity of Selva Verde Lodge, at the same time, vesper rats are regular visitors to human buildings, where they may encounter predators such as basilisks that are commonly found around the buildings at Selva Verde Lodge (J. M. Mora pers. obs.). Moreover, both species are arboreal and relatively common in the humid forests of Costa Rica's northern lowlands (Timm *et al.* 1989; Alvarado *et al.* 2022). While the green basilisk is diurnal and the Sumichrast's vesper rat is nocturnal, they may overlap in activity hours and locations.

In another event, a female green basilisk captured a night lizard in the area of Selva Verde Lodge, but early in the morning (07:10 hr), a time when both species may coincide (Quirós Rosales *et al.* 2023). Another green basilisk captured a hatchling green iguana (*Iguana rhinolopha*) at 09:36 hr, as both species exhibit diurnal activity (Alvarado *et al.* 2022). In this case, the male basilisk grabbed the hatchling iguana from the back of its body and began eating it, starting from the tail and moving toward the head (Alvarado *et al.* 2022).

Large lizards in the Middle America region, mainly iguanas, ctenosaurs, and basilisks, are primarily herbivorous (Mora 2010; Astorga-Acuña and Mora 2023). However, most of them at least opportunistically consume vertebrate prey (Astorga-Acuña and Mora 2023; Quirós Rosales *et al.* 2023). Basilisks in Mesoamerica are known to prey on several vertebrate species, yet only one mammal predation event was reported, involving a free-tailed bat (Molossidae; Hirth 1963), before this report.

Understanding the structure of food webs contributes to our comprehension of ecosystem function and biodiversity loss (Zeng *et al.* 2014). Despite the high diversity of rodents and lizards in the Neotropics, only a limited number of predation events between these 2 groups have been observed and documented. Therefore, even opportunistic observations such as the one we are presenting here deserve publication, aiming to enhance our understanding of trophic relationships and other ecological roles of small rodents in tropical habitats.

Figure 2. A Sumichrast's vesper rat *Nyctomys sumichrasti* being consumed by an adult female green basilisk (*Basiliscus plumifrons*) at Selva Verde Lodge, Sarapiquí, Heredia, Costa Rica. Photo by: R. Alvarado, and deposited in the UTA Digital Collection (The University of Texas at Arlington) under catalog number: UTADC 9896.

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Philander opossum as prey of *Didelphis marsupialis* in a rainforest in México

Philander opossum como presa de *Didelphis marsupialis* en una selva tropical húmeda en México

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Neotropical rainforests hold a high mammalian diversity with complex species interactions. Opossums are a common group of mammals inhabiting these forests. In México, the common opossum *Didelphis marsupialis* and the four-eyed opossum, *Philander opossum* are sympatric species in these forests. The study site is located at Los Tuxtlas Biological Station in Veracruz, México. We filmed a video *in situ* of an interaction between 2 species of opossums using a cell phone camera. The morphological characteristics of both species of opossums correspond to adult individuals of *D. marsupialis* and *P. opossum*. The video shows an individual of *D. marsupialis* crossing a trail and carrying a corpse of an individual of *P. opossum* in its snout. We document the first report of *P. opossum* as a prey of *D. marsupialis* in a rainforest in México and discuss whether it was due to predation or to an opportunistic encounter of a corpse that was removed for later consumption. *Didelphis marsupialis* is known to act as a scavenger and to hunt other opossum species. Our observations coincide with a study documenting a predation event of *D. marsupialis* over *P. opossum* in Barro Colorado, Panamá, and adds valuable information on *D. marsupialis* feeding habits in tropical rainforests.

Key words: Common opossum; feeding habits; four-eyed opossum; Los Tuxtlas; Veracruz.

Las selvas húmedas Neotropicales albergan una diversidad de mamíferos con interacciones complejas entre especies. Los didélfidos, conocidos como tlacuaches, son mamíferos comunes en estas selvas húmedas. En México, el tlacuache común, *Didelphis marsupialis* y el tlacuache cuatro ojos, *Philander opossum* son especies simpátricas en estas selvas. La zona de estudio se localiza en una selva tropical húmeda de la Estación de Biología Los Tuxtlas, en Veracruz, México. Se filmaron ambas especies de tlacuaches *in situ* usando un teléfono celular. Las características morfológicas de ambas especies corresponden a individuos adultos de *D. marsupialis* y *P. opossum*. El video muestra a un individuo de *D. marsupialis* cruzando una vereda y llevando en su hocico un cadáver, como presa, de un individuo de *P. opossum*. Se documenta el primer reporte de *P. opossum* como presa de *D. marsupialis* en una selva tropical húmeda en México. Se discute si este escenario ocurrió por un evento de depredación, o bien, por un encuentro fortuito con una carcasa que estaba siendo trasladada para su consumo. Se conoce que *D. marsupialis* consume carcasas, aunque también caza otras especies de tlacuaches. Nuestro estudio coincide con observaciones que documentan la depredación de *D. marsupialis* sobre *P. opossum* en Barro Colorado, Panamá y contribuye a proveer información relevante sobre los hábitos alimenticios de esta especie en selvas tropicales húmedas.

Palabras clave: Hábitos alimenticios; Los Tuxtlas; tlacuache común; tlacuache cuatro ojos; Veracruz.

Neotropical rainforests harbor a high diversity of mammals holding complex species interactions. Opossums are a group of mammals that are well represented in these forests (Voss and Jansa 2021). Specifically, México holds 7 species of opossums, among these, *Didelphis marsupialis* and the four-eye opossum *Philander opossum* are sympatric in Los Tuxtlas rainforests and present similar habits (Gardner 1982; Ramírez-Pulido *et al.* 1982; Coates-Estrada and Estrada 1986). Although the differential use of space seems to be a factor that allows the coexistence of species of opossum, some traits such as size and feeding habits, are important features in differentiating their ecology (Leite *et al.* 1996).

The study of the feeding habits of opossums is a fundamental aspect of their natural history (Voss and Jansa 2021). Overall, opossums such as *Didelphis, Lutreolina* and *Philander* are considered omnivorous, and are known to consume large amounts of insects (Sandidge 1953; Leite *et al.* 1996; Cáceres and Monteiro-Filho 2001), crustaceans (González-Ruíz *et al.* 2022), birds (Cordero and Nicolas 1987; Cáceres and Monteiro-Filho 2001), snakes (Cordero and Nicolas 1987; Cáceres and Monteiro-Filho 2001; Niño-Reyes *et al.* 2020), and mammals (*i. e.*, *Felis catus* and *Rattus rattus*; Cordero and Nicolas 1987), including other opossum species (Wilson 1970; Cordero and Nicolas 1987; Macedo *et al.* 2010). Other didelphids are known to prey on species of opossums, such as *Marmosa paraguaya* and *Philander quica* on *Monodelphis* sp. (Macedo *et al.* 2010; Pires *et al.* 2010), and *Lutreolina crassicaudata* on *Marmosa* sp. (Monteiro-Filho and Dias 1990). We report a species interaction between *D. marsupialis* and *P. opossum* in a tropical rainforest in México.

The study site is located at Los Tuxtlas Tropical Biological Station (Los Tuxtlas) in southeastern México. Los Tuxtlas includes a polygon of 644 ha of tropical rainforest surrounded by a landscape matrix of pastures for agriculture and livestock (Coates 2017; Von Thaden *et al.* 2020; Figure 1). Due to deforestation, certain large native mammal species as *Panthera onca* and *Puma concolor* have been extirpated from the region or occur in diminished population abundances as in the case of *Odocoileus virginianus* (Flores-Martínez *et al.* 2014; Ríos-Solis *et al.* 2021). Loss of large predator species for example, is a process that can promote the increase of herbivores and mesopredators abundances (Terborgh 2001). Recent studies in Los Tuxtlas have documented the occurrence of large population abundances of medium-sized mammals, including opossums, such as *D. marsupialis* and *P. opossum* (Ríos-Solis *et al.* 2021; Flores-Martínez *et al.* 2022).

We filmed a video of an interaction between two opossums approximately at 30 km of the Catemaco-Montepío road (18º 34' 59'' N, 95º 04' 06'' W; at 300 m altitude), using an iPhone 8 cell phone camera, and with the help of lighting from a Toyota, Hilux pickup truck (Appendix 1).

The video was taken at 23:24 hr on February 3, 2023, and shows one large opossum crossing a trail, carrying a corpse of another smaller opossum in its snout. The large opossum exhibits a mottled color pattern, showing a distinctive shift in coloration within the first third of the tail; it was identified as an adult of *D. marsupialis*. The smaller opossum has a uniform grayish coloration, with a black tail except for the last third, where it changes to white; it was identified as an adult of *P. opossum*. Despite detecting human presence, *D. marsupialis* continued carrying its prey until reaching the edge of the trail. Once it reaches a vegetation patch, the individual of *D. marsupialis* is observed to pause for a moment to hold its prey more firmly after a maneuvering to avoid a branch that was blocking its path (Figure 2a-c).

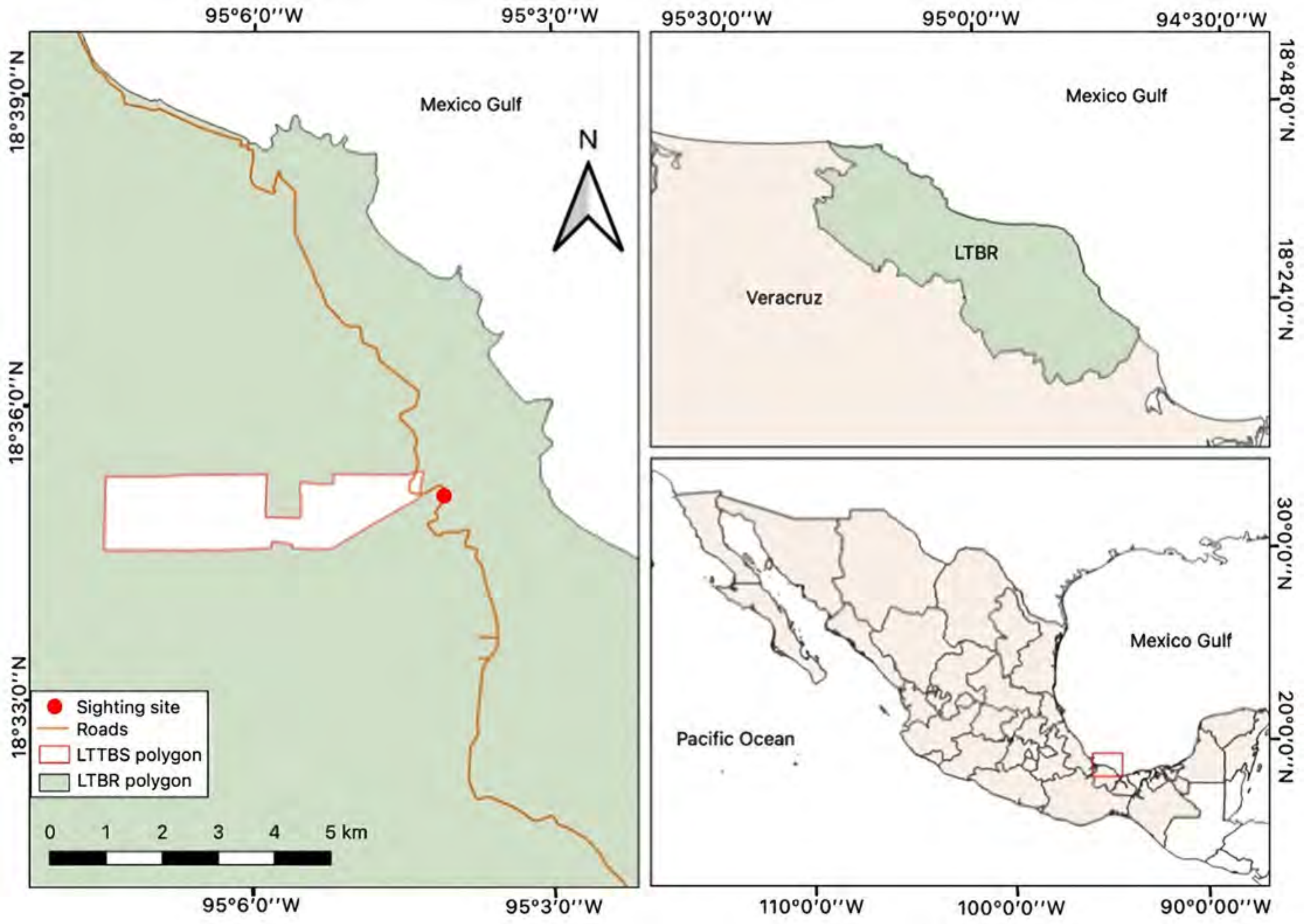

Figure 1. Maps depicting the study site near Los Tuxtlas Tropical Biology Station (LTTBS) and its geographic location within Los Tuxtlas Biosphere Reserve (LTBR), Veracruz, México.

This study reports the first record of direct evidence of an individual of *P. opossum* as prey of an adult individual of *D. marsupialis* at Los Tuxtlas. *Didelphis marsupialis* is known to be an opportunistic species with omnivorous feeding habits (Cordero and Nicolas 1987). We do not know if this episode resulted from a predation event or by encountering a corpse of an adult individual of *P. opossum* and opportunistically removing it. On the other hand, a scenario for a potential predation event is supported by the fact that we observed that the general condition of the corpse of *P. opossum* with an apparent absence of *rigor mortis*, based on the flexibility of its body, suggests that the specimen had not been dead for long. This suggests that, more than being a scavenger event, it could be a hunting event. Moreover, the video was recorded in February, coinciding with the dry season and low fruit production at Los Tuxtlas (Dunn *et al.* 2010). Therefore, it is possible that *D. marsupialis* may resort to hunting as a

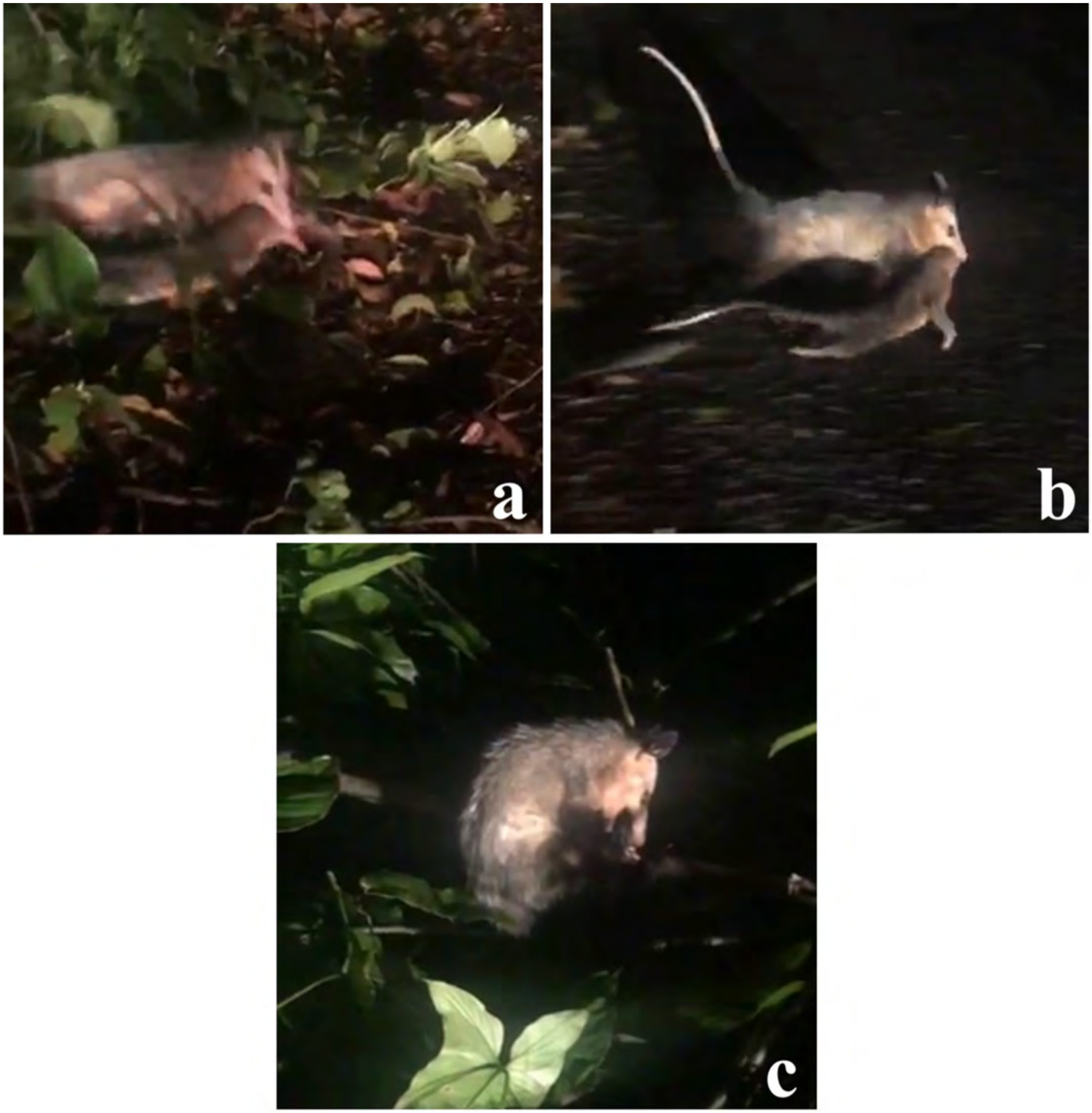

Figure 2. a-c) Sequence of images showing an adult individual of the common opossum, *Didelphis marsupialis* crossing a road and carrying the corpse of an adult individual of the four-eyed opossum, *Philander opossum* in its snout, near Los Tuxtlas Tropical Biology Station, Veracruz, México. Images and video are available in jj@ib.unam.mx and vladimir.rojas@st.ib.unam.mx.

strategy to compensate for the scarcity of other trophic resources, as has been observed in *Didelphis, Lutreolina* and *Philander* (Voss and Jansa 2021). Predation interactions between opossums have been reported on multiple occasions (Monteiro-Filho and Dias 1990; Macedo *et al.* 2010; Pires *et al.* 2010), including a description of confrontation, and the subsequent predation by an individual of *D. marsupialis* on *P. opossum* in Barro Colorado, Panamá (Wilson 1970).

A second possibility is that *D. marsupialis* encountered a corpse of an individual of *P. opossum* and opportunistically removed it to feed elsewhere (Niño-Reyes *et al.* 2020). A scavenging behavior have been documented in other opossum species as *Lutreolina crassicaudata* (Facure and Ramos 2011), *D. aurita* (Carvalho *et al.* 2005), *D. virginiana* (McManus 1974; Hopkins and Forbes 1980; Sandidge 1953), and *D. marsupialis* (Cordero and Nicolas 1987). Further, opossums of the genus *Didelphis* are not fast animals, reaching maximum running speeds of only 7.4 km/h, which can complicate hunting success (McManus 1974). This study documented a fortuitous event of the feeding habits of opossums adding relevant information to their natural history (Leite *et al.* 1996; Flores-Martínez *et al.* 2014; Voss and Jansa 2021; Flores-Martínez *et al.* 2022).

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Appendix 1

Video of an adult individual of the common opossum (*Didelphis marsupialis*) crossing a road and carrying the corpse of an adult individual of a four-eyed opossum (*Philander opossum*), in the rainforest near Los Tuxtlas Tropical Biology Station, Veracruz, México. Video available in https://drive.google.com/file/d/1VjaOCUXYZn3-Y2886ccj-rZVqJfASqlW/

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New records and distributional extensions of *Peropteryx leucoptera*, *Gardnerycteris crenulatum*, and *Lampronycteris brachyotis* in Bolivia

Nuevos registros y ampliación de las distribuciones de *Peropteryx leucoptera*, *Gardnerycteris crenulatum* y *Lampronycteris brachyotis* en Bolivia

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In the last 5 years, the knowledge of bats (Chiroptera) in Bolivia has advanced significantly, adding 10 species and an updated list for the country. Still, some species are represented by a few voucher specimens ($n < 8$), such as *Peropteryx leucoptera* (Emballonuridae), *Gardnerycteris crenulatum*, and *Lampronycteris brachyotis* (Phyllostomidae). Here, we provide new records that extend the geographic distribution of these species in Bolivia, along with morphometric data. Based on specimens collected and deposited in systematic collections, we performed qualitative and quantitative comparisons of external and craniodental variables with the original taxonomic descriptions of the 3 species. We also compiled and projected in maps the localities corresponding to historical records in Bolivia. The new records represent distributional extensions to 10 biogeographic provinces in Bolivia. The specimens of *P. leucoptera* come from the southeastern region of the country. For *G. crenulatum* and *L. brachyotis* we present the southernmost and the easternmost records in Bolivia, respectively. The specimens of *P. leucoptera* tend to be smaller than others collected in the region, while the specimens of *G. crenulatum* are slightly larger than those reported from other countries. The new records extend the known geographic ranges of these species between 197 and 736 km in Bolivia. We recommend increasing efforts to update the geographic distributions of other species with scarce records in Bolivia.

Key words: Chiroptera; Emballonuridae; geographic distribution; mammals; Phyllostomidae; South America.

En los últimos 5 años, el conocimiento de los murciélagos (Chiroptera) de Bolivia ha avanzado significativamente, adicionándose 10 especies y una lista actualizada para el país. A pesar de los avances en el conocimiento de la fauna de murciélagos, algunas especies han sido registradas por pocos especímenes de referencia ($n < 8$), tales como *Peropteryx leucoptera* (Emballonuridae), *Gardnerycteris crenulatum* y *Lampronycteris brachyotis* (Phyllostomidae). Aquí reportamos nuevos registros para estas especies que amplían sus distribuciones en Bolivia y señalamos datos morfométricos adicionales. La revisión incluye especímenes colectados y depositados en colecciones sistemáticas, realizamos comparaciones cualitativas y cuantitativas de variables externas y cráneo-dentales con las descripciones taxonómicas originales de las 3 especies. También compilamos y proyectamos en mapas las localidades correspondientes a registros históricos en Bolivia. Los nuevos registros representan extensiones de distribución a 10 provincias biogeográficas dentro de Bolivia. Los especímenes de *P. leucoptera* provienen de la región sureste del país. Para *G. crenulatum* y *L. brachyotis* presentamos el registro más austral y oriental en Bolivia, respectivamente. Los especímenes de *P. leucoptera* tienden a ser más pequeños que otros colectados en la región, mientras que los especímenes de *G. crenulatum* son ligeramente mayores que aquellos reportados en otros países. Los nuevos registros extienden entre 197 y 736 km los rangos geográficos conocidos para estas especies en Bolivia. Recomendamos incrementar los esfuerzos orientados a la actualización de las distribuciones de otras especies con escasos registros en Bolivia.

Palabras clave: Chiroptera; distribución geográfica; Emballonuridae; mamíferos; Phyllostomidae; Sudamérica.

In Bolivia, the study of bats has shown important advances in the last 5 years as a product of research carried out by a group of mammalogists associated to different national and international institutions. The results include the first records of 10 species (*Peropteryx leucoptera*, *P. pallidoptera*, *Anoura latidens*, *Micronycteris sanborni*, *Gardnerycteris koepckeae*, *Sturnira giannae*, *Molossus fluminensis*, *Eptesicus langeri*, *E. brasiliensis*, *E. diminutus*) and an updated check list of bats known in the country (Poma-Urey *et al.* 2019; Velazco and Patterson 2019; Calderón-Acevedo and

Muchhala 2020; Loureiro *et al.* 2020; Poma-Urey *et al.* 2020, 2021; Acosta *et al.* 2021a; Siles *et al.* 2021; Siles and Wallace 2021; Poma-Urey *et al.* 2023). Some bat species have been reported in Bolivia in very restricted geographic areas or by few voucher specimens. This is particularly true for *Peropteryx leucoptera* (Emballonuridae; 5 specimens), *Gardnerycteris crenulatum* (Phyllostomidae; 7 specimens), and *Lampronycteris brachyotis* (Phyllostomidae; 2 specimens; Aguirre and Urioste 1994; Anderson 1997; Acosta *et al.* 2021b; Poma-Urey *et al.* 2021).

Previous records of *P. leucoptera* in Bolivia are limited to 3 localities in 2 biogeographic provinces: 1) Southeastern Amazon, and 2) Beniana (Navarro 2011; Poma-Urey *et al.* 2021). *Lampronycteris brachyotis* has been recorded in 2 localities in 2 biogeographic provinces: 1) Beniana, and 2) Southwestern Amazon (Navarro 2011; Acosta *et al.* 2021b). *Gardnerycteris crenulatum* has been recorded in 13 localities (some records without voucher specimen) in 4 biogeographic provinces: 1) Southwestern Amazon, 2) South-Central Amazon, 3) Beniana, and 4) Peruvian-Bolivian Yungueña (Anderson 1997; Emmons 1998; Terán 2010; Navarro 2011).

Here, we provide new records and distributional extensions of *P. leucoptera*, *G. crenulatum*, and *L. brachyotis* in Bolivia. To this end, we based our analysis in the recognition of diagnostic characters and morphometric data and compared this information with that of other specimens collected in the region. Finally, we spatially projected the records to provide a geographical context.

The new records of *P. leucoptera*, *G. crenulatum*, and *L. brachyotis* in Bolivia are based on 18 specimens deposited at the Museo Noel Kempff Mercado (MNKM), Santa Cruz, Bolivia. For each individual examined we took external measurements (in mm), including total length (TL), tail length (T), hindfoot length (HF), forearm length (FA), and weight (W) in g. We also took 12 cranio-dental measurements, based on the criteria proposed by Simmons and Voss (1998), Barquez *et al.* (1999) and Díaz *et al.* (2021): greatest length of skull (GLS), condyloincisive length (CIL), condylocanine length (CCL), postorbital breadth (PB), braincase breadth (BB), mastoid breadth (MB), zygomatic breadth (ZB), maxillary toothrow length (MTL), across molars breadth (BAM), across canines breadth (BAC), mandibular toothrow length (LMT), and mandible length (LM).

To identify the specimens, we used the external and cranio-dental measurements, in addition to diagnostic characters. We based the identification on the following authors: *Peropteryx*.- Hood and Gardner (2008), Lim *et al.* (2010), and Velazco *et al.* (2021); *Gardnerycteris*.- Hurtado and Pacheco (2014), Hurtado and D'Elía (2018), and Díaz *et al.* (2021); *Lampronycteris*.- Williams and Genoways (2008), Rocha *et al.* (2013), and Díaz *et al.* (2021). Finally, we compiled the geographic information of the specimens analyzed and documented in the literature, to confirm additional localities of *P. leucoptera* (*e.g.*, Poma-Urey *et al.* 2021), *G. crenulatum* (*e.g.*, Anderson 1997; Emmons 1998; Aguirre 2002; Terán 2010; Siles and Wallace 2021), and *L. brachyotis* (*e.g.*, Acosta *et al.* 2021b). We projected the new records and the historical collection localities in maps and listed the corresponding biogeographic provinces (Appendix 1). The provinces biogeographic are based on Navarro (2011).

We reviewed 18 museum specimens corresponding to *P. leucoptera* (1), *G. crenulatum* (16), and *L. brachyotis* (1); of these, 1 specimen of *G. crenulatum* and 1 of *L. brachyotis* were collected in January 2023 at the Centro de Estudios Alta Vista (Knowledge Bases for Restoration Project).

The new record of *P. leucoptera* (Figure 1a), collected in June 2021, corresponds to an adult male (MNKM 5826; Appendix 1), for which the diagnostic and external morphological characters match: size (FA 39 mm - 48 mm; Hood and Gardner 2008; Lim *et al.* 2010; Velazco *et al.* 2021); translucent wings, gradually darkening to brown from tips to body; and large pterygoid pits (Velazco *et al.* 2021; Figure 1b). In contrast, *P. pallidoptera*, similar to *P. leucoptera*, exhibits translucent and evenly tinged pale brown wings, and smaller pterygoid pits separated by the presphenoid bone (Lim *et al.* 2010; Velazco *et al.* 2021). The external measurements are within the interval of variation of *P. leucoptera*, while cranio-dental measurements tend to be smaller with respect to other specimens in the region (specifically GLS, CIL, CCL, ZB, MTL, and LM; Table 1). The specimen, 1 adult male, MNKM 5826, was collected by L. H. Acosta Salvatierra and J. L. Poma-Urey in July 19, 2021, using mist nets at the entrance of a cave at the department Santa Cruz, San José de Chiquitos, Taturuquí (17° 54´ 25.65” S, 60° 40´38.19” W, 480 m), where the predominant vegetation corresponds to Chiquitano Forest (Figure 2). Other species found in the same cave were *Peropteryx macrotis* and *Glossophaga soricina*. This locality belongs to the Western Cerradense biogeographic province (Figure 2).

For *G. crenulatum*, the new records correspond to adult males (8) and adult females (8); this species differs from other phyllostomids by the following combination of characters: medium size (FA 45 mm - 51 mm); wing membrane attached to the metatarsals; nasal blade with crenulations and hairs; dorsal fur with a faint or marked white line; and presence of 2 lower incisors and 2 lower premolars (Hurtado *et al.* 2014; Hurtado and Pacheco 2014; Díaz *et al.* 2021). It can be differentiated among its congeners by the grayish to blackish brown color of the dorsal fur (reddish or golden brown in *G. koepckeae*) and thin, whitish dorsal line (broad and yellowish in *G. keenani*). *Gardnerycteris crenulatum* exhibits a narrow basioccipital bone at cochlear level and superficial basisphenoid pits, while *G. keenani* exhibits a broad basioccipital and shallow basisphenoid pits (Hurtado and D'Elía 2018). All the specimens reviewed here match the previously described diagnostic characters (Figure 1c). The external and cranio-dental measurements are included in Table 2, all of them within the interval of variation for this species, although Bolivian specimens tend to be larger both externally and cranially with respect to other specimens in the region (Table 2). The specimens were captured with mist nets in 8 lowland localities: Department Santa Cruz:

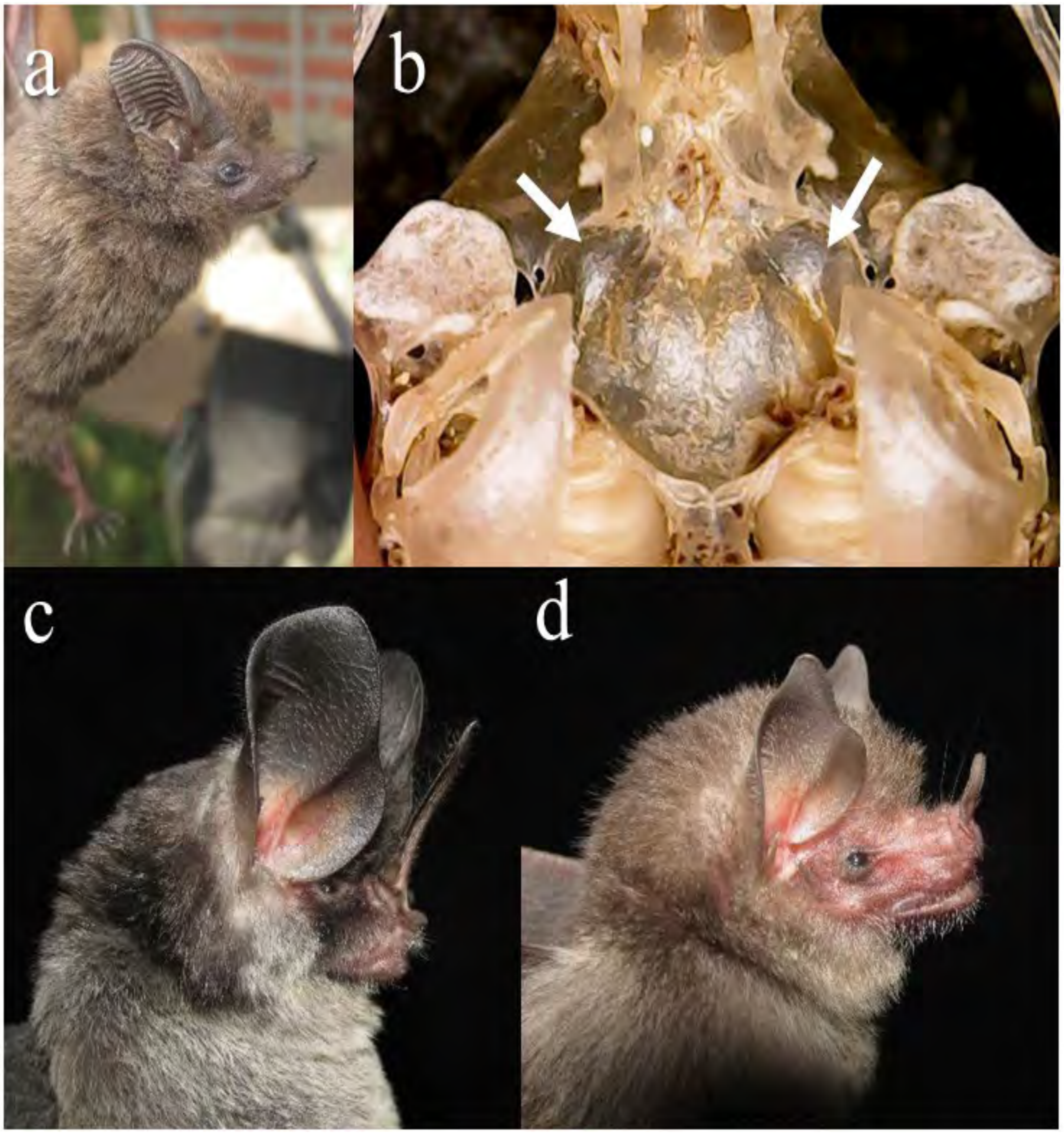

Figure 1. Appearance and morphological characters of bats in Bolivia: a) *Peropteryx leucoptera* (MNKM 5826); b) pterygoid pits (pointed out by white arrows) of *P. leucoptera* (MNKM 5826); c) *Gardnerycteris crenulatum* (MNKM 5823); d) *Lampronycteris brachyotis* (MNKM 5824).

Concepción, Centro de Estudios Alta Vista (16° 5' 29.76'' S, 61° 50' 18.79'' W, 433 m). January 22, 2023. 1 adult male, MNKM 5823. Laguna Marfil (15° 25' 36.54'' S, 60° 18' 22.92'' W, 213 m). October 24, 2019. 1 adult female, MNKM 5815. Área Protegida Municipal Bajo Paragua (14° 0' 36.1'' S, 62° 1' 21.78'' W, 207 m). August 19, 2021. 1 adult male, MNKM 5825. Parque Noel Kempff Mercado, Flor de Oro (13° 33' 10'' S, 61° 0' 51'' W, 172 m). September 21, 1995. 1 adult female, MNKM 1911. Parque Noel Kempff Mercado, Pampa de Termiteros (14° 40' 38.1'' S, 60° 54' 46.22'' W, 189 m). October 11, 2002. 2 adult females, MNKM 3281, 3282. September 13, 2017. 1 adult male, MNKM 5586. Department Beni: Comunidad Maravilla, Lago Largo (12° 54' 44.15'' S, 65° 46' 20.22'' W, 154 m). June 5, 2016. 1 adult male, MNKM 5611. Quiquibey, Tierra Comunitaria de Origen Pilón Lajas (14° 38' 15.7'' S, 67° 30' 38.8'' W, 242 m). June 24, 1999. 1 adult male, MNKM 2845. Reserva Paraba Barba Azul (13° 44' 51.9'' S, 66° 5' 56.9'' W, 156 m). July – Augut, 2010. L. H. Acosta Salvatierra, captured and released 7 specimens, 3 males and 4 females. The specimen MNKM 5823, was collected between 0.5 and 3 m above the ground in Centro de Estudios Alta Vista, in the Western Cerradense Occidental biogeographic province (Figure 2), where the vegetation corresponds to a semi-dry sub-humid forest of Chiquitanía and Beni, affected in 2019 by fires. Other species captured were *Artibeus lituratus*, *A. obscurus*, *Desmodus rotundus*, *L. brachyotis*, and *G. soricina*.

The new record, collected in January 2023, of *L. brachyotis* corresponds to a subadult female (MNKM 5824; Figure 1d). This species exhibits the following diagnostic and external morphological characters: medium size (FA 38.3 mm - 42.5 mm); ears pointed with concave upper outer edge and lacking a connecting skin band; lower lip with a pair of "V"-shaped tubercles; metacarpals gradually variable in length, fifth being shortest; length of the calcaneus equal to or greater than the length of the feet (Williams and Genoways 2008; Díaz *et al.* 2021); GLS between 20.2 mm - 22.8 mm; and upper incisors of chisel-shaped with length less than half the height of the canines (Rocha *et al.* 2013). The most similar species in Bolivia belongs to the

Table 1. Comparisons of external and cranio-dental measurements (mm) and weight (g) of *Peropteryx leucoptera* from Bolivia (MNKM 5826, this study*) with specimens previously recorded in South America: Bolivia (Poma-Urey *et al.* 2021), Brazil (Mikalauskas *et al.* 2014), Colombia (Suárez-Castro *et al.* 2012), Ecuador (McDonough *et al.* 2010), Perú, Guyana, and French Guiana (Lim *et al.* 2010). The values correspond to mean, (interval), and sample size.

	Bolivia*	Bolivia	Brazil	Colombia	Ecuador	Perú	Guyana	French Guiana
TL	62	64.8 (62 - 73) 5	-	67.8 (60 - 82) 5	58 (54 - 62) 2	67 (65 - 69) 5	60 (56 - 66) 6	64 (61 - 66) 6
T	14.5	16.1 (14.5 - 19.0) 4	14.2 (13.4 - 14.8) 3	13.5 (11 - 17) 4	12.3 (12.0 - 12.5) 2	14.6 (13 - 16) 5	10.2 (5 - 13) 6	14 (12 - 17) 6
HF	9	8.4 (5.0 - 10.0) 5	7.6 (6.7 - 8.5) 3	8 (7 - 9) 5	8.5 (7 - 10) 2	9.8 (9 - 10) 4	8.3 (7 - 9) 6	8.9 (8.0 - 10.0) 6
E	16	14.3 (8.5 - 19) 5	15.4 (14.3 - 17.6) 3	16.6 (13 - 18) 5	17.5 (17 - 18) 2	19 (17 - 20) 5	15.5 (13 - 16) 6	16.6 (15.0 - 18.5) 6
FA	42.7	46.4 (44.6 - 48.5) 5	43.5 (42.9 - 44.1) 3	42.4 (39.9 - 44.3) 5	44.3 (42.2 - 46.4) 2	45.4 (45 - 46) 5	42.8 (42 - 44) 6	43.8 (42 - 45) 6
W	5.5	-	8.5 (8.2 - 9.0) 3	-	-	8.3 (8.0 - 8.5) 4	5.6 (4 - 7) 5	6.5 (5.5 - 7.8) 6
GLS	14.59	14.9 (14.4 - 16.4) 5	15.6 (15.4 - 15.7) 3	15.6 (15.1 - 16.1) 2	15.8	-	15.3 (14.9 - 15.6) 3	-
CIL	13.32	-	14.6 (14.2 - 14.9) 3	14.3 (13.8 - 14.7) 2	14.8	-	14.0 (13.9 - 14.1) 3	-
CCL	12.64	14.1 (13.9 - 14.3) 5	-	-	-	-	-	-
PB	3.10	3.4 (2.9 - 3.7) 5	3.4 (3.3 - 3.6) 3	3.5 (3.4 - 3.6) 2	3.4	-	3.3 (3.1 - 3.3) 4	-
BB	6.99	6.8 (6.4 - 7.6) 5	7.4 (7.3 - 7.5) 3	7.1 (6.8 - 7.4) 2	7.1	-	7.2 (7.0 - 7.3) 4	-
MB	7.67	7.9 (7.7 - 8.3) 5	8.1 (8.0 - 8.2) 3	8.0 (7.9 - 8) 2	7.9	-	7.8 (7.6 - 8.0) 4	-
ZB	8.70	-	9.8 (9.5 - 9.9) 3	10.1	10.2	-	9.5 (9.3 - 9.6) 4	-
MTL	5.62	6.3 (6.0 - 6.6) 5	6.3 (6.2 - 6.4) 3	6.5 (6.3 - 6.6) 2	6.5	-	6.1 (6.1 - 6.2) 4	-
BAM	6.36	5.8 (5.3 - 7.6) 5	7.2 (7.1 - 7.2) 3	7.2 (6.9 - 7.5) 2	7.4	-	6.9 (6.7 - 7.0) 4	-
BAC	3.75	3.7 (3.4 - 3.9-9 5	4.2 (4.1 - 4.3) 3	-	-	-	-	-
LMT	5.80	6.5 (5.4 - 7.1) 5	6.5 (6.4 - 6.6) 3	-	-	-	-	-
LM	9.22	10.2 (9.8 - 10.7) 5	11.2 (11.1 - 11.3) 3	-	-	-	-	-

genus *Micronycteris*, and they can be differentiated from *L. brachyotis* by the presence of a skin band between the ears (Williams and Genoways 2008). Another similar species is *Trinycteris nicefori*, but with a body size slightly smaller (FA 37.1 mm - 40.2 mm; GLS 19.5 mm - 20.2 mm), the calcar smaller than the foot, and the upper incisors not chisel-shaped (Rocha *et al.* 2013; Acosta *et al.* 2021b). The specimen MNKM 5824 matches all the diagnostic characters of *L. brachyotis*. However, the external and cranial measurements are outside the lower limit of the interval reported for this species because it corresponds to a subadult (Table 2), with unfused phalanges epiphysis. In addition, it exhibited a soft-textured fur with a chromatic pattern where grayish brown predominates, different from the yellowish color frequently indicated for adult specimens (Figure 1d; Table 1; Williams and Genoways 2008). The specimen MNKM 5824

Table 2. External and cranio-dental measurements (mm) and weight (g) of *Gardnerycteris crenulatum* from Bolivia (this study*), Colombia (Morales-Martínez *et al.* 2020) and other countries of the Neotropics (Brazil, Ecuador, French Guiana, Guatemala, Panama, Perú, Suriname, Trinidad and Tobago, Venezuela; Hurtado *et al.* 2014). The values correspond to mean, (± standard deviation), and sample size. For *Lampronycteris brachyotis*, the values include the data here reported (MNKM 5824, this study*) and those of previous records from Brazil and Bolivia (Brandão *et al.* 2016; Acosta *et al.* 2021b). The values correspond to mean, (interval), and sample size.

	Gardnerycteris crenulatum			*Lampronycteris brachyotis*		
	Bolivia*	**Colombia**	**Neotropics**	**Bolivia***	**Bolivia**	**Brazil**
TL	90.0 (± 12.26) 9	79.7 (± 6.64) 18	84.1 (± 3.80) 95	63	74.3 (64.5 - 84.1) 2	63.1 (54.7 - 68.1) 5
T	24.2 (± 1.66) 9	23.2 (± 2.86) 19	23.3 (± 2.54) 96	11	10.8 (10.0 - 11.6) 2	10.7 (8.2 - 12.0) 5
HF	11.9 (± 1.59) 9	10.5 (± 0.90) 12	11.6 (± 1.30) 96	12	12.2 (12.0 - 12.4) 2	11.0 (10.0 - 12.0) 5
E	26.6 (± 1.59) 9	23.4 (± 1.98) 19	24.0 (± 1.57) 96	16	14.4 (11.5 - 17.3) 2	14.9 (13.9 - 18.0) 5
FA	50.0 (± 1.68) 16	47.6 (± 1.79) 19	48.0 (±3.39) 96	38.23	41.8 (41.5 - 42.1) 2	40.7 (39.8 - 42.3) 5
W	15.1 (± 3.35) 7	-	-	8	13.3 (12.5 - 14.0) 2	14.1 (12 - 18) 4
GLS	21.9 (± 0.46) 6	21.8 (± 0.55) 26	21.5 (± 0.68) 92	20.20	21.5 (21.4 - 21.6) 2	21.2 (21.1 - 21.3) 2
CIL	19.7 (± 0.38) 6	19.3 (± 0.47) 26	19.1 (± 0.61) 91	17.83	19.6	-
CCL	19.0 (± 0.45) 6	-	-	17.01	18.9 (18.9 - 19.0) 2	-
PB	4.1 (± 0.15) 6	4.2 (± 0.14) 26	4.3 (± 0.16) 91	5.24	5.1 (5.1 - 5.2) 2	5.1 (5.0 - 5.1) 2
BB	8.7 (± 0.32) 6	8.2 (± 0.21) 26	8.7 (± 0.38) 91	8.56	8.9 (8.7 - 9.1) 2	8.9 (8.8 - 9.1) 2
MB	11.9 (± 0.39) 6	11.2 (± 0.37) 26	9.7 (± 0.35) 92	9.20	9.8 (9.5 - 10.1) 2	10.1 (10.1 - 10.1) 2
ZB	12.2 (± 0.42) 6	11.8 (± 0.32) 25	12.1 (± 0.46) 90	9.05	10.8 (10.7 - 10.9) 2	11.0 (10.7 - 11.2) 2
MTL	7.9 (± 0.14) 6	7.8 (± 0.21) 26	7.9 (± 0.23) 92	7.55	8.6 (8.4 - 8.8) 2	8.3 (8.3 - 8.3) 2
BAM	8.6 (± 0.15) 6	8.1 (± 0.17) 26	8.3 (± 0.30) 92	6.40	7.2 (7.1 - 7.3) 2	7.1 (6.9 - 7.3) 2
BAC	5.3 (± 0.23) 6	5.3 (± 0.16) 26	5.3 (± 0.22) 92	3.80	3.9 (3.6 - 4.2) 2	4.1 (4.0 - 4.3) 2
LMT	8.7 (± 0.17) 6	-	8.9 (± 0.27) 91	7.68	8.8 (8.6 - 9.0) 2	-
LM	13.5 (± 0.31) 6	-	13.9 (± 0.50) 91	12.79	14.3 (14.0 - 14.6) 2	14.1 (13.9 - 14.2) 2

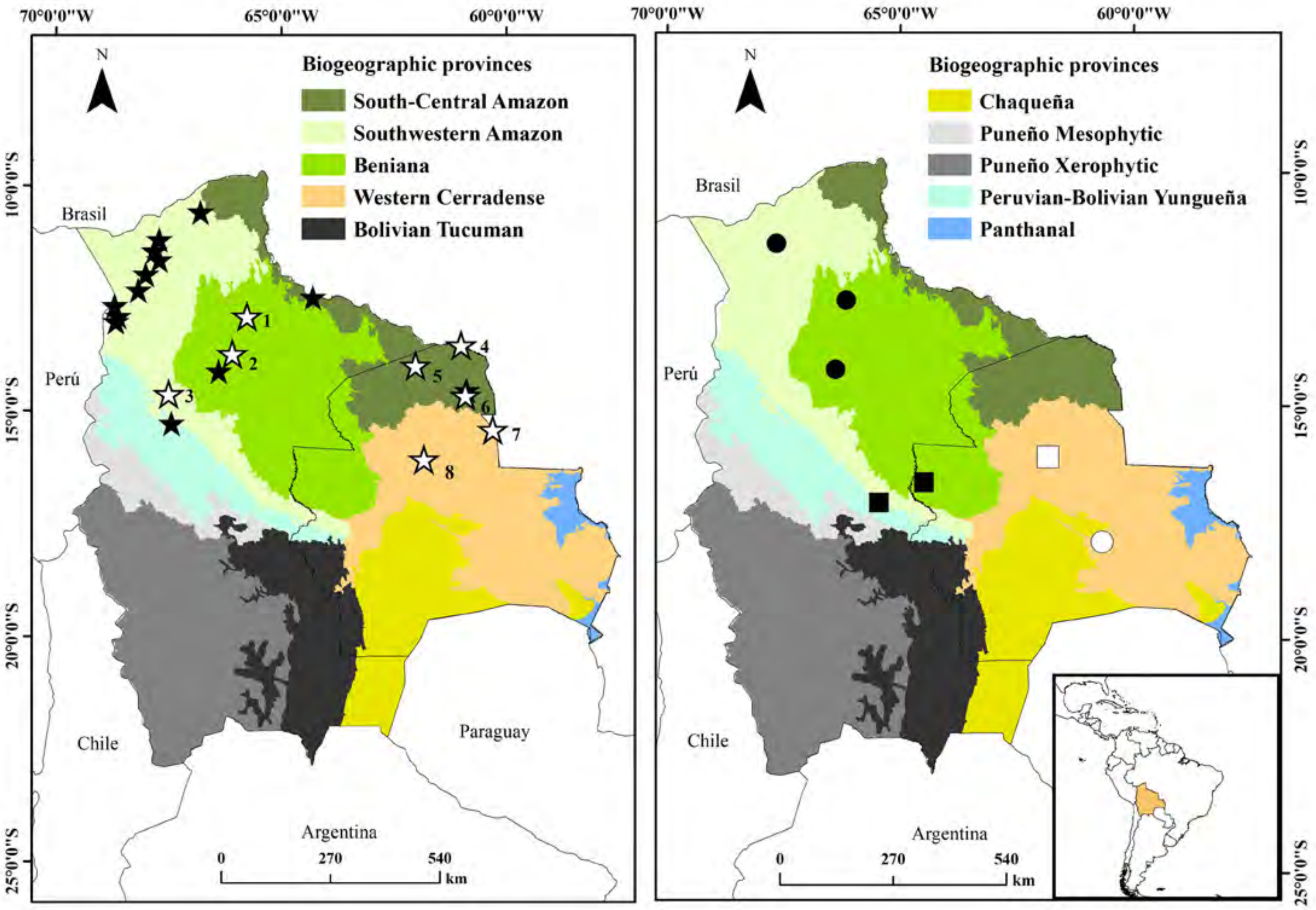

Figure 2. Collection localities in Bolivia of *Gardnerycteris crenulatum* (left; white stars = new record, black stars = previous records), *Peropteryx leucoptera* (right; white circle = new record, black circles = previous records), and *Lampronycteris brachyotis* (right; white square = new record, black squares = previous records). The biogeographic provinces were defined according to Navarro (2011). The new localities of the 3 species are, for *G. crenulatum*: 1) Comunidad Maravilla, Lago Largo, 2) Reserva Paraba Barba Azul, 3) Tierra Comunitaria de Origen Pilón Lajas, 4) Parque Noel Kempff Mercado, Flor de Oro, 5) Área Protegida Municipal Bajo Paragua, 6) Parque Noel Kempff Mercado, Pampas de Termiteros, 7) Laguna Marfil, and 8) Centro de Estudio Alta Vista; *P. leucoptera*: Taturuquí, San José de Chiquitos; and *L. brachyotis*: Centro de Estudio Alta Vista.

was captured with mist nets in Centro de Estudios Alta Vista (16° 5´ 29.7" S, 61° 50´ 18.8" W, 433 m). Mist nest was located on the banks of a water dam where dominant vegetation is Chiquitano Forest, corresponding to the Western Cerradense biogeographical province. Other species captured were *A. lituratus*, *A. obscurus*, *D. rotundus*, *G. crenulatum*, and *G. soricina*.

The new records increase the knowledge on the current distribution of bat species poorly documented in Bolivia and scarcely represented in national systematic collections. In the case of *P. leucoptera* MNKM 5826, the new record (fourth for Bolivia and first for the department of Santa Cruz), extends its geographic range 736 km south of its nearest record in the department of Beni: Refugio de Vida Silvestre "Espíritu" (Appendix 1), and to a new biogeographic province, the Western Cerradense (Figure 2; Navarro 2011; Poma-Urey *et al.* 2021). Similarly, in the case of *G. crenulatum* MNKM 5823, the new records extend its geographic range 197 km south of its nearest record in the Parque Noel Kempff Mercado, Pampas de Termiteros (Appendix 1), including the province Western Cerradense (Figure 2); and the southernmost known record slightly increases the elevational limits reported for this species in the country to 433 m (330 m; Siles and Wallace 2021). In the case of *L. brachyotis* MNKM 5824, the new locality extends its geographic range in the country 290 km to the east of the closest record and includes a new biogeographic province Cerradense Occidental (Figure 2; Navarro 2011; Acosta *et al.* 2021b).

We highlight the importance of these new records as a source of information to evaluate morphological variations, mainly in the case of *G. crenulatum*. The morphometry of this taxon has been scarcely documented in Bolivia and to date is restricted to some external and cranial measurements of 3 specimens (FA 51 mm - 53 mm; Aguirre and Urioste 1994; Anderson 1997). In addition, is important to continue documenting the diversity of bats in Bolivia, and in this sense, systematic collections play a very important role in preserving voucher specimens. We recommend the review of specimens deposited in the systematic collections of the country, especially in the cases of those taxa little studied or documented (*e.g.*, *Promops* spp. or *Eumops* spp.; Anderson 1997), to have a better understanding of their distributional patterns, habitat preferences, and abundance.

Finally, although the species studied are classified of "Least Concern" according to the International Union for Conservation of Nature (IUCN), their presence in the sampling localities and their preferences for primary forests (Solari *et al.* 2019), and taking into account other bioindicator species, could, together with these bats, suggest satisfactory ecological conditions (Schulze *et al.* 2000).

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Appendix 1

Locations of previous records of the bats examined.

Family Emballonuridae

Peropteryx leucoptera

Bolivia. Beni: Versalles (12° 44' S, 66° 10' W, 168 m). Refugio de Vida Silvestre "Espíritu" (14° 13' S, 66° 24' W, 162 m). Pando: Reserva Nacional Amazónica Manuripi-Heath, San Miguel (11° 31' S, 67° 40' W, 171 m); (Poma-Urey *et al.* 2021).

Family Phyllostomidae

Gardnerycteris crenulatum

Bolivia. Beni: mouth of the río Baures (12° 30' S, 64° 18' W, 139 m); (Anderson 1997). Espíritu (14° 8' S, 66° 24' W, 170 m); (Aguirre 2002). La Paz: Bajo Inicua (15° 17' 51'' S, 67° 26' 44'' W, 330 m); (Siles and Wallace 2021). Parque Nacional y Área de Natural de Manejo Integrado Madidi, sabanas de Antas (12° 55' 9.44'' S, 68° 38' 0.70'' W, 211 m). Puerto Moscoso (13° 2' 4.81'' S, 68° 41' 0.69'' W, 227 m). Pampas del Heath (12° 40' 48.24'' S, 68° 42' 42.52'' W, 184 m). Comunidad Toromonas (12° 20' 20.9'' S, 68° 10' 55.8'' W, 216 m). Comunidad El Tigre (11° 58' 58.4'' S, 68° 0' 51.6'' W, 180 m); (Terán 2010). Pando: Centro Dieciocho (10° 36' S, 66° 47' W, 163 m). Arroyo Hermoso (11° 13' S, 67° 42' W, 192 m). 15 km NW of Puerto Camacho (11° 28' S, 67° 50' W, 236 m). San Miguel (11° 40' S, 67° 43' W, 206 m); (Anderson 1997). Santa Cruz, Parque Nacional Noel Kempff Mercado, Los Fierros (14° 34' S, 60° 52' W, 218 m); (Emmons 1998).

Lampronycteris brachyotis

Bolivia. Cochabamba, Santuario de Vida Silvestre Cavernas de Repechón (17° 3' 39.60'' S, 65° 28' 26.40'' W, 491 m). Santa Cruz, Bosque Experimental Elías Meneses (16° 38' S, 64° 30' W, 191 m); (Acosta *et al.* 2021b).

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New records of small mammals in the diet of the buff-fronted owl, *Aegolius harrisii* and the black-and-white owl, *Strix nigrolineata*, along with a review of mammal prey of owls in Colombia

Nuevos registros de pequeños mamíferos en la dieta del mochuelo canela, *Aegolius harrisii* y del búho carinegro, *Strix nigrolineata*, con una revisión de mamíferos presas de búhos y lechuzas en Colombia

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The diet of Colombian owls has been scarcely studied. The consumption of bats and other small mammals has been recorded for *Aegolius harrisii* and *Strix nigrolineata* in Central and South America; however, there was no information on this topic in Colombia for both species. We present new observations of the predation of mammals by owls in Colombia and a brief review of historical records. We reported the attempt of consumption of a bat of genus *Platyrrhinus* by the buff-fronted owl (*Aegolius harrisii*) and the presence of bats (*Dermanura* and *Rhogeessa*) and shrews (*Cryptotis*) in one pellet of the black-and-white owl, *Strix nigrolineata*, in the Andes of Colombia. The literature review showed that at least 30 mammal species have been recorded in the diet of 8 additional owl species in the country. Rodents are the prey with the highest number of reports, which include taxa from forested, urban, and peri-urban areas. This information might be useful for subsequent studies on the possible effects of habitat loss on mammal consumption by owls and the role as a controller of zoonotic agent hosts.

Key words: Andes; coffee plantations; Chiroptera; diet; Eulipotyphla; Rodentia; small mammals.

La dieta de los búhos y lechuzas de Colombia ha sido escasamente estudiada. El consumo de murciélagos y otros pequeños mamíferos ha sido registrado para *Aegolius harrisii* y *Strix nigrolineata* en otros países de Centro y Sudamérica; sin embargo, no había información sobre el tema para Colombia. Presentamos nuevas observaciones de la depredación de mamíferos por búhos en Colombia y una breve revisión de registros históricos. Reportamos el intento de consumo de un murciélago del género *Platyrrhinus* por parte del búho bicolor (*Aegolius harrisii*) y la presencia de murciélagos (*Dermanura* y *Rhogeessa*) y musarañas (*Cryptotis*) en una egagrópila del búho carinegro (*Strix nigrolineata*), en los Andes de Colombia. La revisión de la literatura y datos de colecciones biológicas arrojó un total de al menos 30 especies de mamíferos que han sido registradas en la dieta de 8 especies adicionales de búhos en el país. Los roedores son las presas con mayor número de reportes, que incluyen taxa de bosques, áreas urbanas y periurbanas. Esta información puede ser útil para estudios posteriores sobre los posibles efectos de la pérdida del hábitat en el consumo de mamíferos por búhos y su papel como controladores de hospederos de agentes zoonóticos.

Palabras clave: Andes; cafetales; Chiroptera; dieta; Eulipotyphla; mamíferos pequeños; Rodentia.

Small mammals and other vertebrates constitute a significant portion of the diet of owls (Strigiformes). This preference can be attributed to the fact that smaller individuals are more readily and efficiently captured and consumed by these predators (Bueno and Motta-Junior 2009). Studies on trophic habits is one of the most developed areas of research within the biology and ecology of Neotropical owls (Tytonidae and Strigidae), but most of these have evaluated the diet of a limited number of species (Bellocq 2000; Bó *et al.* 2007; Cadena-Ortiz *et al.* 2013; Mella *et al.* 2016; Restrepo-Cardona *et al.* 2018). In Colombia, one of the countries that hold a large diversity of owls, with 28 species (Ayerbe Quiñones 2018; Chaparro-Herrera *et al.* 2021; Hilty 2021), the available information about their ecology, especially of what mammals are included in their diet, is scarce (Chaparro-Herrera *et al.* 2015; Restrepo-Cardona *et al.* 2018). Some species such as the American barn owl, *Tyto alba* (considered as *T. furcata* by Uva *et al.* 2018) have been thoroughly studied in terms of its diet. Through these studies, a wide range of small mammal species has been identified as components of the barn owl's diet (Delgado-V. and Cataño 2004; Delgado-V. and Calderón-F. 2007; Delgado-V. and Ramírez 2009). In contrast, other species, rare or randomly distributed, like buff-fronted owl (*Aegolius harrisii*), are scarcely documented (Penagos *et al.* 2018), and consequently there is a lack of information regarding its diet. Another example is the black-and-white owl (*Strix nigrolineata*), a species for which comprehensive diet data is currently unavailable for Colombia.

In particular, the buff-fronted owl, *A. harrisii,* is a little-known species distributed in South America (Córdoba and Ahumada 2005; König *et al.* 2008; Penagos *et al.* 2018). In Argentina and Brazil, its diet includes insects, rodents, and bats (Barlow and Cuello 1964; Willard *et al.* 1991; Barrionuevo *et al.* 2008). It lives mainly in subtropical and tropical humid montane forest, and in Colombia it is known from few localities and from specimens of the Andean region deposited in natural history collections (von Sneidern 1954; Fitzpatrick and Willard 1982; Hilty and Brown 2001; Córdoba and Ahumada 2005; Parra-Hernández *et al.* 2007; Ayerbe-Quiñones *et al.* 2008; Girão and Albano 2010; Calderón-Leytón *et al.* 2011; Penagos *et al.* 2018).

Similarly, the black-and-white owl, *S. nigrolineata,* is distributed from southern México to northern Perú (König *et al.* 2008). Their diet includes rodents (Ibañez *et al.* 1992; Gerhardt *et al.* 1994), amphibians, birds, and insects (Ibañez *et al.* 1992; Gerhardt *et al.* 1994: Sandoval *et al.* 2008). *Strix nigrolineata* is a widely distributed owl species, found in the west to the Andes, in an elevational range between 0 to 2,400 m (Salaman and Stiles 2002; Moreno-Bejarano and Álvarez-León 2003; Strewe and Navarro 2003; Ayerbe-Quiñones and López-Ordoñez 2011; Acevedo-Charry *et al.* 2014; López-O. *et al.* 2014; Chaparro-Herrera *et al.* 2020).

The efforts to document the diet of owls in Colombia, based on incidental observations (*e.g.*, Borrero 1967; Riaño *et al.* 2017; Padilla 2019; Rodríguez-Villamil 2022), and pellet analyses (Delgado-V. and Cataño 2004; Delgado-V. and Calderón-F. 2007; Delgado-V. and Ramírez 2009; Restrepo-Cardona *et al.* 2021), are key to identify ecological interactions (Chaparro-Herrera *et al.* 2015). To contribute to the knowledge of the mammal's prey of owls in Colombia for future assessments of the role of these predator as biological controllers, we documented observations of mammals in the diet of *A. harrisii* and *S. nigrolineata* and performed a review of mammals predated by owls in wildlife.

On August 22, 2010, at approximately 19:50 hr, we documented an attempt of predation of a bat by an owl, inside mixed crops of "caturra" coffee (*Coffea arabica*) and citrus trees, close to small remnants of oak forest (*Quercus humboldtii*), located in the Bella Vista farm (2° 36' 00" N, 76° 31' 01.2" W; 1,850 m; Figure 1), El Cairo, Municipality of Cajibío, Department of Cauca. The observation was obtained circumstantially during the monitoring of bats using mist nets in the study area. The owl was identified based on external traits (Hilty and Brown 2001; Ayerbe Quiñones 2018). The bat specimen was identified using specialized keys (Gardner 2008), and deposited in the mammalian collection of the Universidad del Cauca (MHNUC). Additional data of mammal's prey of owls, came from the analysis of a single pellet regurgitated by an owl collected on November 8, 2020, in the area of influence of the Manso River in Corregimiento Berlín, Vereda La Reforma (5° 34' 49" N, 74° 56' 35" W; 843 m; Figure 1), Municipality of Samaná, Department of Caldas. The owl was observed standing in a tree in a dry forest ecosystem and was identified using external traits (Hilty and Brown 2001; Ayerbe Quiñones 2018).

The collected pellet was examined at the Museo de Historia Natural of the Universidad de Caldas (MHN-UCa), Manizales, Colombia. The pellet was manually washed and disintegrated to finding bone fragments of mammals. To identify the fragments of teeth and other bones of mammals, specialized keys were used (Gardner 2008). Specimens were compared with those deposited at the MHN-UCa, and were deposited into it. To contrast our observational records with existing information regarding of the mammalian prey preferences of both owl species, a brief literature review was conducted. Simultaneously, we delved into the available body of knowledge concerning the mammal prey spectrum of owls in the wild, specifically within the Colombian context. For this, we searched for additional records cited in scientific articles in databases such as Web of Science, Science Direct, Scopus, and Google Scholar. We consider all the sections of the publications (Title, Keywords and Abstract), except in Google scholar, and all years. We used the combinations of Boolean operators in English and Spanish to identify studies [Colombia OR South America AND Owls OR Tytonidae OR Strigidae AND diet AND "Prey mammals"].

We captured an individual of *Aegolius harrisii* (Figure 2a) in a mist net installed inside mixed crops. The owl captured (Figure 2b) had 1 individual of the bat *Platyrrhinus dorsalis* on its left claws, so the bat was dead when the mist net was checked. The owl was photographed and released. The individual of *P. dorsalis* was prepared as skin and skull specimen (MHNUC OME 1097). External measurements of the individual, taken in the field were: total length: 65.56 mm, foot length: 12.48 mm, ear length: 17.05 mm, forearm length: 46.79 mm, and weight: 25 g. Other species of bats caught in the area included *Artibeus lituratus*, *Dermanura phaeotis*, *Sturnira giannae*, *Carollia brevicauda*, *C. perspicillata*, *Glossophaga soricina*, *Molossus molossus*, and *Histiotus humboldti*.

The pellet was regurgitated by an owl identified as *S. nigrolineata* by the presence of white and black stripes covering the neck, stomach, and chest. The analyses of the pellet showed the presence of unidentified invertebrates

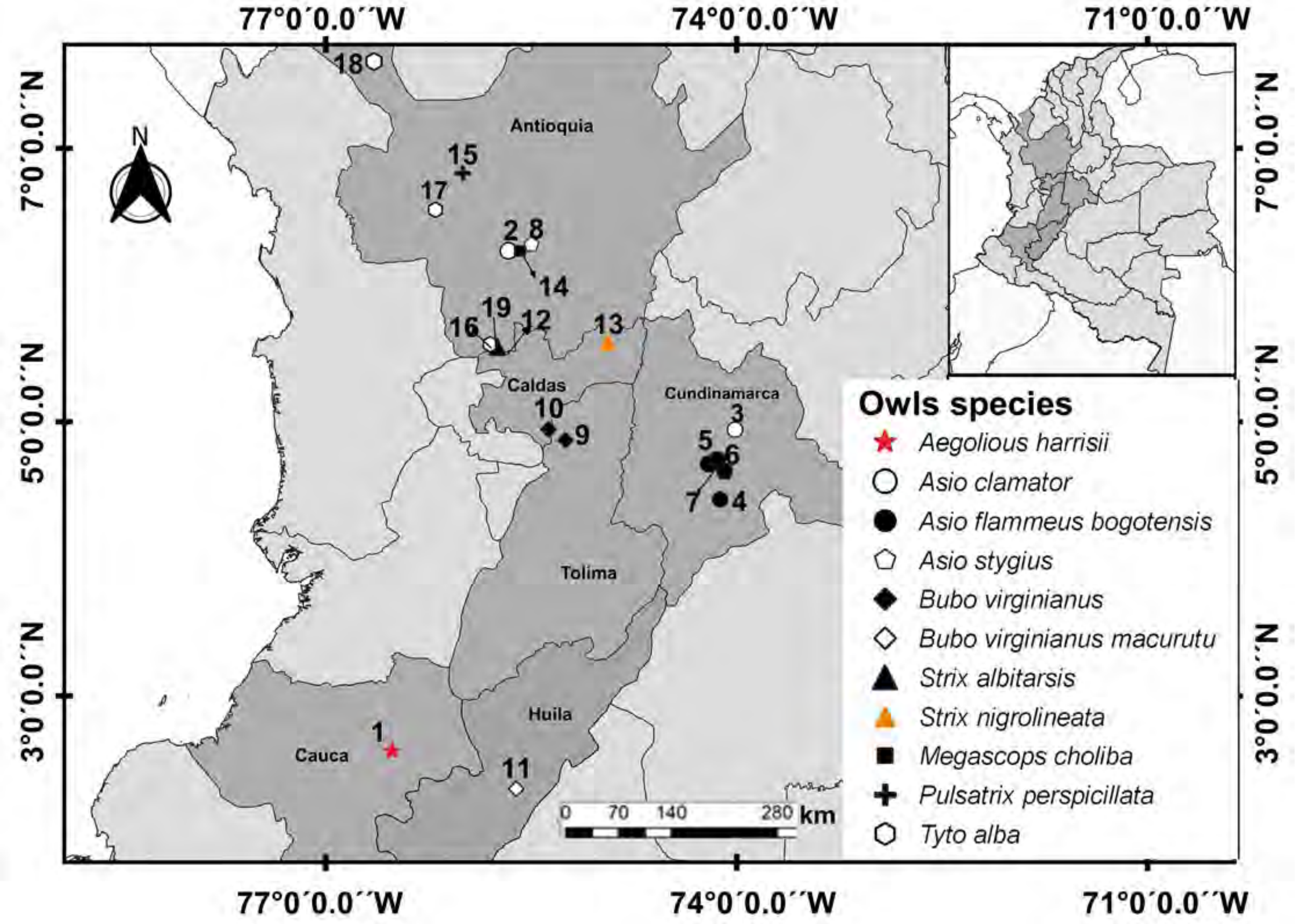

Figure 1. Localities of the studies on mammals found in the diet of Colombian owls. New records and localities are highlighted with a red star (Cajibío, Cauca) and an orange triangle (Samaná, Caldas). The number of the localities are shown in Appendix 2.

and several bone fragments of the maxilla of 3 individuals of the shrew *Cryptotis* sp., and some teeth of bats of the genus *Dermanura* and the species *Rhogeessa io* (MHN-UCa-M 3425, MHN-UCa-M 3427, respectively).

The searching for mammals in the diet of *A. harrisii* yielded records of 8 species from 3 orders (Didelphimorphia, Chiroptera, and Rodentia), in 8 papers from Argentina (5), Brazil (1), Uruguay (1), and Paraguay (1; Table 1). The searching for mammals in the diet of *S. nigrolineata* in America yielded records of 16 species belonging to 2 orders (Chiroptera and Rodentia), in 5 articles from Guatemala (2), México (1), and Venezuela (2; Table 1). The mammals preyed on by other owls in Colombia, were at least 30 species, consumed by 8 owl species, belonged to 6 orders (Didelphimorphia, Paucituberculata, Eulipotyphla, Chiroptera, Rodentia, and Lagomorpha; Figure 2c), and reported in 12 publications. The American barn owl, *Tyto furcata* (but listed as *T. alba*) was the most studied owl with 4 publications and at least 23 mammal species documented in its diet (Appendix 1). The better represented order of mammals in the diet of owls in Colombia were Rodentia and Chiroptera.

Our record of an attempt of possible predation of a bat by *A. harrisii* in Colombia is the first documented for the species in the country. In addition, the record of the attempted predation on bats contributes to the knowledge of the trophic ecology of this species, for which prey has not been previously included on a national scale. Some attempts of predation of bats trapped in mist nets have been previously recorded for the species in Argentina, for *Sturnira erythromos*, whereas in Brazil, skulls of *S. lilium* have been recorded in pellet analysis (Lima and Castro 1994; Barrionuevo *et al.* 2008; Girão and Albano 2010), therefore, it can be considered that bats might be an important part of the diet of the Colombian owls. Our record also contributes to providing recent information on the distribution of the species of *A. harrisii*. In the Department of Cauca, *A. harrisii* has been historically reported in 3 localities on the eastern slope of the Western Cordillera (Municipality of El Tambo), the Popayán Plateau and the western flank of the Central-Eastern Cordilleras (Ayerbe-Quiñones *et al.* 2008).

For *S. nigrolineata*, our observations are also the first on the diet of this species in Colombia. However, bats have

Table 1. Mammals in the diet of *Aegolius harrisii* and *Strix nigrolineata* in the Neotropics. Data reported in scientific literature and this work.

Taxon	Country	Type of record	Elevation (m)	Latitude	Longitude	References
			Aegolius harrisii			
Didelphimorphia						
Thylamys sponsoria	Argentina	Pellets	1,384	24° 45' 46" S	65° 22' 52" W	Rodríguez 2013
Chiroptera						
Sturnira erythromos	Argentina	Observation	650	28° 01' 59" S	65° 34' 59" W	Barrionuevo *et al.* 2008
Sturnira lilium	Brazil	Pellets	965	12° 35' 26" S	41° 42' 01" W	Lima and Castro 1994
Platyrrhinus dorsalis	Colombia	Observation	1,850	2° 36' 00" N	76° 31' 01" W	This work
Rodentia						
Oligoryzomys sp.	Argentina	Pellets	1,384	24° 45' 46" S	65° 22' 52" W	Rodríguez 2013
Oligoryzomys nigripes	Uruguay	Pellets	140	31° 41' 26" S	55° 51' 33" W	Barlow and Cuello 1964; Azpiroz *et al.* 2018
Calomys sp.	Argentina	Pellets	1,384	24° 45' 46" S	65° 22' 52" W	Rodríguez 2013
Oryzomys fornesi	Paraguay	-	178	24° 28' 20" S	55° 41' 40" W	Storer 1989
Unidentified	Argentina	Trail camera	550-600	26° 31' S	55° 00' W	Bodrati *et al.* 2019
			Strix nigrolineata			
Eulipotyphla						
Cryptotis sp.	Colombia	Pellet	873	5° 34' 49" N	74° 56' 35" W	This study
Chiroptera						
Saccopteryx bilineata	Venezuela	Pellets	300	9° 04' N	69° 47' W	Ibañez *et al.* 1992
Pteronotus davyi	México	Stomach contents	210	17° 28' 50" N	89° 02' 43" W	Kuns *et al.* 1954
Phyllostomus discolor	Venezuela	Pellets	300	9° 04' N	69° 47' W	Ibañez *et al.* 1992
Carollia perspicillata	Venezuela	Pellets	300	9° 04' N	69° 47' W	Ibañez *et al.* 1992
Artibeus gr. *jamaicensis*	Venezuela	Pellets	300	9° 04' N	69° 47' W	Ibañez *et al.* 1992
Artibeus gr. *jamaicensis*	Guatemala	Pellets	250	17° 13' N	89° 37' W	Gerhardt *et al.* 1994
Chiroderma villosum	Venezuela	Pellets	300	9° 04' N	69° 47' W	Ibañez *et al.* 1992
Dermanura cf. *cinerea*	Venezuela	Pellets	300	9° 04' N	69° 47' W	Ibañez *et al.* 1992
Dermanura sp.	Colombia	Pellets	873	5° 34' 49" N	74° 56' 35" W	This study
Uroderma sp.	Venezuela	Pellets	300	9° 04' N	69° 47' W	Ibañez *et al.* 1992
Uroderma convexum	Guatemala	Pellets	250	17° 13' N	89° 37' W	Gerhardt *et al.* 1994
Lasiurus frantzii	Venezuela	Pellets	300	9° 04' N	69° 47' W	Ibañez *et al.* 1992
Lasiurus (*Dasypterus*) *ega*	Venezuela	Pellets	300	9° 04' N	69° 47' W	Ibañez *et al.* 1992
Rhogeessa io	Colombia	Pellets	873	5° 34' 49" N	74° 56' 35" W	This study
Eumops auripendulus	Venezuela	Pellets	300	9° 04' N	69° 47' W	Ibañez *et al.* 1992
Eumops glaucinus	Venezuela	Pellets	300	9° 04' N	69° 47' W	Ibañez *et al.* 1992
Molossus molossus	Venezuela	Pellets	300	9° 04' N	69° 47' W	Ibañez *et al.* 1992
Molossus pretiosus	Venezuela	Pellets	300	9° 04' N	69° 47' W	Ibañez *et al.* 1992
Molossus rufus	Guatemala	Pellets	250	17° 13' N	89° 37' W	Gerhardt *et al.* 1994
Rodentia						
Oligoryzomys fulvescens	Guatemala	Pellets	250	17° 13' N	89° 37' W	Gerhardt *et al.* 1994
Mus musculus	Venezuela	Pellets	300	9° 04' N	69° 47' W	Ibañez *et al.* 1992
Rattus rattus	Venezuela	Pellets	300	9° 04' N	69° 47' W	Ibañez *et al.* 1992

been extensively documented in the diet of this owl in other countries such as Guatemala and Venezuela (Kuns and Tashian 1954; Ibañez *et al.* 1992; Gerhardt *et al.* 1994). Besides that, we reported for the first time the shrews *Cryptotis* sp., as part of its diet and added records of *Dermanura* sp. and *Rhogeessa io*. Although we found no rodents in the diet of *S. nigrolineata,* 3 species (Table 1) have been registered in Venezuela (Ibañez *et al.* 1992) and Guatemala (Gerhardt *et al.* 1994).

Finally, the limited information on the diet of owls in Colombia limits our capability to explore patterns or tendencies in these ecological interactions. Nonetheless, it has been documented that habitat preferences are likely a key factor in the presence of mammal prey in pellet samples (Delgado-V. and Ramirez 2009). Considering that most of the owl diet reports in Colombia come from pellets collected in urban (abandoned houses or populated centers) or sub-urban areas of the country, several prey items include exotic rodents (*Mus musculus*, *Rattus rattus*, and *R. norvegicus*) that are adapted to human-disturbed environments (Delgado-V. *et al.* 2005). The presence of exotic species in the owl's diet also shed light on their possible role as controller of zoonotic agent hosts. In other South American countries such as Chile, changes in human-disturbed landscapes, owls' prey on exotic and native species acting as potential controllers of zoonotic reservoirs (Muñoz-Pedreros *et al.* 2016, 2018). Furthermore, the finding of opportunistic and exotic taxa that are favored by anthropic impact to the detriment of native species in the diet of native owls also provides an important input to assess biodiversity loss (Sax and Gaines 2003).

With our results, at least 32 mammal species are part of the diet of owls in Colombia, a number that seems underestimated considering that the country holds a high diversity of small mammals (Ramírez-Chaves *et al.* 2021). Our observations are the first records of mammal prey of *A. harrisii* and *S. nigrolineata* in Colombia. Of the 28 owl species reported in Colombia (Ayerbe Quiñones 2018; Chaparro-Herrera *et al.* 2021; Hilty 2021), 20 lack information about mammals as part of their diet. This confirms that the information on the interactions between mammals and owl species in Colombia is still limited (Chaparro-Herrera *et al.* 2015; Restrepo-Cardona *et al.* 2019).

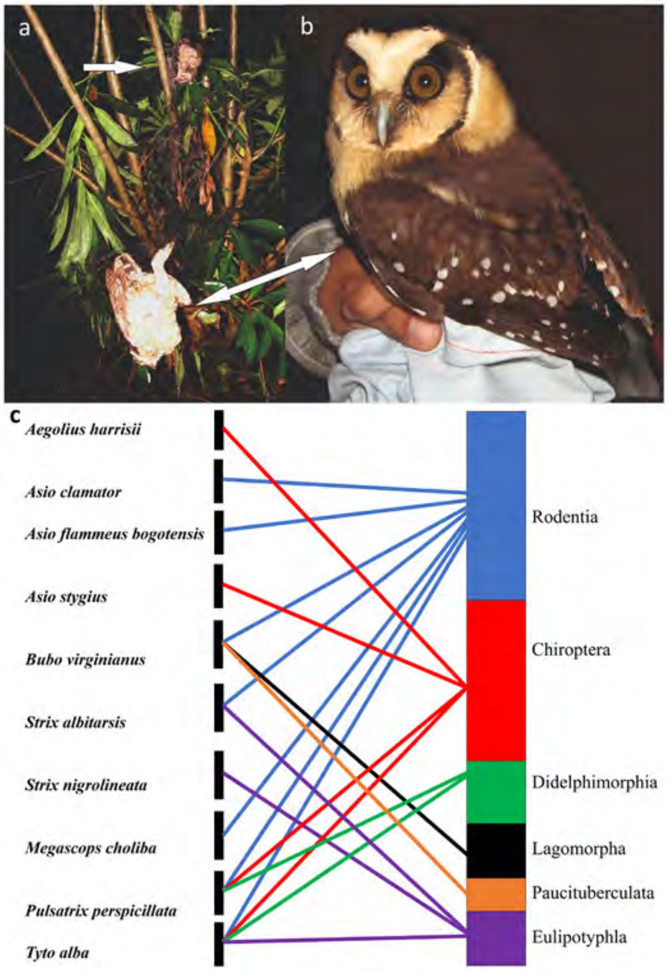

Figure 2. Details of the attempted predation of bat *Platyrrhinus dorsalis* by *Aegolius harrisii*. a) dead *Platyrrhinus dorsalis* in the mist net (white arrow); b) captured individual of *A. harrisii*; c) summary of owl species of Colombia and the orders of mammals included in their diet.

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Appendix 1

Mammals prey of owls (Strigiformes) in Colombia. Data was extracted from scientific review of literature and from this work. Localities (in parentheses) are shown in Appendix 2. Locality 10*: *M. musculus* was obtained in the gizzard of one specimen (MHN-UCa-A 1170) of *Bubo virginianus nacuruto* found dead at Natural National Park Los Nevados, Villamaría, Caldas (4° 56' 42" N, 75° 22' 27" W, 3,027 m).

Owl Species	Order's prey	Species prey	References
Aegolius harrisii	Chiroptera	*Platyrrhinus dorsalis* (1)	This study
Asio clamator	Rodentia	*Mus musculus* (2); *Rattus rattus* (2); *R. norvegicus* (2); Sigmodontinae (2); *Cavia aperea* (3)	Delgado-V. *et al.* 2005; Riaño *et al.* 2017
Asio flammeus bogotensis	Rodentia	*M. musculus* (4); *Cryptotis thomasi* (4)	Camargo-Martínez and Rodríguez-Villamil 2019
		M. musculus (5) ; *Microryzomys* sp. (5); *Rattus* sp. (5); Unidentified (6)	Restrepo-Cardona *et al.* 2021; Rodríguez-Villamil 2022
		R. rattus (7); *R. norvegicus* (7), *Sigmodon hirsutus* (7)	Borrero 1962
Asio stygius	Chiroptera	*Artibeus lituratus* (8)	Borrero 1967
Bubo virginianus	Paucituberculata	*Caenolestes fuliginosus* (9)	This study; Restrepo-Cardona *et al.* 2019; Padilla 2019
	Rodentia	*M. musculus* (10*); Sigmodontinae (9); *Thomasomys* sp. (9) *S. hirsutus* (11)	
	Lagomorpha	*Sylvilagus* sp. (9)	
Strix albitarsis	Didelphimorphia	*Marmosa* sp. (12); *Marmosops* sp. (12)	Restrepo-Cardona *et al.* 2018
	Eulipotyphla	*Cryptotis* sp. (12)	
	Rodentia	*Reithrodontomys mexicanus* (12); *Thomasomys* sp. (12); *T. aureus* (12; Sigmodontinae (12)	
Strix nigrolineata	Eulipotyphla	*Cryptotis* sp. (13)	This study
	Chiroptera	*Dermanura* sp. (13); *Rhogeessa io* (13)	
Megascops choliba	Rodentia	*M. musculus* (14)	Delgado-V. 2007
Pulsatrix perspicillata	Didelphimorphia	*Didelphis* sp. (15); *Marmosa* sp. (15)	Restrepo-Cardona *et al.* 2018
	Chiroptera	*Artibeus lituratus* (15); *Phyllostomus discolor* (15); *P. hastatus* (15)	
	Rodentia	*Akodon affinis* (15); *R. norvegicus* (15); Sigmodontinae (15)	
Tyto alba	Didelphimorphia	*Marmosa* sp. (18, 19); *Marmosops* sp. (16)	Delgado-V. and Cataño-B. 2004; Delgado-V. and Calderón-F. 2007; Delgado-V. and Ramírez 2009; Restrepo-Cardona *et al.* 2018
	Eulipotyphla	*Cryptotis* sp. (16, 19)	
	Chiroptera	*Carollia* sp. (19); *Sturnira* sp. (16); Molossidae (18)	
	Rodentia	*A. affinis* (16, 19); *Handleyomys fuscatus* (19); *Heteromys australis* (16); *Melanomys caliginosus* (19); *Microryzomys* sp. (16); *M. musculus* (17); Muridae (18); *Nectomys* sp. (17); *Nephelomys* cf. *pectoralis* (16, 19); *Neusticomys* sp. (15); *Rattus* sp. (15, 18); *R. mexicanus* (15, 18); *Rhiphidomys latimanus* (16); Sigmodontinae (15, 18); *Sigmodon* sp. (16); *S. hispidus* (16); *Oligoryzomys* sp. (16); *Zygodontomys brevicauda* (16)	

Appendix 2

Localities of studies of mammals found in the diet of owls in Colombia, reported in scientific literature.

Owl species	Number	Locality	Elevation (m)	Latitude N	Longitude W
Aegolious harrisii	1	Cauca, Cajibío, El Cairo	1,850	2° 36' 00"	76° 31' 01.2"
Asio clamator	2	Antioquia, Medellín, Cerro at northwest of the city	1,670	6° 15'	75° 40'
Asio clamator	3	Cundinamarca, Cajicá, Universidad Militar Nueva Granada.	2,250	4° 56' 34"	74° 00' 43"
Asio flammeus bogotensis	4	Cundinamarca, Corinto, Cerro Redondo, Usme.	3,198	4° 26' 11"	74° 07' 15"
A. f. bogotensis	5	Cundinamarca, Mosquera, San Antonio	2,540	4° 41' 32"	74° 12' 26"
A. f. bogotensis	6	Cundinamarca, Bogotá, Ciudadela Universitaria UNAL	2,553	4° 38' 18"	74° 05' 18"
A. f. bogotensis	7	Cundinamarca, Bogotá, Engativá, Jaboque	2,544	4° 43' 36"	74° 8' 29"
A. stygius	8	Antioquia, Piedras Blancas, near Medellín	2,500	6° 17' 46"	75° 29' 54"
Bubo virginianus	9	Caldas, Murillo, Corazón Lake	4,020	4° 52'	75° 15'
B. virginianus	10	Caldas, Villamaría, Potosí, Brisas	4,070	4° 56' 42"	75° 22' 27"
B. v. macurutu	11	Huila, Gigante, 3.6 km south Río Loro	751	2° 19' 18"	75° 36' 34"
Strix albitarsis	12	Antioquia, Jardín, La Tebaida	2,430	5° 33'	75° 45'
Strix nigrolineata	13	Caldas, Norcasia, Berlín	873	5° 34' 49"	74° 56' 35"
Megascops choliba	14	Antioquia, Medellín, Street 48	1,469	6° 15'	75° 35'
Pulsatrix perspicillata	15	Antioquia, Ciudad Bolívar, urban area	1,183	6° 49'	76° 00'
Tyto alba	16	Antioquia, Jardín, urban area and El Clavel Nature Reserve	1,706	5° 34'	74° 48'
T. alba	17	Antioquia, Santa Rosa de Osos, La Clara, La Montañita	1,100	6° 33'	76° 12'
T. alba	18	Antioquia, Apartadó, Urabá	50	7° 52'	76° 37'
T. alba	19	Antioquia, Jardín, urban zone	1,760	5° 34'	75° 48'

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Scavenging insects found on a carcass of the endangered Galápagos sea lion *Zalophus wollebaeki*

Insectos carroñeros encontrados sobre un cuerpo de lobo marino de Galápagos *Zalophus wollebaeki*

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Zalophus wollebaeki is a species of sea lion endemic to the Galápagos Islands. Dead bodies of Galápagos sea lions are frequently found on beaches, but little is known about their decomposers. The objective of this study is to report a sample of insects found on a sea lion carcass. In November 2022, a dead *Z. wollebaeki* was found on Caamaño Islet, from which we collected and identified pupae and adult of scavenging insects. We found 2 species of beetles and 1 of fly. The specimens were identified as *Phaleria manicata* (Coleoptera: Tenebrionidae), *Dermestes ater* (Coleoptera: Dermestidae), and *Galopagomyia inoa* (Diptera: Sarcophagidae). *Phaleria manicata* and *G. inoa* are reported for first time on a carcass of a sea lion. In the Galápagos, scavenging insects and their role in the decomposition process are little known. Consequently, more studies should focus on understanding the ecological role of scavenger communities in the different ecosystems of the Galápagos Islands.

Key words: Coastal ecosystems; decomposition; endemic species; insular scavengers.

El lobo marino (*Zalophus wollebaeki*) es una especie endémica de las Galápagos. Cadáveres de lobos marinos de las Galápagos se encuentran con frecuencia en las playas, pero poco se conoce sobre sus descomponedores. El objetivo del presente trabajo es reportar una muestra de insectos encontrados sobre un cadáver de lobo marino. En noviembre de 2022 se halló un cuerpo de *Z. wollebaeki* en el islote Caamaño del que se recolectaron e identificaron pupas y adultos de insectos carroñeros. Se encontraron 2 especies de escarabajos y 1 de mosca. Los especímenes fueron identificados como: *Phaleria manicata* (Coleoptera: Tenebrionidae), *Dermestes ater* (Coleoptera: Dermestidae) y *Galopagomyia inoa* (Diptera: Sarcophagidae). *Phaleria manicata* y *G. inoa* se reportan por primera vez en el cuerpo de un lobo marino. En las Galápagos, los insectos carroñeros y el papel que desempeñan en el proceso de descomposición son poco conocidos. Por lo tanto, más estudios se deben focalizar en comprender el papel ecológico de las comunidades de descomponedores en los distintos ecosistemas de las Islas Galápagos.

Palabras clave: Descomponedores insulares; descomposición; ecosistemas costeros; especies endémicas.

Zalophus wollebaeki Sivertsen, 1953 (Carnivora: Otariidae) is a species of sea lion, endemic of the Galápagos Islands (Alava and Salazar 2006), Ecuador. The IUCN has classified the Galápagos sea lion as an endangered species (EN) due to a significant decrease in its populations over the last 40 years. This decline has been attributed mainly to natural events (*e.g.*, El Niño events) and infectious diseases (*e.g.*, Canine Distemper virus; Trillmich 2015). Carcasses of sea lions are frequently found on beaches. For example, between the years 2008 and 2012, Denkinger *et al.* (2015) reported 308 dead Galápagos sea lions at Wreck Bay, the Galápagos Islands. However, as far as we know, there is no information about carrion-eating insects associated with carcasses of this species.

Carrion-eating insects (*e.g.*, flesh flies and dermestid beetles), and other decomposers, are important for ecosystems because they help to recycle dead biomass, which is an ephemeral and rich resource (Barton *et al.* 2013). Species identification and knowledge about their biology would contribute to better understanding of processes in beach ecosystems of the Galápagos Islands. In this study, we report the insects found on a decaying body of *Z. wollebaeki*, and discuss the role of scavenging insects in the functioning of the coastal ecosystems of the Galápagos.

In November 2022, a dead body of an adult male of *Z. wollebaeki* was found at Caamaño islet (0° 45´ S, 90° 16´ W; Figure 1) in a mixed state of decomposition; some bones were exposed but also muscle and skin were present (Figure 2a, b). The Caamaño islet is known as a breeding and resting place for sea lions (Wolf and Trillmich 2007) and is located between the south of Santa Cruz and northwest of Santa Fe Islands (Figure 1). For identification purposes we collected a small sample of only adult beetles and fly pupae from the carcass; larvae of dermestid beetles and flies were abundant but we did not collect those because of the difficulties to identify immature stages. The pupae were reared until they emerged as adult flies, we used plastic containers with absorbent paper in the base, kept

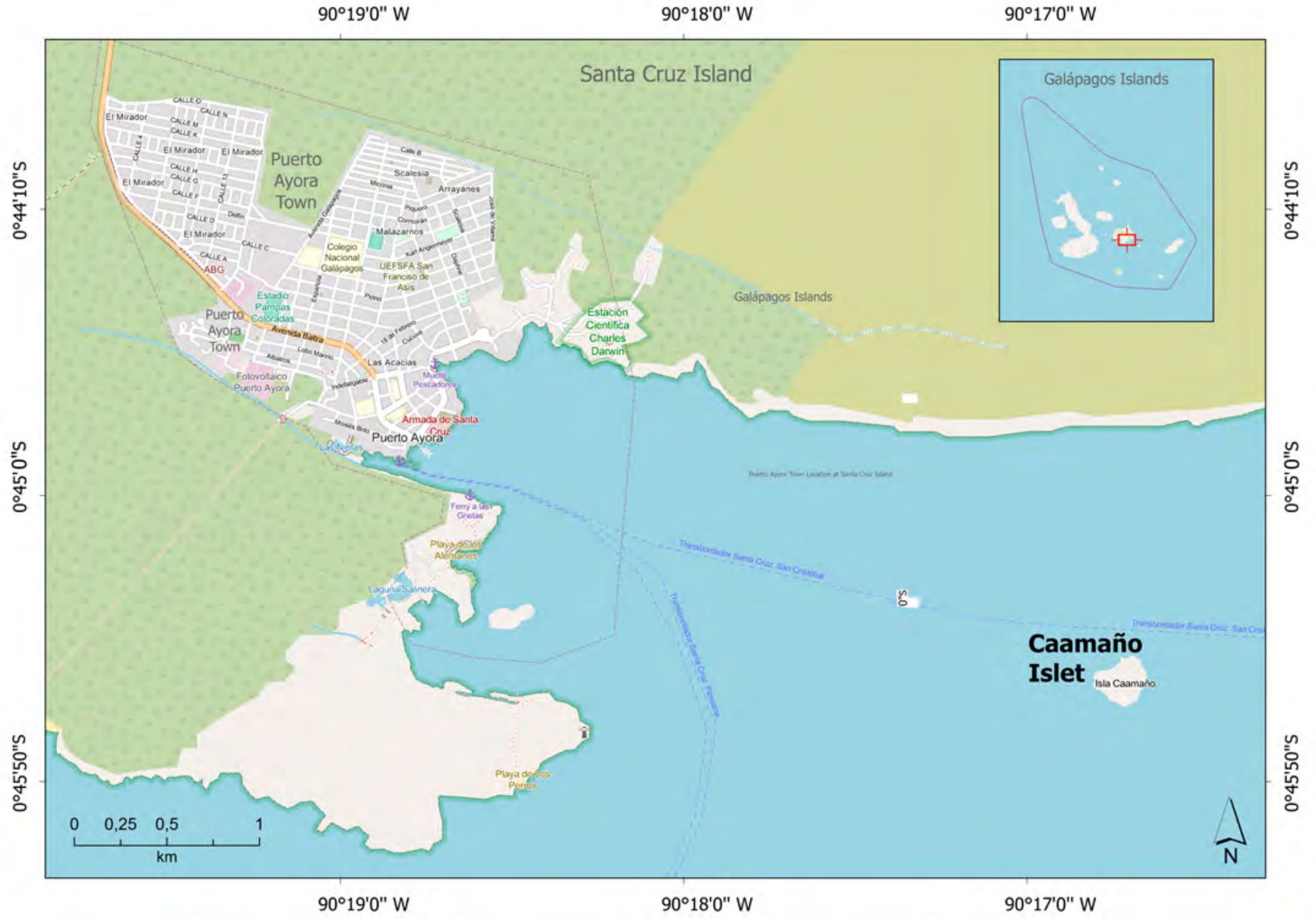

Figure 1. Location of Caamaño Islet in relation to Santa Cruz Island in the Galápagos Islands. Inset: the marine reserve of the Galápagos Islands, Ecuador.

at room temperature (21.5 °C) and high humidity (95 %). The adult specimens were frozen and then were mounted with pins and identified with relevant taxonomic keys (De Souza-Lopes 1978; Kingsolver 1991; Triplehorn 1991; Peacock 1993; Peck 2006 for Coleoptera, and Brown *et al.* 2009 for Diptera), and by comparing them with the holdings of the Invertebrate Collection of the Charles Darwin Research Station (ICCDRS), the Galápagos Islands, Ecuador.

The examined dead sea lion carried a tag with the code 6B3-698F (1905), assigned by the long-term project "Biología poblacional y salud del lobo marino de Galápagos" started by F. Trillmich and now led by O. Krüger from Bielefeld University in Germany. Records of this project indicate that this animal was born on October 13, 2012. The skeleton of this sea lion is preserved at the Vertebrate Collection of the Charles Darwin Research Station, the Galápagos, Ecuador, with the accession number VCCDRS 3303.

On the remains of this sea lion, we found 2 species of beetles and 1 of fly. Regarding the beetles, 2 specimens of *Phaleria manicata* Boheman, 1858 (Coleoptera: Tenebrionidae; ICCDRS 49998, 49999) were identified based on the following morphological characters: pronotum bearing coarse setae, apical angle of rotibial strongly lobed and without constriction on outer margins, distance between eyes less than the diameter of one eye in ventral view, long setae along distal margins of abdominal sterna and femur present (Triplehorn 1991; Figure 2c). In addition, 3 specimens of *Dermestes ater* DeGeer, 1774 (Coleoptera: Dermestidae; ICCDRS 49995, 49996, 49997) were identified based on: face of coxa concave, median ocellus absent, elytral apex lacking serrations and spines, abdominal venter with pattern, and lateral sulcus opposite of coxa (Kingsolver 1991; Figure 2d). Finally, 4 adult specimens of fly belonging to *Galopagomyia inoa* Walker, 1849 (Diptera: Sarcophagidae: ICCDRS 50000, 50001, 50002, 50003) were identified by abdominal tergite VI-VII with a distinctive pair of plates and marginal bristles (De Souza-Lopes 1978; Figure 2e).

In this study, we reported 3 species of insects found on a decaying body of *Z. wollebaeki*: the Galápagos endemic fly, *Galopagomyia inoa* and 2 beetles, 1 introduced, *Dermestes ater,* and the other endemic, *Phaleria maniacata* (Peck 2006; Sinclair 2009, 2023).

Scavenging insects, such as Diptera and Coleoptera, are widely recognized for their role in the colonization and decomposition of carcasses (Genise *et al.* 2000; Campobasso *et al.* 2001; Sinclair 2009). However, despite their significance, we know little about carrion insects and their function in the ecosystems of the Galápagos. Beatles of the genera *Phaleria* and *Dermestes* have been found to forage the remains of marine species of the Peruvian coast (*e.g.*, green turtle, magnificent frigatebird, blue-footed booby; Giraldo-Mendoza 2019; Iannacone *et al.* 2023). Therefore, the presence of these genera using the corpse of a marine mammal at the Galápagos Islands makes sense in a biogeographic context by the affinities of the biota of the Pacific coast of South America (*i.e.,* Chile, Ecuador and Perú) with the Galápagos islands (*e.g.*, Bisconti *et al.* 2001).

In general, tenebrionids like *Phaleria manicata* colonize fresh corpses, while dermestids prefer corpses in an advanced state of decomposition (López-Caro *et al.* 2019). The simultaneous presence of these beetles on the body of *Z. wollebaeki* at Caamaño islet could be explained by a transitional stage of decomposition of the carcass, with some parts more decomposed than others. Previously, *P. manicata* was reported eating dung from the Galápagos sea lions (Peck 2006), and here we document its presence on a decomposing body. In this study, we also report for the first time the presence of the carrion fly *G. inoa* on a carcass of *Z. wollebaeki*.

Previously, larvae of *G. inoa* have been recorded in exposed eggs of the east Pacific green sea turtle (*Chelonia mydas*), and inside the eggs and on hatchlings of giant

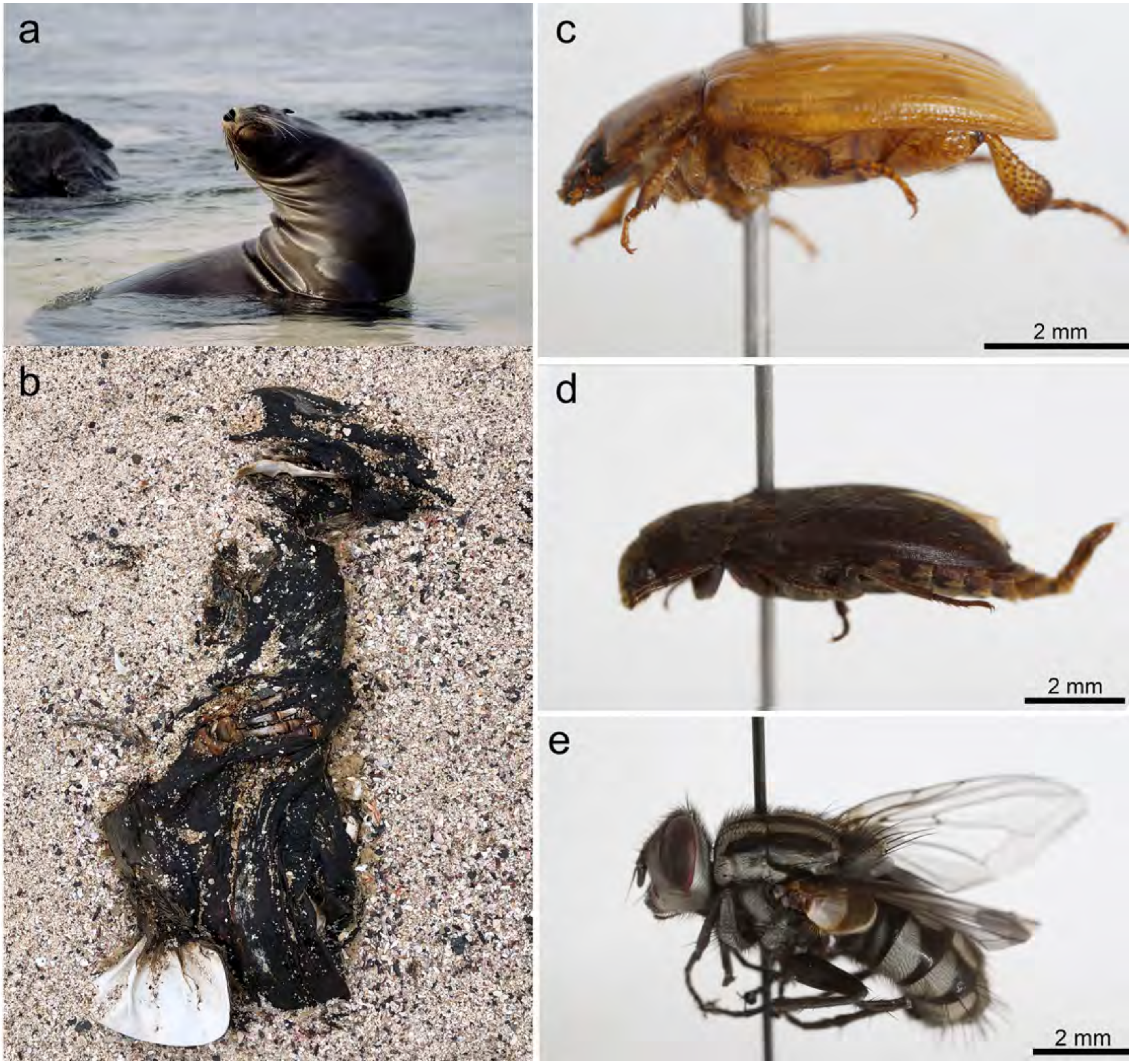

Figure 2. *Zalophus wollebaeki***:** a) adult (photo by J. M. Garcia); b) corpse of the adult male VCCDRS 3303 at Caamaño islet, Galápagos, Ecuador (photo by A. Childs). Specimens collected: c) *Phaleria manicata* ICCDRS 49998, d) *Dermestes ater* ICCDRS 49996, e) *Galopagomyia inoa* ICCDRS 50002.

tortoises of Santiago Island *Chelonoidis darwini* (Sinclair 2023). The notes on the giant tortoise of Santiago as a host of *G. inoa* comes from the notes associated with specimens ICCDRS-12660, 12662, and 12663. The collector of those specimens mentioned to us: *"When the egg hatched, the fly entered and lay the eggs in the tortoise' venter. The flies may dig tunnels to reach the eggs. We raised some larvae flies feeding them with blood of tortoises and the larvae became adults"* (Cruz Márquez, pers. comm).

In the Galápagos, the absence of big scavengers, such as vultures, and population declines of primary consumers, *e.g.*, *Buteo galapagoensis*, the Galápagos hawk (Jaramillo *et al.* 2016), could have an impact in the decomposition process. The lack of large scavengers would increase the amount of available biomass and its temporal availability, allowing smaller consumers, like invertebrates, to dominate the decomposition process (*e.g.*, Moleón *et al.* 2017; Muñoz-Lozano *et al.* 2019; Redondo-Gómez *et al.* 2022). In this context, Redondo-Gómez *et al.* (2022), studied the communities of vertebrate and invertebrate scavengers on a small Mediterranean island, and noted that when comparing sea and land scavenger communities, the vertebrate scavengers dominated the decomposition in the sea, while the invertebrate scavengers dominated on land.

Finally, the Galápagos may be an interesting place to study the diversity of scavenger arthropods, their patterns of succession and other ecological aspects in the different habitats of the islands. For example, how different are the scavenger communities and the decomposition processes between the coastal arid environments and the more humid highlands of the Galápagos?

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Mutualistic relationship between Baird´s tapir *Tapirus bairdii* and brown basilisk *Basiliscus basiliscus* at Corcovado National Park, Costa Rica

Relación mutualista entre el tapir centroamericano *Tapirus bairdii* y el cherepo *Basiliscus basiliscus* en el Parque Nacional Corcovado, Costa Rica

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Some symbiotic relationships, like mutualism, benefit individuals of the species involved. While there are documented instances of animals feeding on blood-feeding organisms that infest other vertebrates, cases of reptiles feeding on mammals are rare. In this note, we present a case of a brown basilisk, *Basiliscus basiliscus*, feeding on the back of a Baird's tapir, *Tapirus bairdii*, in Costa Rica. Observations were conducted in Corcovado National Park, Costa Rica, where one of the authors (D. Paniagua) leads excursions with tourist groups. During these excursions, brown basilisks have been observed on the backs of tapirs, hunting horseflies (Tabanidae) that land on them to feed on their blood. At least 10 instances of this behavior between brown basilisk and tapirs were recorded. These cases were observed more frequently on hot days and when there was sufficient water in puddles or other sources. When tapirs rested in dry areas, the presence of brown basilisk was not observed. This behavior aims to feed on female horseflies, which constantly harass tapirs by trying to land and feed on their blood. Brown basilisk obtain food and help tapirs by reducing painful horsefly bites and the potential spread of diseases. This mutualistic behavior had not been previously described for either of these 2 species.

Key words: Behavior; horsefly; mammal; reptile; Tabanidae.

Algunas relaciones simbióticas, como el mutualismo, benefician a los individuos de las especies involucradas. Aunque existen registros de animales que se alimentan de organismos hematófagos que infestan a otros vertebrados, los casos de reptiles que se alimentan sobre mamíferos son escasos. Aquí reportamos el caso del cherepo, *Basiliscus basiliscus* alimentándose sobre la danta, *Tapirus bairdii*, en Costa Rica. Las observaciones se llevaron a cabo en el Parque Nacional Corcovado, Costa Rica donde uno de los autores (D. Paniagua) realiza excursiones con grupos de turistas. Durante tales excursiones, se ha observado a basiliscos en la espalda de tapires cazando tábanos (Tabanidae) que aterrizan en ellos para alimentarse de su sangre. Se obtuvieron al menos 10 observaciones de este comportamiento entre basiliscos y tapires. Estos casos se observaron con mayor frecuencia en días calurosos y cuando hay suficiente agua en los charcos u otras fuentes. Cuando los tapires descansan en lugares secos, no se ha observado la presencia de basiliscos. Este comportamiento tiene como objetivo alimentarse de tábanos hembra, que constantemente acosan a los tapires intentando posarse y alimentarse de su sangre. El cherepo obtiene alimento y ayuda a los tapires al reducir las picaduras dolorosas de los tábanos y la propagación potencial de enfermedades. Este comportamiento mutualista no había sido descrito anteriormente para ninguna de estas 2 especies.

Palabras clave: Comportamiento; mamífero; reptil; Tabanidae; tábano.

Some symbiotic relationships are negative for individuals of one of the species involved, such as ectoparasitism or predation, while others are positive (Smith and Smith 2007). Among the latter category, mutualistic relationships benefit both species involved (Begon *et al.* 2006). For example, just in Africa, at least 96 bird species have developed feeding associations with various mammal species, including several ungulates (Dean and McDonald 1981; Rodríguez 2020). As a result, the birds obtain food, and the mammals are relieved of ectoparasites.

Potential advantages for individuals participating in mixed-species associations are very diverse and include: a reduction in parasite load, reduced risk of predation, and increased access to food and other resources (Dickman 1992). In many species, associations among individuals may be favored if they increase the *per capita* feeding success, increase access to favorable habitats, or reduce the *per capita* risk of predation (Pulliam and Caraco 1984).

There are records of animals feeding on and cleaning off hematophagous or parasitic organisms that infest other vertebrates, forming mutualistic symbiotic relationships (Villalobos-Juárez and García-Padilla 2023). However, most of the documented cases involve birds feeding on mammals (Dean and McDonald 1981), and more rarely on reptiles such as terrestrial turtles and iguanas (Christian 1980). Even rarer are the cases of reptiles feeding on top of mammals (Villalobos-Juárez and García-Padilla 2023).

Baird's tapir, *Tapirus bairdii* (Gill 1865), ranges from México to Colombia, from sea level up to 3,600 m (Medici 2011; Schank *et al.* 2017). In Costa Rica, it can be found throughout the country, from coastal areas to the highest peaks (Mora 2000). Baird's tapir is a large, robust, hoofed mammal with a weight that can reach up to 350 kg, making it the largest terrestrial native mammal in Central America and the Neotropics as a whole (Reid 2009; Medici 2011).

Baird's tapir typically inhabits areas in close proximity to water sources and exhibits a preference for marshy or humid environments. They are highly skilled swimmers and adept divers (Mora 2000; Reid 2009), and often travel along watercourses (Naranjo 2019). Throughout the day, Baird's tapir can be found resting in shaded thickets, as well as in mud wallows or standing water (Reid 2009).

Brown basilisk, *Basiliscus basiliscus* (Linnaeus 1758), known in Costa Rica as cherepo, is distributed along the Pacific slope, spanning from southwestern Nicaragua to northern South America, and on the Atlantic slope of central Panamá, occupying elevations ranging from sea level to 1,200 m (Leenders 2019). Brown basilisk is a sizable lizard characterized by elongated legs and tail, reaching a maximum snout-vent length of 250 mm and a total length of 900 mm in males; females are considerably smaller (Savage 2002). Its coloration is olive-brown, adorned with 2 light stripes running along each side of the body, accompanied by dark crossbands that pattern the body and tail (Savage 2002). Adult males exhibit prominent crests on the head, as well as sail-like crests on the back and tail. These features are less developed or absent in females and smaller juvenile individuals (Leenders 2019). Brown basilisk is commonly encountered along the vegetated edges of streams and rivers in lowland areas, including gallery forests and secondary growth along streams in highly disturbed agricultural areas (Savage 2002). As a defensive strategy, basilisks often retreat into the water to evade predators on land. They even have the ability to run on the surface of water (Leenders 2019). The tendency to limit their time spent in water suggests they may also exercise caution towards potential aquatic predators, including crocodilians (Leenders 2019). The diet of brown basilisk is highly diverse, encompassing insects, scorpions, shrimp, and small vertebrates like lizards, snakes, fish, mammals, and birds (Savage 2002; Solórzano and Hidalgo 2014). Additionally, it supplements its diet with plant material, including flowers, fruits, and buds (Van Devender 1983).

Information about reptiles feeding on top of other vertebrates is still limited (Villalobos-Juárez and García-Padilla 2023). One of the most well-known cases of mutualism is that of the lava lizard (*Microlophus albemarlensis*), which feeds on insects that perch on sea lions or marine iguanas (Stebbins *et al.* 1967; Beebe 1988). Another example involves the mesquite lizard, *Sceloporus grammicus*, which jumps onto the backs and extremities of cattle (*Bos taurus*) when they lay down to prey on stable flies (*Stomoxys calcitrans*), known to alight on cattle to feed on their blood (Villalobos-Juárez and García-Padilla 2023). Here, we present the first documented case of a mutualistic relationship between Baird's tapir and the brown basilisk. The brown basilisk perches on top of Baird's tapir and captures horseflies that feed on the tapir's blood.

The observations were conducted at Corcovado National Park (CNP), located in the Puerto Jiménez county on the southwestern coast of the Osa Peninsula, Costa Rica (Figure 1). This park, established in 1975, encompasses 3,354 marine ha and 42,560 terrestrial ha of lowland tropical rainforest in Southwestern Costa Rica and supports a rich biodiversity (Foerster and Vaughan 2002). The mean annual temperature at CNP ranges between 23 and 26.5 °C depending on elevation (Foerster and Vaughan 2002). This protected area receives 5,500 mm–6,000 mm of precipitation annually, primarily during the rainy season in April through December (Kappelle 2016).

One of the authors (D. Paniagua) routinely leads groups of tourists within CNP, and most of the time, the group observes tapirs during the hikes, frequently near the beach. The size of the tourist group varies from just a couple to up to 10 people. At specific and well-known locations, the group diverts from the main trail to actively search for tapirs. Quite often, the group has spotted tapirs relaxing in mud wallows or shallow standing water near side trails. Although the group typically needs to continue the tour, D. Paniagua has briefly paused to conduct specific observations. These observations have been conducted using the naked eye, as well as through a small telescope or binoculars. Tourists have the opportunity to take pictures using smartphones or their own cameras. However, since D. Paniagua is guiding them, he has only been able to record videos while simultaneously explaining the scenario to the tourists as they take photographs.

On at least 10 occasions, basilisks have been observed on the backs of tapirs preying on horseflies (Tabanidae) that land on them to feed on their blood. These instances are most commonly observed when the day is very hot and there is enough water in the puddles or other water sources. When tapirs rest in dry places, no basilisks have been observed.

On June 21, 2023, at 08:30 hr, a young adult tapir was observed resting at a shallow pond along the Naranjos trail (8° 28′ 21″ N, 83° 35′ 25″ W; 33 m; Figures 1, 2). Another video was recorded on August 2, 2013, at 07:01 hr; this video can be viewed on the Costaricaguide/TikTok page (https://www.tiktok.com/@costaricaguide/video/7247323439776730373?is_from_webapp=1&sender_device=pc&web_id=7241231254254994949).

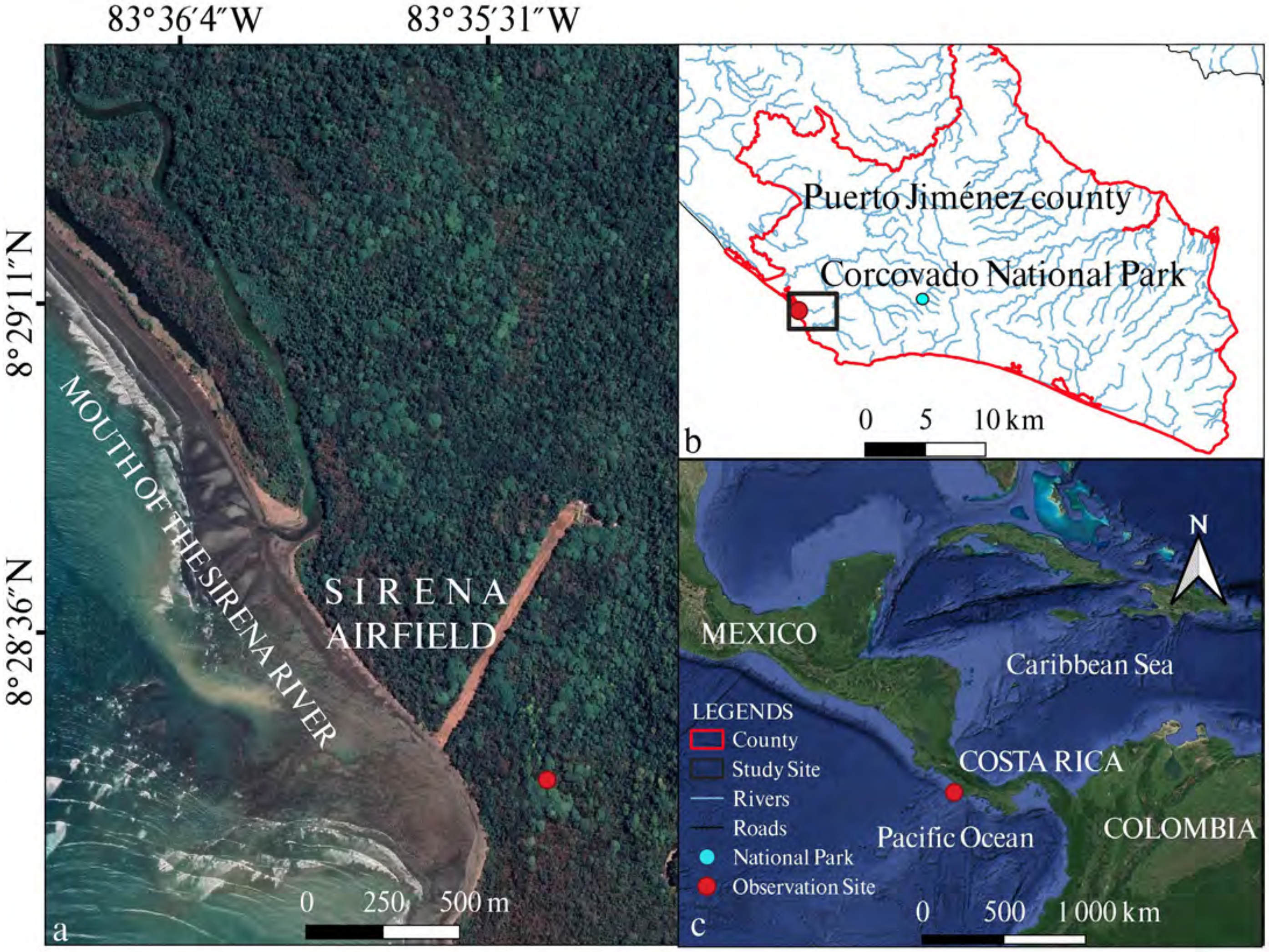

Figure 1. a) The location where a brown basilisk (*Basiliscus basiliscus*) captured horseflies on top of a Baird's tapir (*Tapirus bairdii*) near the Naranjos trail in the Sirena sector; b) the location of Corcovado National Park in the Puerto Jiménez county of c) Costa Rica. Map by G. Chaves.

It was evident that brown basilisk is particularly interested in horseflies. We noticed that basilisks are generally cautious, and when someone approaches, they rapidly scamper away. However, when a horsefly alights on a tapir, the basilisk reapproaches to attempt to catch it. Basilisks remain extremely attentive, and as soon as a fly settles, they swiftly move toward the tapir until they reach the spot where the horsefly has landed. Even if a fly is approaching, should someone come closer to the tapir, the basilisk temporarily retreats, yet as soon as it spots a fly landing, it promptly returns to the tapir and waits for horseflies.

The most significant aspect of our observations is that the basilisk perches on the tapir to capture horseflies that are attracted to it. The basilisk feeds on the horseflies, and perhaps other insects, while the tapir is relieved of the flies that deliver painful bites by slashing the skin with a pair of blades to feed on blood (Hanson and Nishida 2016). Horseflies are typically large and active flies, with females aggressively pursuing blood meals (Gerhardt and Hribar 2019). These flies rely on visual cues, such as the shape, size, and color of their potential hosts, and the movement of these hosts is also crucial (Mullens 2019). Shades of blue, black, or red are particularly attractive to tabanids (Mullens 2019). Baird's tapir is dark brown to dark gray in color (Mora 2000), which may make them more appealing to horseflies.

While tabanids can biologically transmit some pathogens and parasites, they more commonly transmit pathogens mechanically via contaminated blood on their mouthparts (Mullens 2019). They are among the most effective potential mechanical vectors of disease agents. When disturbed or dislodged, they will quickly return to the same host or one nearby within seconds (Mullens 2019). Tabanids serve as vectors for various disease agents in animals, including viruses, bacteria, protozoans, and nematodes. Some examples of disease agents mechanically transmitted by horseflies include the viruses that cause equine infectious anemia, *Anaplasma marginale*, the causative agent of anaplasmosis, and *Trypanosoma vivax* (Desquesnes *et al.* 2013; Mullens 2019). During periods of intense tabanid attacks, animals can experience a daily blood loss of up to 200 mL per individual (Mullens 2019), rendering them more susceptible to other diseases.

Some forms of apparently cooperative behavior are classified as by-product mutualisms, where an individual's behavior maximizes its own immediate fitness, and any positive effects on the fitness of other individuals are coincidental and do not contribute to the selection pressures maintaining the behavior (Bednekoff 1997). As a result, commensal and mutualistic associations among terrestrial vertebrates are clearly dynamic and can form or dissolve under different conditions of predator risk, resource levels, competition, and various other factors (Dickman 1992). Interspecific mutualism can manifest in various forms, with benefits that may be immediate or deferred (Hoeksema and Bruna 2000; Clutton-Brock 2002). The symbiotic relationship between the brown basilisk and Baird's tapir may be localized due to the habitat preferences of both species and the specific conditions in CNP. Both species are associated with habitats characterized by the presence of permanent water sources. Interestingly, horseflies prefer humid habitats where females typically lay eggs, often on plants or other objects overlying shallow water or wet soil, and some lay eggs directly over floating vegetation (Hanson and Nishida 2016). Additionally, the brown basilisk is active during the day, aligning with the diurnal biting habits of horseflies (Mullens 2019).

Figure 2. A brown basilisk, *Basiliscus basiliscus* perching on top of a Baird´s tapir, *Tapirus bairdii* to feed on horseflies close to Naranjos trail, Sirena sector, Corcovado National Park, Costa Rica. Photo from video by D. Paniagua.

There are few documented cases of mutualistic relationships among vertebrates in Costa Rica. Rodríguez (2020) observed and recorded 60 events of interactions between white-tailed deer (*Odocoileus virginianus*) and 4 bird species. Some of these interactions were classified as mutual cooperation, as the bird species directly removed ticks and other ectoparasites from the deer's skin, benefiting both species (Rodríguez 2020). The removal of ticks and ectoparasites is advantageous for white-tailed deer as it prevents blood loss, discomfort, and reduces the risk of disease transmission from these parasites (Rodríguez 2020). Another case of mutualism involving Baird´s tapirs has also been described in Corcovado National Park. In this case, it is a cleaning relationship where the yellow-headed caracara (*Milvago chimachima*) cleans ticks from the tapir (Coulson *et al.* 2018). The tapir clearly benefits by having the caracara free it from ticks and perhaps other parasites.

In a cleaning symbiosis, one species, the cleaner, removes and consumes ectoparasites, necrotic tissue, or mucus from another species, the client or host (Coulson *et al.* 2018). Consequently, the mutualistic relationship between brown basilisks and Baird's tapirs is another example of a cleaning symbiosis. The lizards capture flies for food, preventing them from biting the tapirs and potentially transmitting diseases. The tapir, as an attractive feeding perch, draws flies seeking blood as their food source. Additionally, few predators would approach a tapir, providing some protection for the basilisk while it feeds. Basilisks are cautious and rapidly scamper away if there is danger for them. However, they remain alert and come back when horseflies settle on the tapirs. As mentioned earlier, basilisks possess the ability to run on the water's surface (Leenders 2019), which might explain their method of jumping onto the tapir's back.

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Terrestrial mammals' species richness: diversity and activity patterns in the Darién National Park, Panamá

Riqueza de mamíferos terrestres: diversidad y patrones de actividad en el Parque Nacional Darién, Panamá

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Darién National Park is one of the largest forest blocks of Mesoamerica. Monitoring terrestrial mammal species in this region is essential to define adequate conservation actions to ensure their long-term persistence. We deployed 33 camera trap stations at the Darién National Park and evaluated the relative abundance of terrestrial mammal species, the sampling effort needed to estimate reliable richness estimates, and the activity patterns of the most recorded species. We identified with certainty 24 species of terrestrial mammals. Our survey was quite representative since we detected 85 % of the species that had previously been recorded for this area. Jaguars (*Panthera onca*), ocelots (*Leopardus pardalis*), and margays (*L. wiedii*) showed crepuscular behavior, and pumas (*Puma concolor*) and jaguarundis (*P. yagouaroundi*) showed diurnal behavior. Species that showed more activity during periods of more light were the ñeque (*Dasyprocta puntancta*), coati (*Nasua narica*), temazate (*Mazama temama*), and both species peccaries (*Tayassu pecari* and *Pecari tajacu*). Species with more nocturnal activity were the paca (*Cuniculus paca*), nine-banded armadillo (*Dasypus novemcinctus*), and Baird's tapir (*Tapirus bairdii*). This one of the first studies that evaluates the activity patterns of terrestrial mammals in the Darién and Panamá. We recorded some species that have not been documented in previous camera trapping studies for the region. However, the richness estimators indicated that there are still species that could be detected. Implementation of long-term monitoring programs is a crucial step to better understanding the dynamics of wildlife populations in the region.

Key words: Animal inventory; camera trapping; Panamá isthmus; species accumulation curves; tropical rain forest; wildlife monitoring.

El Parque Nacional Darién, es uno de los mayores bosques de Mesoamérica y el monitoreo de las poblaciones de mamíferos terrestres en esta región es fundamental para definir acciones de conservación que aseguren su persistencia. Colocamos 33 estaciones de foto trampeo y evaluamos la abundancia relativa de los mamíferos terrestres, el esfuerzo de muestreo necesario para obtener una estimación confiable de su riqueza y los patrones de actividad de las especies más registradas. Identificamos con certeza 24 especies de mamíferos. Nuestro muestreo fue representativo, ya que documentamos el 85 % de las especies que ya se habían registrado para esta área. Los jaguares (*Panthera onca*), ocelotes (*Leopardus pardalis*) y margays (*L. wiedii*) mostraron un comportamiento crepuscular, y los pumas (*Puma concolor*) y jaguarundis (*P. yagouaroundi*) un comportamiento diurno. El ñeque (*Dasyprocta puntancta*), el coatí (*Nasua narica*), el temazate (*Mazama temama*) y ambas especies de pecaríes (*Tayassu pecari* y *Pecari tajacu*) mostraron mayor actividad diurna. La paca (*Cuniculus paca*), el armadillo de nueve bandas (*Dasypus novemcinctus*) y el tapir (*Tapirus bairdii*) mostraron mayor actividad nocturna. Este es uno de los primeros estudios que evalúa los patrones de actividad de los mamíferos terrestres para el Darién y todo Panamá. Documentamos algunas especies que no habían sido registradas en estudios previos para la región. Sin embargo, los estimadores de riqueza indicaron que aún existen más especies que podrían ser detectadas. La implementación de programas de monitoreo a largo plazo es un paso crucial para comprender mejor la dinámica de las poblaciones de vida silvestre en la región.

Palabras clave: Bosque lluvioso tropical; curvas de acumulación de especies; foto-trampeo; inventario animal; Istmo de Panamá; monitoreo de vida silvestre.

Panamá, together with the entire Central American region, is one of the countries with the greatest biodiversity in the world, housing between 5 to 12 % of the species present on the planet in just 0.5 % of the earth's surface (Mittermeier *et al.* 1997; Myers *et al.* 2000; Meyer *et al.* 2020). Panamá is located in the southernmost of the Mesoamerican region, where the forests of the Darién province expand to one of the largest tropical rainforest masses in the American Continent: the Colombian Chocó (Moreno *et al.* 2016). This region, including the Darién National Park, is precisely one of the largest tropical rainforest blocks in Panamá where 174 mammal species have been recorded and is one of the places in the region where species such as the jaguar (*Panthera onca*), Baird' tapir (*Tapirus bairdii*) and white-lipped peccary (*Tayassu pecari*) could persist long-term (Sanderson *et al.* 2002; ANAM 2007; Moreno *et al.* 2016; de la Torre *et al.* 2018a; Schank *et al.* 2020; Thornton *et al.* 2020). For this reason, monitoring these and other mammal species populations within the Darién National Park is essential to understand their conservation status in the region, and to define adequate management and conservation actions to ensure their long-term persistence.

Monitoring of terrestrial mammal species implies a great challenge, since most of these species are cryptic, secretive, and nocturnal, which makes it difficult to observe them directly in the field (Trolle 2003; Yasuda 2004; Rovero and Marshall 2009). However, the monitoring of terrestrial mammals' populations through camera trapping has become a very widespread tool in the last decade, and this technique has been used to estimate densities of species such as the jaguar, ocelot (*Leopardus pardalis*), puma (*Puma concolor*), Bairds' tapir in Mesoamerica (Silver *et al.* 2004; Dillon and Kelly 2007; Kelly *et al.* 2008; de la Torre and Medellín 2011; de la Torre *et al.* 2016; Harmsen *et al.* 2017; Rivero *et al.* 2021). Furthermore, the information obtained through the camera traps also allows to study of other aspects of terrestrial mammals, such as their activity patterns or circadian cycles (Monroy-Vilchis *et al.* 2009; Romero-Muñoz *et al.* 2010; Foster *et al.* 2013; Briones-Salas *et al.* 2016), the habitat features that are associated positively and negatively with their occurrence (Monroy-Vilchis *et al.* 2009; Foster *et al.* 2010; de la Torre *et al.* 2018b), as well as the interactions between the different species (Harmsen *et al.* 2009; Monroy-Vilchis *et al.* 2009; Foster *et al.* 2010, 2013). For this reason, Fundación Yaguará Panamá since 2014 has focused on monitoring the jaguar and other emblematic species, such as the Bairds' tapir and the white-lipped peccary, in the Darién National Park through camera traps to generate a robust baseline that can help guide future conservation actions focused on these species throughout this region. Evaluating the diversity and abundance of terrestrial mammals in the long term will allow us to understand if the protection scheme in this region is helping to maintain the populations of emblematic species, as well as document the presence of rare or threatened species to improve their conservation in the region. In addition, understanding the activity patterns of these species will allow establishing a baseline to assess the impact that human activities and other disturbances could have on the behavior of these species, in order to improve the management of the protected areas in the region.

In this study, we examined the terrestrial mammals' species richness and activity patterns in the Darién National Park, Panamá. We used the camera trapping technique to test the hypothesis that the terrestrial mammal community in the Darién National Park has high species richness and a high occurrence of large mammal species. We also evaluated the activity patterns of the most recorded species, and we classified their activity as diurnal, nocturnal, cathemeral, or crepuscular to test the hypothesis that their activity patterns are similar to those reported to other regions of their distribution range.

Study area. Our study area was in the Serranía de Pirre within the Darién National Park, Panamá (Figure 1a). Darién National Park is located at the southernmost end of the land bridge between Central and South America (Claudino-Sales 2019). This region is one of the most species-rich expanses of lowland and highland rainforests in the world and contains a great occurrence of endemism over a broad range of taxa (Walshburger *et al.* 2008; Méndez-Carvajal *et al.* 2021). Annual rainfall ranges between 3,000 mm-4,000 mm and there is a marked dry season with less than 100 mm a month from January through March. The mean temperature ranges between 16 °C-35 °C, with an annual mean of 26 °C (Claudino-Sales 2019). Tropical rainforests of Darién National Park are relatively undisturbed and contain the most diverse and species-rich terrestrial ecosystems of tropical Central America (Walshburger *et al.* 2008; Meyer *et al.* 2015a; Claudino-Sales 2019; Méndez-Carvajal *et al.* 2021).

Survey design. Our study was accomplished using the camera trapping technique. We deployed the camera traps using the pre-existed trails that occur in the Serranía de Pirre inside the Darién National Park, and the survey was carried out from October 2020 to May 2021. We placed 33 camera trap stations which were active at different times during the sampling period giving a final sampling effort of 3,465 camera trap days. Due to the limited number of camera traps available for the study and the high incidence of equipment theft in the region, we decided to implement this survey using different blocks to cover as much surface as possible of the National Park and surrounding forest areas. Some camera trap stations were active from October 2020 to the end of March 2021, while others were only active from October 2020 to December 2020, or from March to May 2021, December 2020 to May 2021, and other camera trap stations were stolen (Figure 1b; Table 1). For this reason, the sampling effort was considered continuous using different temporal sampling blocks (Figure 1b; Table 1), although not all the stations were active during the entire period of the 219 days that the survey lasted.

Camera trap stations were placed 1-3 km apart and in sites where terrestrial mammals' signs were previously observed. To increase the probability of detection, all camera trap stations were set out with 2 camera traps, one on either side of the trail, to photograph simultaneously both sides of the animals that passed along the trails. In each camera trap station, 1 of the cameras was configured to take a video 15 sec long for each detection, and the other one was configured to take 3 pictures for each detection. Camera traps were positioned 40-50 cm above the ground, and at least 3 m off the trail where we expected the animals to pass.

Data analysis. To have an estimate of the species richness of large and medium mammals in our study area, we identified the species in the photographs and videos obtained through camera traps (Reid 2009). We identified all the species of mammals recorded at the species level

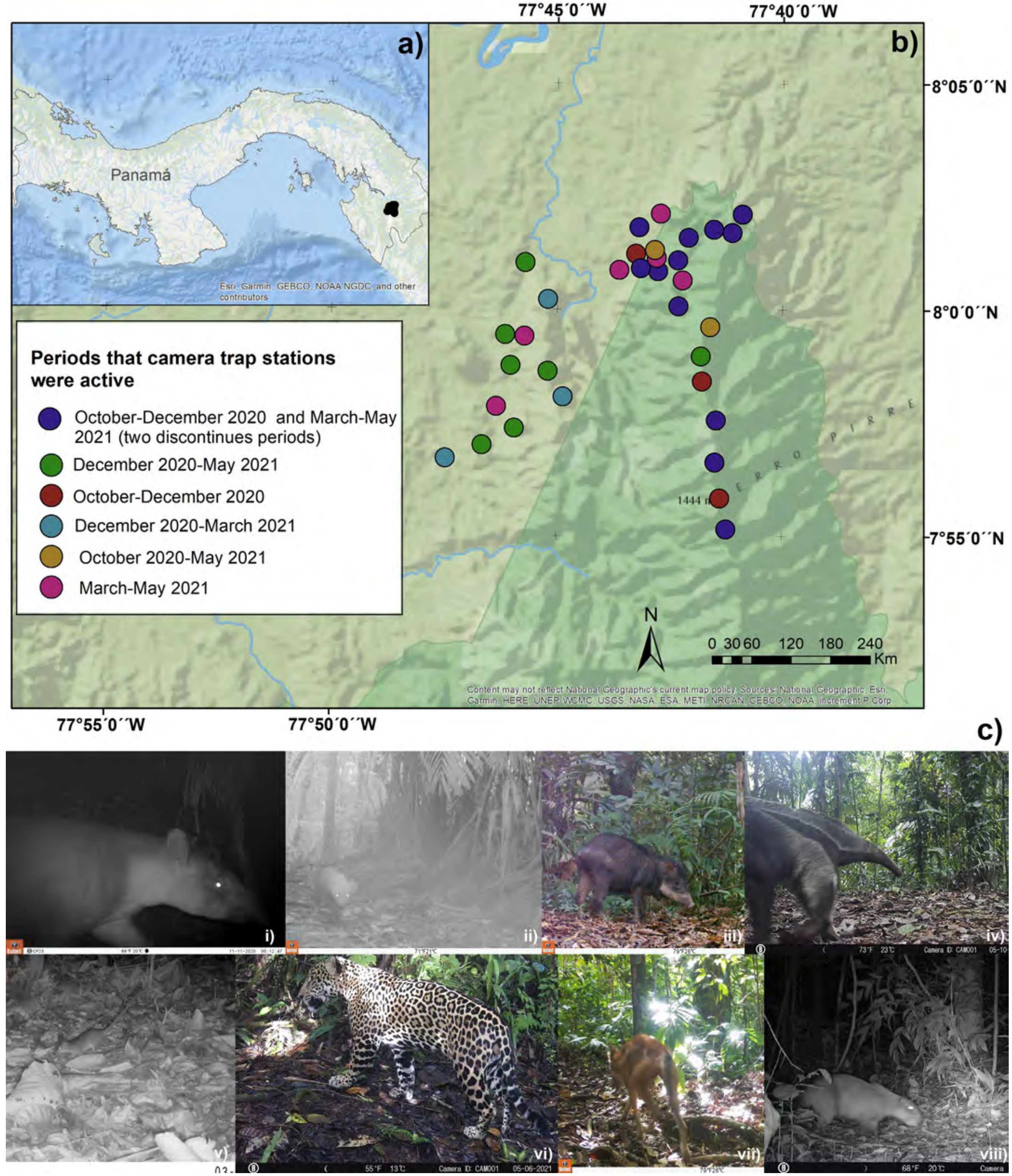

Figure 1. a) Localization of our study area in Panamá. b) Spatial and temporal distribution of the camera trap stations used in this study in the Darién National Park, Panamá. c) Images obtained by the camera traps of the terrestrial mammals of the Darién National Park, Panamá: i) *Tapirus bairdii*; ii) *Speothos venaticus*; iii) *Tayassu pecari*; iv) *Myrmecophaga tridactyla*; v) *Marmosa* sp.; vi) *Panthera onca*; vii) *Canis latrans*; vii) *Hydrochoerus isthmius*.

whenever it was possible. Species identified included large ones (> 10 kg) such as the Bairds' tapir (250 kg), to medium ones (101 g-10 kg) such as the tropical rabbit (*Sylvilagus brasiliensis*–1 kg), and small ones (1-100 g) such as the red tail squirrel (*Sciurus granatensis*–350 g). However, most of the recorded species are considered medium or large mammal species (Ceballos and Oliva 2005; Reid 2009). To obtain a proxy of the abundance of the medium and large terrestrial mammal species in the Darién National Park, we evaluated the relative abundance of these species by calculating the number of independent records per each 1,000 camera trap days through the following formula (Chávez *et al.* 2014):

(Number of independent records * 1,000) / the total effort calculated in trap days.

Independent records were calculated using the independence criteria for each record of an hourly interval, that is, if a record of a species was obtained at a camera trap station it was considered a new independent record until 60 min had elapsed from the first record (Chávez *et al.* 2014). Group species were considered as only 1 record without considering the number of individuals recorded by the camera traps.

To evaluate if our survey was well represented, we used species-accumulation curves graphing the addition of new species as the sampling effort on camera trap days increased along the sampling. We also evaluated the performance of 6 incidence-based nonparametric richness estimators: ICE, Chao 2, Jackknife 1, Jackknife 2, Bootstrap, and MMRuns (Colwell and Coddington 1994; Colwell 2006). Because nonparametric species richness estimators are directly related to the closed population of capture-recapture models, one of the assumptions is that the species community composition did not change over the survey time, which means that the community was closed to the colonization of new species or migration (Tobler *et al.* 2008). So then, we assumed that the continuous duration of 219 days of our survey did not violate this assumption.

We used EstimateS to compute the rarefaction curves and nonparametric richness estimators, and we used 1,000 randomizations for the analysis (Colwell 2006). For all richness estimators, we plotted the resulting curves using the sampling effort in camera trap days on the X-axis. To assess the integrity of our sampling and the precision of the total number of species estimated by the different estimators, we compared the resulting number of species with a list of terrestrial mammal species also obtained by camera trapping for the study area (Meyer *et al.* 2015a).

In order to understand the activity patterns of the terrestrial mammals that occur in Darién National Park, we registered the time of each record of these species during the survey. Analysis of this information was done through the "activity" package for R (Rowcliffe 2015). For this analysis, we only used the independent records obtained at time intervals of 1 hr between each one. To estimate the activity patterns, the times recorded were converted into their 24-hr equivalence in a ratio of 0 to 1. These analyses were only implemented with those species that had more than 15 independent records during the survey, and we classified the activity preference of the most recorded species as diurnal (< 20 % of observation in the dark period), nocturnal (> 80 % of observations in the dark period), crepuscular (> 50 % of observations during the crepuscular phase), or cathemeral activity (sporadic and random intervals of activity during the light and dark periods (Jiménez *et al.* 2010; Gray and Phan 2011; Botts *et al.* 2020).

During the survey, we clearly identified a total of 24 species of terrestrial mammals in the 33 camera trap stations (potentially 25 since we registered a marsupial of the *Marmosa* genus that likely is *Marmosa isthmica*; Figure 1c; Table 2). The 4 species with the highest relative abundance were the ñeque (*Dasyprocta punctacta*), followed by the collared peccary (*Pecari tajacu*), the red-tailed squirrel (*Sciurus granatensis*), and the ocelot (*L. pardalis*). The 4 species with the lowest number of records were the bush dog (*Speothos venaticus*), the coyote (*Canis latrans*), the lesser capybara (*Hydrochoerus isthmius*), and the tropical rabbit (*Sylvilagus brasiliensis*; Table 1).

Results showed that our survey was quite representative since we recorded 85 % of the terrestrial mammal species that had previously been recorded for this area using the camera trapping technique (Meyer *et al.* 2015a). Even during the camera trap survey, rare and difficult-to-record species in the region such as the bush dog (*S. venaticus*), coyote (*C. latrans*), and giant anteater (*Myrmecophaga tridactyla*) were recorded. However, the results of the richness estimators evaluated, except for the MMRuns, indicated a negative bias in our sampling and that some rare and secretive species were still missing from our survey (Figure 2a).

The results of activity patterns analyses showed that jaguars, ocelots, and margays (*L. wiedii*) have crepuscular behavior, having their activity peaks during sunrise and sunset (Figure 2b). Pumas and jaguarundis (*Puma yagouaroundi*) showed more diurnal behavior, showing more activity during the hours with more light throughout the

Table 1. Camera trapping sampling blocks used in the Darién National Park, Panamá including the sampling periods of each of the blocks and the number of camera traps stations used in each block.

Block ID	Sampling periods	Camera trap stations in this block
1	October-December 2020 and March-May 2021 (2 discontinues periods)	12
2	December 2020-May 2021	7
3	October-December 2020	3
4	December 2020-March 2021	3
5	October 2020-May 2021	2
6	March-May 2021	6

day (Figure 2b). The species that showed more activity during periods of more light during the day were the ñeque, coati (*Nasua narica*), venado corzo (*Mazama temama*), and both species peccaries (*T. pecari* and *Pecari tajacu*; Figure 2b). In contrast, the species with the most activity at night were the paca (*Cuniculus paca*), the nine-banded armadillo (*Dasypus novemcinctus*), and Baird's tapir (Figure 2b).

Results of species accumulation curves showed that our survey was quite representative since practically 85 % of the species that had previously been recorded using the camera trapping technique for this area were recorded in this survey (Meyer *et al.* 2015a). Our results supported our prediction that the terrestrial mammal community in the Darién National Park has high species richness and a high

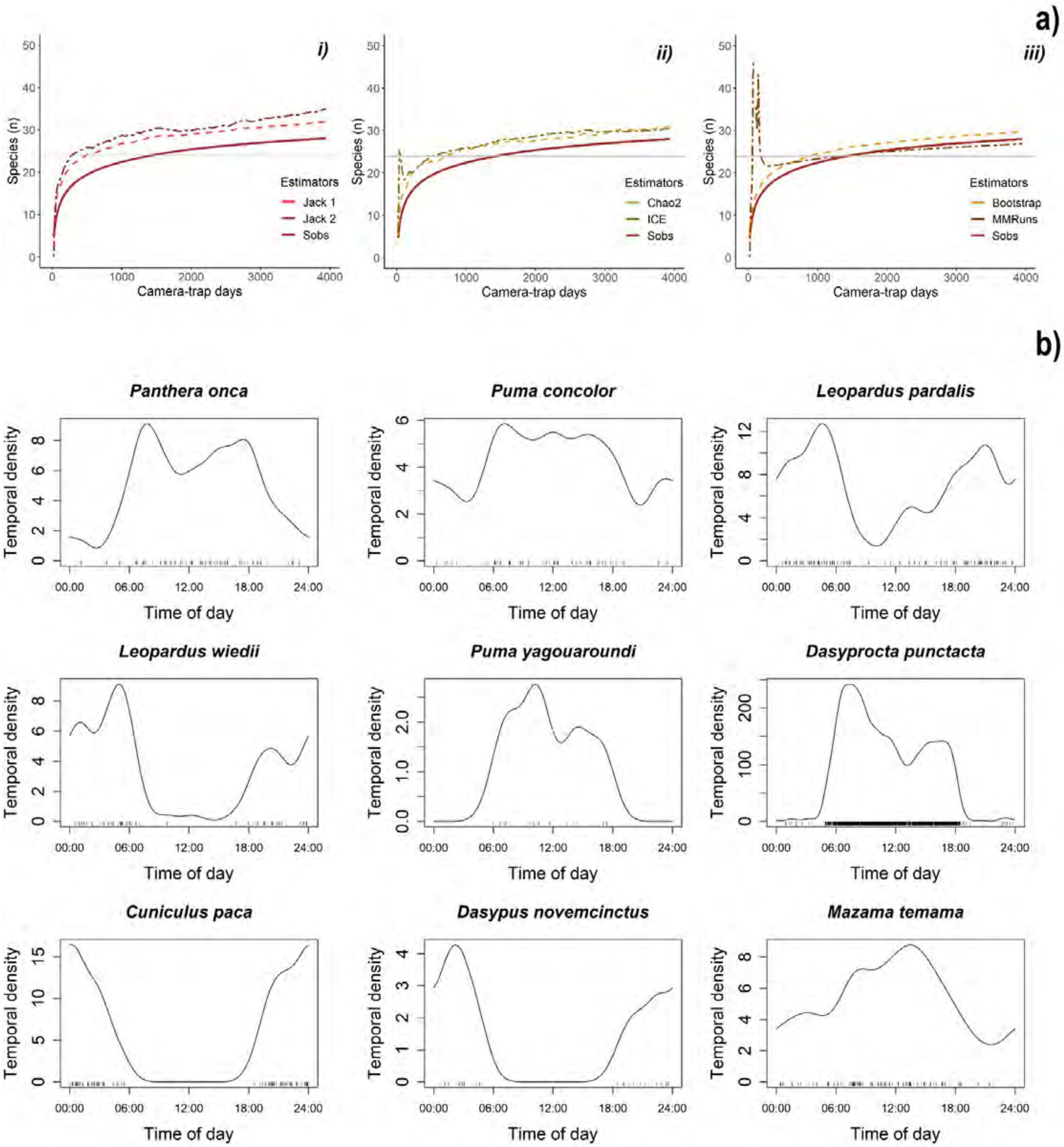

Figure 2. a) Comparison of the different richness estimators for medium and large terrestrial mammals' species for the data obtained in the survey in the National Park Darién, Panamá: i) Jackknife 1 and Jackknife 2; ii) ICE and Chao 2; and iii) Bootstrap and MMRuns. The number of species previously recorded for the region in other studies with camera traps was 26 (Meyer *et al.* 2015a). b) Activity patterns of the most recorded medium and large terrestrial mammal species in the Darién National Park, Panamá.

occurrence of large mammal species, such as the jaguar, white-lipped peccary, and Baird’s tapir. Furthermore, we recorded other species that have not been documented in other studies that have used the camera trapping technique in the region, such as the lesser capybara, coyote, and potentially Robinson’s mouse opossum (*M. robinsoni*; Table 2). Also, the results showed that monitoring using camera trapping technique is quite useful to register species that could be considered rare, since during our survey we recorded species such as the bush dog (*S. venaticus*), which is difficult to detect but it is potentially expanding its range towards the Panama Bridge (Meyer *et al.* 2015b).

Similarly, to other studies implemented with camera traps in the region (Meyer *et al.* 2015a), our results demonstrated the camera trapping technique's efficiency in assessing the species richness and relative abundance of the terrestrial mammal species that occur within the Darién National Park. However, the richness non-parametric estimators predicted that there are still species to be detected, this is probably because some species with a very low probability of detection were not recorded in our survey, such as species with more arboreal or aquatic habits than terrestrial, or by their secretive nature. This could happen with species such as the weasel (*Mustela frenata*), the greater grison (*Galictis vitatta*), the river otter (*Lontra longicaudis*), Allen's olingo (*Bassaricyon alleni*), kinkajou (*Potos flavus*) and porcupine (*Coendou rosthchildi*). Since that in our survey, we probably detected most of the species in the study area (more than 75 % of the species present in the region) and since the probability of detection is highly variable among the recorded species, the more likely richness estimator for our survey could be the Jack 1 and Jack 2 (Tobler

Table 2. Species recorded during the survey in Darién National Park, Panamá including the total number of records, independent records, and relative abundance of these species.

Class	Order / Family	Species	Total records obtained	Independent records (1 hour)	Relative abundance	Activity pattern
MAMMALIA	DIDELPHIMORPHIA					
	Didelphidae	*Didelphis marsupialis*	264	93	26.84	Nocturnal
		Marmosa sp. (likely *M. isthmica*)	4	4	1.15	-
		Unidentified opossums (*Metachirus nudicaudatus* or *Philander opossum*)	68	29	8.37	-
	CINGULATA					
	Dasypodidae	*Dasypus novemcintus*	232	33	9.52	Nocturnal
	PILOSA					
	Myrmecophagidae	*Tamandua mexicana*	42	9	2.60	Cathemeral
		Myrmecophaga tridactyla	32	6	1.73	Diurnal
	RODENTIA					
	Caviidae	*Hydrochoerus isthmius*	12	1	0.29	-
	Cuniculidae	*Cuniculus paca*	499	133	38.38	Nocturnal
	Dasyproctidae	*Dasyprocta puntacta*	15,648	2,125	613.28	Diurnal
	Echimyidae	Unidentified rodent	99	44	12.70	-
	Sciuridae	*Sciurus granatensis*	730	221	63.78	Diurnal
	LAGOMORPHA					
	Leporidae	*Sylvilagus brasiliensis*	2	2	0.58	-
	CARNIVORA					
	Canidae	*Cerdocyon thous*	9	3	0.87	-
		Canis latrans	1	1	0.29	-
		Speothos venaticus	2	1	0.29	-
	Felidae	*Leopardus wiedii*	224	82	23.67	Crepuscular
		Leopardus pardalis	658	170	49.06	Crepuscular
		Puma yagouaroundi	101	26	7.50	Diurnal
		Puma concolor	469	103	29.73	Cathemeral
		Panthera onca	702	123	35.50	Crepuscular
	Mustelidae	*Eira barbara*	119	21	6.06	Diurnal
	Procyonidae	*Nasua narica*	136	24	6.93	Diurnal
		Procyon cancrivorus	14	7	2.02	-
	PERISSODACTYLA					
	Tapiridae	*Tapirus bairdii*	97	15	4.33	Nocturnal
	ARTIODACTYLA					
	Cervidae	*Mazama temama*	993	132	38.10	Diurnal
	Tayassuidae	*Tayassu pecari*	289	18	5.19	Diurnal
		Pecari tajacu	7,361	257	74.17	Diurnal

et al. 2008). This would indicate that species richness that could be detected using the camera trapping technique in our study area would range between 28 and 32 species.

Results supported our hypothesis that activity patterns of the most recorded species are similar in Darién National Park to those reported in other regions of their distribution range. Activity patterns analyses showed that the top predator of this ecosystem, the jaguar, has a crepuscular behavior, with its activity peaks during sunrise and sunset, which is similar to what has been found in other tropical forests, but also in dry, and temperate forests of México and South America (Monroy-Vilchis *et al.* 2009; Di Bitetti *et al.* 2010; Romero-Muñoz *et al.* 2010; Hernández-Saintmartín *et al.* 2013; Briones-Salas *et al.* 2016). Otherwise, ocelots and margays were also crepuscular, but their activity decreased significantly during the brightest hours of the day, and pumas and jaguarundis showed more diurnal behavior, displaying more activity during the brightest hours of the day. These differences between the felid species in their activity patterns could be a mechanism that allows their coexistence in areas of sympatry (Di Bitetti *et al.* 2010). Jaguars and pumas showed a high overlap, although pumas were more active during the daylight hours. In the case of small felids, the temporal segregation pattern is clearer, jaguarundis have more diurnal habits compared to ocelots and margays, and potentially segregation between ocelots and margays occurs in spatial terms since margays have more arboreal habits (Di Bitetti *et al.* 2010).

Regarding other species, the ones that showed more activity during the periods of more light during the day were the ñeque, the coati, the venado corzo, and both species of peccaries (Figure 2b). These species have shown similar diurnal activity patterns in other regions of Mesoamerica such as Costa Rica, and southern México (Pérez-Irineo and Santos-Moreno 2016; Arroyo-Arce *et al.* 2017; Botts *et al.* 2020; Falconi-Briones *et al.* 2022). However, venado corzo has shown cathemeral activity patterns in the tropical rainforests of Oaxaca, México (Pérez-Irineo and Santos-Moreno 2016). In contrast, the species with more activity during the night were the nine-banded armadillo, the paca, and Baird's tapir (Figure 2b). Nine-banded armadillos have been classified as nocturnal species by several studies, though they can change their activity patterns according to environmental conditions, such as forest patch sizes (Norris *et al.* 2010). Pacas have shown nocturnal activity patterns in the tropical forests of Costa Rica and the Humid Chaco in Argentina (Arroyo-Arce *et al.* 2017; Huck *et al.* 2017; Botts *et al.* 2020). In general Baird´s tapirs show nocturnal activities in the tropical rainforest of southern México, and in most of their distribution ranges (Pérez-Irineo and Santos-Moreno 2016; Falconi-Briones *et al.* 2022; Sánchez-Pinzón *et al.* 2020), but in some areas such as montane forests in México shown cathemeral activity (Carbajal-Borges *et al.* 2014).

This study demonstrates the efficiency of the camera trapping technique to be implemented in the biological monitoring of the region to evaluate year after year the state of conservation of the Darién National Park. Implementation of long-term monitoring programs is a crucial step to better understanding the dynamics of wildlife populations within the National Park because these will add information to evaluate different aspects of the basic ecology of emblematic species. It is necessary to replicate these kinds of efforts in other large forest blocks in Mesoamerica to monitor the occurrence and conservation status of wildlife in these wild areas.

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Mastofauna associated with culverts along a road within the Yasuní National Park, Ecuador

Mastofauna asociada a estructuras de drenaje en un acceso vial dentro del Parque Nacional Yasuní, Ecuador

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Road construction is one of the main boosters of biodiversity loss. Fortunately, culverts can function as passes for certain wildlife species. This study recorded the mammal species that may use these structures to move from one side of a road to the other. The mammals visiting 11 culverts on a road within the Yasuní National Park were recorded over a month using camera traps. The capture rate (TC) and the visitation rate (TV) were calculated to quantify the most visited site and the most frequent visitor species. A sampling effort of 365 camera-trap days yielded 7,110 records with 264 independent events corresponding to 10 mammal species. The highest visitation rates corresponded to *Cuniculus paca* (52.05) and *Mazama americana* (9.86); the other species had a visit rate lower than 3. *Cuniculus paca* was recorded in 10 culverts. *Cuniculus paca* was the only species recorded inside a culvert; however, we cannot conclude that it crossed from one side to the other. The rest of the species approached the culverts, but there was no evidence of their entry. The use of culverts likely depends on the construction characteristics and the required conditions. However, implementing culverts can mitigate adverse impacts to the fauna, so future research is necessary.

Key words: Barrier effect; mammals; phototrapping; protected area; road; underground passages; wildlife crossing.

La construcción de carreteras es una de las principales razones que acelera la pérdida de biodiversidad. Afortunadamente, las estructuras de drenaje pueden actuar como pasos para ciertas especies de fauna silvestre. Nos propusimos registrar las especies de mamíferos que podrían utilizar estas estructuras para movilizarse de un lado al otro de una carretera. En una carretera dentro del Parque Nacional Yasuní, mediante trampas fotográficas, se registró durante un mes los mamíferos que frecuentaron 11 estructuras de drenaje. Se calculó la tasa de captura (TC) y la tasa de visita (TV), permitiéndonos cuantificar que sitio fue más visitado y que especies realizaron más visitas. Con un esfuerzo de muestreo de 365 trampas-día, se obtuvieron 7,110 registros con 264 eventos independientes que corresponden a 10 especies de mamíferos. Las mayores tasas de visita fueron de *Cuniculus paca* (52.05) y *Mazama americana* (9.86), el resto de las especies presentaron una tasa de visita menor a 3. *Cuniculus paca* fue registrada en 10 estructuras de drenaje. *Cuniculus paca* fue la única especie registrada dentro de un drenaje; sin embargo, no podemos concluir que cruzó de un lado al otro. El resto de las especies se acercaron a los drenajes, pero no se evidencia su ingreso. Consideramos que el uso de los drenajes depende de las características constructivas y una serie de condiciones requeridas; sin embargo, su implementación puede mitigar impactos negativos a la fauna, por lo que futuras investigaciones son necesarias.

Palabras clave: Área protegida; carretera; cruce de fauna; efecto barrera; fototrampeo; mamíferos; pasos subterráneos.

Road construction causes landscape fragmentation, loss of habitats, and ecosystem degradation (Ochoa 2008; Ministerio de Medio Ambiente y Medio Rural y Marino 2010; Ibisch *et al.* 2016; Pulsford *et al.* 2019; Benítez *et al.* 2021). It leads to changes in the original forest composition and structure, affecting the mobility patterns and behavior of species and disrupting dispersal, migration, and genetic exchange processes (López-Barrera 2004; Peña-Becerril *et al.* 2005; Mata *et al.* 2006; Arroyo-Rodríguez and Mandujano 2007; de la Torre *et al.* 2012; Garzón-Santomaro *et al.* 2019; Benítez *et al.* 2021; Pozo-Montuy and Bonilla-Sánchez 2022; Ruíz-Ramírez *et al.* 2022). Roads transform the habitat, generating pollution, noise, and artificial light, thus exacerbating the deterioration of ecosystems (Benítez *et al.* 2021; Pozo-Montuy and Bonilla-Sánchez 2022; Ruíz-Ramírez *et al.* 2022). All these adverse impacts may reduce population abundance and increase the species extinction risk (Jaeger and Fahrig 2004; Morera et al. 2008; Ochoa 2008; Rubio-Rocha *et al.* 2022).

The construction of wildlife crossings has been one of the measures to mitigate the adverse impacts of roads (Wang *et al.* 2017; Delborgo *et al.* 2020). These crossings or passes are permanent structures designed exclusively for a certain species or group of species (specific fauna crossings) or built for a different purpose (*i.e.*, connect water bodies, canals, sewers, culverts) not designed for wildlife crossing but that can be used for that purpose (non-specific wildlife crossings; Torres 2011).

Road construction near or within protected areas in the Ecuadorian Amazon directly threatens biodiversity (Espinosa *et al.* 2018). The Yasuní National Park (PNY, in Spanish) is the largest protected area in mainland Ecuador and is considered one of the most biodiverse zones worldwide (Bass *et al.* 2010). Despite this, oil companies have built roads for oil extraction activities that modify the original landscape (Espinosa *et al.* 2014). Culverts are built along these roads to mitigate impacts on water bodies (Envirotec 2011; Abad *et al.* 2014).

In this context, the mammal species that may use culverts to move from one side of the road to the other, *i.e.*, for which culverts function as non-specific animal passes, were recorded through photo trapping.

The study was conducted within the oil facility (Block) 31 at the Tiputini-Apaika road within the Yasuní National Park, located at Cononaco parish, Aguarico canton, Orellana province (Figure 1a). The road runs from the southern bank of the Tiputini River, on the PNY border, to the Apaika oil platform (Envirotec 2011). The dominant vegetation type along the road is the flood forest of the Amazonian alluvial plain; there are also patches of flood forest where the palm *Mauritia flexuosa* predominates (Ministerio del Ambiente de Ecuador 2013).

The Tiputini-Apaika road comprises sections of unpaved compacted soil alternating with sections covered with syn-

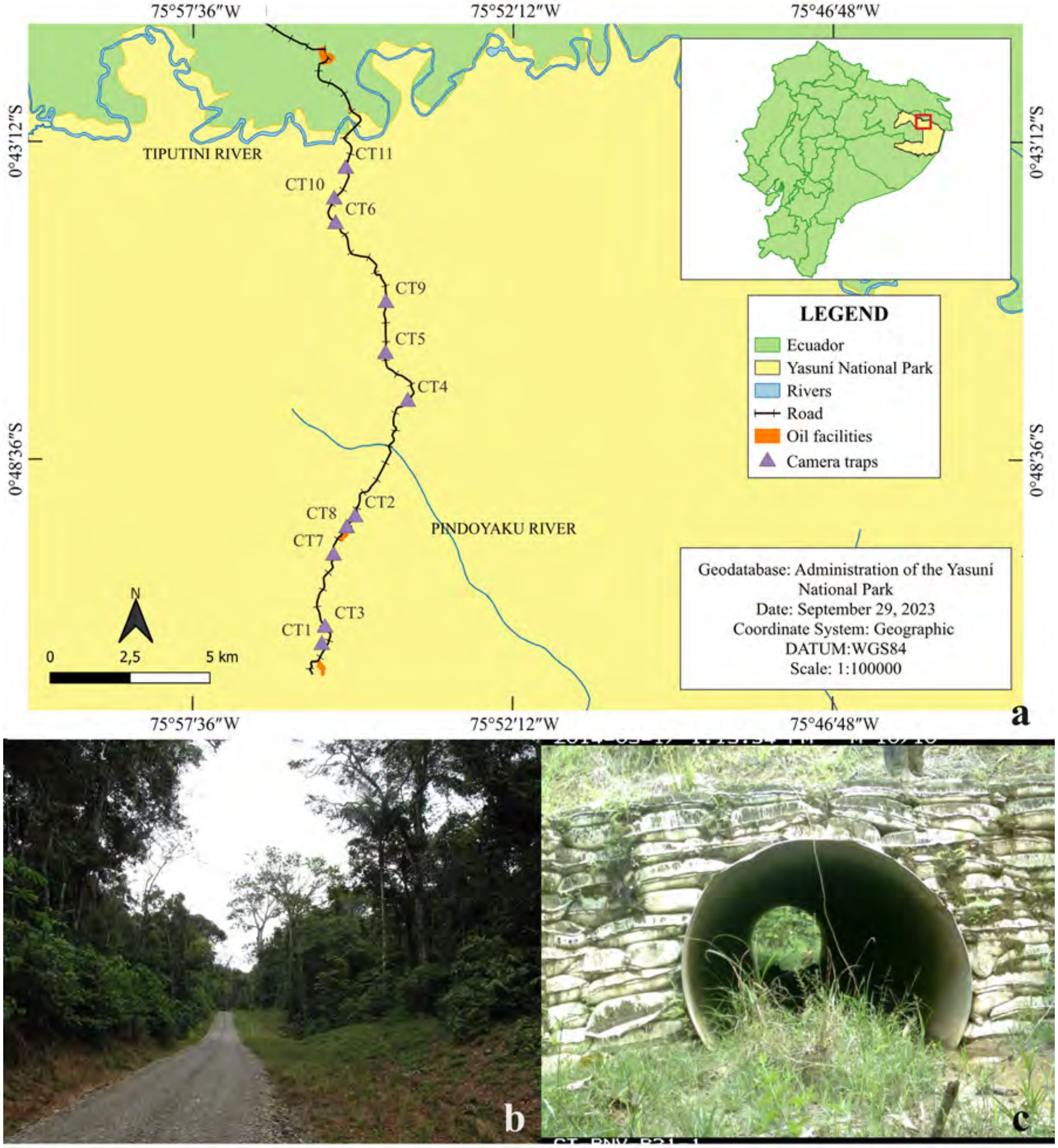

Figure 1. a) Map of the study area. Tiputini-Apaika road and location of the phototrapping stations in the Yasuní National Park, Ecuador; b) Tiputini-Apaika road within the Yasuní National Park; c) Culverts (drainage structures installed in water bodies).

thetic materials called Geoterra and MegaDeck/Durabase, which are placed on the compacted soil (Envirotec 2011). It measures 20 km long by 10 m wide, and its access is restricted to oil company vehicles that circulate at a maximum allowed speed of 35 km/h (Envirotec 2011).

In the low-rainfall months of September and October 2014 (Bass *et al.* 2010; Envirotec 2011), 11 of 82 drainage structures (culverts) were selected along the Tiputini-Apaika road (Figure 1; Table 1). Culverts were selected based on the presence of mammal footprints at the inlets-outlets and considering that they were easily accessible to install camera traps. Culverts are galvanized structures measuring 12 m long and approximately 1.5 m in diameter, with soil-cement heads installed at both ends (Envirotec 2011). All culverts had very small water flows that grew and flooded these structures during heavy rains (Figure 1c).

Camera traps were installed facing one of the culvert inlets. One RECONYX H600 HyperFire camera trap was used per culvert, set to capture 10 consecutive photographs with no waiting time between detections. These cameras were installed considering the criteria of Tobler *et al.* (2008) and Díaz-Pulido and Payán (2012), such as the position of the camera trap relative to the target and the ground, fixing the equipment in firm and stable places, and with an unobstructed field of view.

For the data analysis, records were considered independent when more than 30 min passed between consecutive photographs of the same species at a given photo trapping station. Consecutive photographs of different species were also considered independent records regardless of the time elapsed (Blake *et al.* 2011).

The capture rate (TC, for its acronym in Spanish) by site was calculated by dividing the number of independent captures by the number of sampling days and multiplied by 100 (correction coefficient). This allowed quantifying the visits to each site over 100 days. Similarly, the visitation rate (TV, for its acronym in Spanish) for each species was calculated by dividing the number of independent records by the number of days of total sampling and multiplied by 100 (correction coefficient). This allowed quantifying independent events by species for 100 days (Rovero *et al.* 2014; Mandujano and Pérez-Solano 2019; Table 2).

A sampling effort of 365 camera-trap days resulted in 7,110 photographic records, of which 259 are independent records of 10 mammal species, with 1 unidentified rodent species. In addition, an individual of the Neotropical otter (*Lontra longicaudis*) was recorded by direct observation. Of these species, 6 are included in Ecuador's Red List (Tirira 2021), the International Union for the Conservation of Nature Red List (IUCN 2023), and the appendices to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 2023; Table 2).

The site with the highest number of independent visitations was CT5, with 24 % of the records (TC = 16.99, *n* = 62), followed by CT6 and CT2, with 15% each (TC = 10.96, *n* = 40, and TC = 10.68, *n* = 39, respectively). The other sites recorded a TC of less than 10 (Table 1).

The species with the highest number of independent captures was *Cuniculus paca,* with 72 % of the records (TV = 52.05, *n* = 190), followed by *Mazama americana,* with 13.6 % of independent records (TV = 9.86, *n* = 36). The rest of the species had a TV lower than 3: *Coendou* sp. (TV = 1.64, *n* = 6), *Dasyprocta fuliginosa* (TV = 1.37, *n* = 5), *Procyon cancrivorus* and *Leopardus pardalis* (TV = 1.09, *n* = 4), *Dicotyles tajacu* (TV = 1.75, *n* = 7)*, Panthera onca* and *Pecari tajacu* (TV = 0.27, *n* = 1; Table 2).

Cuniculus paca was recorded in 10 of the 11 sites studied and appears within a culvert (Figure 2a). *Mazama americana* (Figure 2b) and *D. fuliginosa* were recorded in 4 sites. *Procyon cancrivorus* and *T. terrestris* (Figure 2c) were recorded in 3 sites and *L. pardalis* in 2. The remaining species were recorded only in a single site each (Table 2), including *P. onca* (Figure 2d).

The lowland paca (*C. paca*) had the highest visitation rate, recorded in 10 of the 11 sites sampled. These findings are similar to those obtained by Monge-Velázquez and Sáenz

Table 1. Data from camera traps (CT) installed in culverts along the Tiputini-Apaika road within the Yasuní National Park, Ecuador.

Camera	Traps/ day	South Latitude	West Longitude	Photographs Captured	N° of independent records	Capture rate	N° of species
CT1	36	0° 51´ 45´´	75° 55´ 25´´	260	20	5.48	3
CT2	36	0° 49´ 34´´	75° 54´ 51´´	1,410	39	10.68	4
CT3	10	0° 51´ 27´´	75° 55´22´´	70	2	0.55	2
CT4	36	0° 47´ 36´´	75° 53´58´´	350	18	4.93	7
CT5	36	0° 46´ 48´´	75° 54´21´´	1,640	62	16.99	5
CT6	36	0° 44´ 35´´	75° 55´11´´	1,140	40	10.96	1
CT7	35	0° 50´ 13´´	75° 55´13´´	610	22	6.03	2
CT8	35	0° 49´ 46´´	75° 55´ 0,2´´	10	1	0.27	1
CT9	35	0° 45´ 56´´	75° 54´ 20´´	60	6	1.64	4
CT10	35	0° 44´ 10´´	75° 55´ 13´´	1,030	35	9.59	1
CT11	35	0° 43´ 39´´	75° 55´ 1,6´´	530	19	5.21	4

Figure 2. a) Lowland paca (*Cuniculus paca*) was the only species recorded within the culvert and had the highest visitation rate; b) red deer (*Mazama americana*) attained the second-highest visitation rate; c) the Amazon tapir (*Tapirus terrestris*) was recorded in three culverts; d) a jaguar (*Panthera onca*) was recorded in a single photo trapping station in the Yasuní National Park, Ecuador.

(2022) in a coastal zone of Costa Rica, where culverts have also been installed. Similarly, *C. paca* is one of the species with the highest crossing frequency in the study by Torres (2011).

On the other hand, the direct observation of a culvert used as a crossing by the Neotropical otter, *L. longicaudis*, suggests that this species may be using these sites. However, considering that the otter was in a flooded culvert and that it moved away using the culvert as an escape route upon noticing the presence of the observer, the observation could be a fortuitous event explained by the aquatic and elusive habits of the species (Vallejo and Pozo 2022).

Due to its size, the jaguar (*Panthera onca*) is unlikely to use culverts as crossings; these structures measure 1.5 m in diameter, and large species such as the jaguar prefer large, open structures (Torres 2011; Kintsch *et al.* 2015). González-Gallina *et al.* (2018) recorded at least 6 individuals of *P. onca* using animal passes measuring 3 m wide and 4.5 m high; this same study recorded no jaguar approaching culverts 1.8 m in diameter, similar to those included in the present study. Along the Tiputini-Apaika road, oil company and PNY workers have repeatedly observed jaguars crossing the road throughout the oil plant operation.

The presence of carnivores in culverts suggests that these sites, visited by potential prey (*e.g.*, small and medium-sized rodents), represent hunting opportunities for predators. Although culverts may not be used as crossings, they may be sites of potential food availability. For instance, the ocelot, *Leopardus pardalis,* is an opportunistic predator that feeds on a wide range of prey (Moreno *et al.* 2006), including birds and mammals, mainly rodents such as the agouti (*Dasyprocta fuliginosa*) and the lowland paca (*C. paca*) recorded in this study, as well as amphibians and reptiles that may use these sites as shelters and that the ocelot can visit in search of prey (Macas-Pogo *et al.* 2023). However, a long-term study conducted in the Banff National Park, Canadá, reported only 5 predation events over 13 years; the authors concluded that there is no association between crossing structures and predation events (Clevenger and Ford 2010).

As for the ungulates captured, none used culverts as crossings, consistent with the reports by Torres (2011) and González-Gallina *et al.* (2018). However, these same studies did report crossing events of white-tailed deer, *Odocoileus virginianus*, using fauna crossing structures, *i.e.*, structures designed for this purpose. As with the jaguar and large mammal species, the size of these structures is crucial for their use (Kintsch *et al.* 2015).

The culverts installed along the Tiputini-Apaika road were not built for use as fauna crossings; however, this study recorded two crossing events by *C. paca* and *L. longicaudis*. It could be stated that most of the recorded fauna does not use culverts to move across and that the records of the present work were incidental since, according to Fernández-Buces *et al.* (2022) and Monge-Velázquez and Sáenz (2022), culverts are attractive sites to wildlife.

As the sites where these structures were installed are flooded, it can be expected that species of terrestrial habits do not use them to cross the road (Jochimsen *et al.* 2004). Most of the recorded fauna likely use them only as watering holes and food-seeking sites, as is the case with the crab-eating raccoon (*Procyon cancrivorous*), an omnivorous species that feeds on fish, amphibians, reptiles, and aquatic crustaceans (Phillips 2005).

On the other hand, the recording of threatened species such as the Neotropical otter, the Amazonian tapir, and the jaguar (Table 2) highlights the need to install different types of fauna crossings (*i.e.*, specific fauna crossings) in sensitive sites such as the PNY. The size and behavior of the species expected to use the crossings must be taken into account to construct them accordingly, taking into account the design, type of material used, dimensions, inlets and outlets, as well as the traffic and noise level of the road (Monge-Velázquez and Sáenz 2022). Ruediger and DiGiorgio (2007) indicate that the building material of crossings is irrelevant for some species but is very important for others, while Corlatti *et al.* (2009) describe the particular characteristics of crossings for some wildlife groups.

Culverts can serve as non-specific wildlife crossings. However, a long-term monitoring plan should be implemented to gather conclusive information contributing to the effective management of the protected area.

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Table 2. List of species, visitation rate, and threat categories recorded along the Tiputini-Apaika road within the Yasuní National Park. [1]Ecuador's Red Book. [2]International Union for the Conservation of Nature. [3]Convention on International Trade in Endangered Species of Flora and Fauna. DD: Data deficient. LC: Least concern. NT: Near threatened. VU: Vulnerable. EN: Endangered. CR: Critically endangered. I and II: Appendices 1 and 2.

Taxonomy	N° of captures	N° of independent records	Visitation rate	[1]LRE	[2]IUCN	[3]CITES
ARTIODACTYLA						
Cervidae						
Mazama americana	1,350	36	9.86	NT	DD	--
Tayassuidae						
Dicotyles tajacu	10	1	0.27	NT	LC	II
CARNIVORA						
Felidae						
Leopardus pardalis	50	4	1.10	NT	LC	I
Panthera onca	20	1	0.27	EN	NT	I
Procyonidae						
Procyon cancrivorus	90	4	1.10	LC	LC	--
Mustelidae						
Lontra longicaudis		Direct observation		VU	NT	I
PERISSODACTYLA						
Tapiridae						
Tapirus terrestris	370	9	2.47	EN	VU	II
RODENTIA						
Cuniculidae						
Cuniculus paca	4,940	190	52.05	NT	LC	III
Dasyproctidae						
Dasyprocta fuliginosa	70	5	1.37	LC	LC	--
Erethizontidae						
Coendou sp.	80	6	1.64	--	--	--
Incertae sedis	30	3	0.82	--	--	--

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New record of *Cryptotis mayensis* in the Gulf of México coastal plains

Nuevo registro de *Cryptotis mayensis* en la Planicie Costera del Golfo de México

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The Yucatán small-eared shrew, *Cryptotis mayensis* (Merriam, 1901), is a little-known shrew that inhabits lowlands covered by tropical forests in the Yucatán Peninsula in México, as well as in Guatemala and Belize. As part of a study evaluating rodent populations in oil palm plantations (*Elaeis guineensis*), a specimen of *C. mayensis* was captured within a young palm plantation located in the Gulf of México coastal plains on the borders of Tabasco and Campeche. The species record is located 60 km north of the nearest species records, which extends its distribution area. Furthermore, since the specimen was captured in a monoculture surrounded by pastures for livestock farming, it could indicate that *C. mayensis* can inhabit sites with high disturbance.

Key words: Campeche; mammal survey; oil palm; shrew; Tabasco.

La musaraña de orejas pequeñas de Yucatán, *Cryptotis mayensis* (Merriam, 1901), es una musaraña poco conocida que habita en tierras bajas cubiertas por bosques tropicales en la Península de Yucatán en México, así como en Guatemala y Belice. Como parte de un estudio de evaluación de poblaciones de roedores en plantaciones de palma de aceite (*Elaeis guineensis*), se capturó un ejemplar de *C. mayensis* al interior de una plantación joven de palma que está localizada en la Planicie costera del Golfo de México en los límites de Tabasco y Campeche. El registro de la especie se encuentra a 60 km al norte de los registros más cercanos de la especie, lo que extiende el área de distribución de ésta; además, debido a que el ejemplar fue capturado en un monocultivo rodeado de pastizales para la ganadería, podría indicar que *C. mayensis* tiene capacidad de habitar en sitios con alta perturbación.

Palabras clave: Campeche; listado mamíferos; musaraña; palma de aceite; Tabasco.

The Yucatán small-eared shrew, *Cryptotis mayensis* (Merriam, 1901), is a species of small to medium size within its genus; it possesses short fur, ranging from silver-gray to dark silver-gray, albeit lighter in comparison to other species in the *C. nigrescens* group (Woodman and Timm 1993; Carraway 2007). The ventral coloration is silver-gray, and the dorsal coloration is lighter gray. The tail is notably short (approximately 33 % of head-body length) and covered in short silver-gray fur. The eyes are minuscule, and the ears are small and barely visible beneath the hair (Woodman and Timm 1993; Reid 2006). The species' range extends from México, encompassing the states of Yucatán and Quintana Roo, to the eastern and central regions of Campeche, as well as reaching into Guatemala and Belize (Carraway 2007; Cuarón *et al.* 2016; see Figure 1). *Cryptotis mayensis* appears to have a disjunct geographical distribution, as it has been reported in barn owl *Tyto alba* pellets in the state of Guerrero (Choate 1970; Carraway 2007; see discussion on these records in Monroy-Gamboa 2021; Figure 1).

The shrew *Cryptotis mayensis* inhabits lowlands covered by deciduous and semi-deciduous tropical forests, as well as dry scrublands on the Yucatán Peninsula. It is typically found at altitudes that generally do not exceed 100 m (Álvarez and Martínez 1967; Woodman and Timm 1993; Cuarón *et al.* 2016). Despite limited knowledge regarding its ecology, it is classified as a nocturnal carnivore that preys on insects, snails, and earthworms (Carreón-Arroyo and Ceballos 2005). According to the International Union for Conservation of Nature (IUCN), it is considered a species of least concern (Cuarón *et al.* 2016), and it is listed as a species subject to special protection under the Official Mexican Legislation NOM-059-SEMARNAT-2010 (SEMAR-

NAT 2010).

As part of a study aimed at identifying rodent species responsible for damage in oil palm plantations (*Elaeis guineensis*), we captured 1 individual of *C. mayensis* on May 4, 2023. The capture was made using a Sherman trap (H. B. Sherman Traps Inc.; Tallahassee, Florida) placed within a cultivated area in the boundary between Emiliano Zapata, Tabasco, and Carmen in Campeche, México (Figure 1). The capture site was located within the Caballitos plantation, owned by Uumbal Agroforestal (17° 55' 58" N, 91° 46' 12" W; Figure 2d). The Caballitos plantation is situated in the Coastal Plain of the Gulf of México, at an elevation of approximately 10 m.

The climate in the region is warm and humid, characterized by abundant summer rains, with an average annual temperature ranging from 26°C to 28°C and an average annual precipitation between 1,500 to 2,000 mm (INEGI 2015). Originally, the region was predominantly covered by semi-deciduous tropical forests (Rzedowski 2006), which, like a significant portion of the Coastal Plain of the Gulf of México, has largely been converted into pastures for livestock and agricultural areas for over 50 years (Tudela 1989). Currently, most of the site is covered by induced pastures for livestock (Kolb and Galicia 2012) and secondary woody vegetation in various stages of succession. In the past 10 years, a significant portion of the induced pastures has been converted into oil palm plantations (Hernández-Rojas *et al.* 2018).

The *C. mayensis* record occurred within a 2-year-old plantation where the palm trees reached a height of approximately 2 m. We placed 100 Sherman traps (7.62 x 8.89 x 22.86 cm) within a 100 x 100 m quadrant for 2 consecutive nights. The traps were baited with oat flakes, activated in the late afternoon (around 16:00 to 18:00 hr), and checked between 7:00 and 9:00 hr the following day. After the first day, the traps were removed and placed back in the exact locations for the second night of sampling. The captured rodents included the toltec cotton rat (*Sigmodon toltecus*) and the fulvous pygmy rice rat (*Oligoryzomys fulvescens*). Captured individuals were sexed and released at the capture site immediately after processing. The capture and handling of the organisms followed the criteria established by Sikes *et al.* (2016) and were conducted under collecting permit No. SGPA/DGVS/O392O/22 issued by the Secretariat of Environment and Natural Resources (SEMARNAT).

During the second night of sampling, a shrew was captured with the following measurements: total length = 75 mm, tail length = 15 mm, hind leg length = 10 mm, and

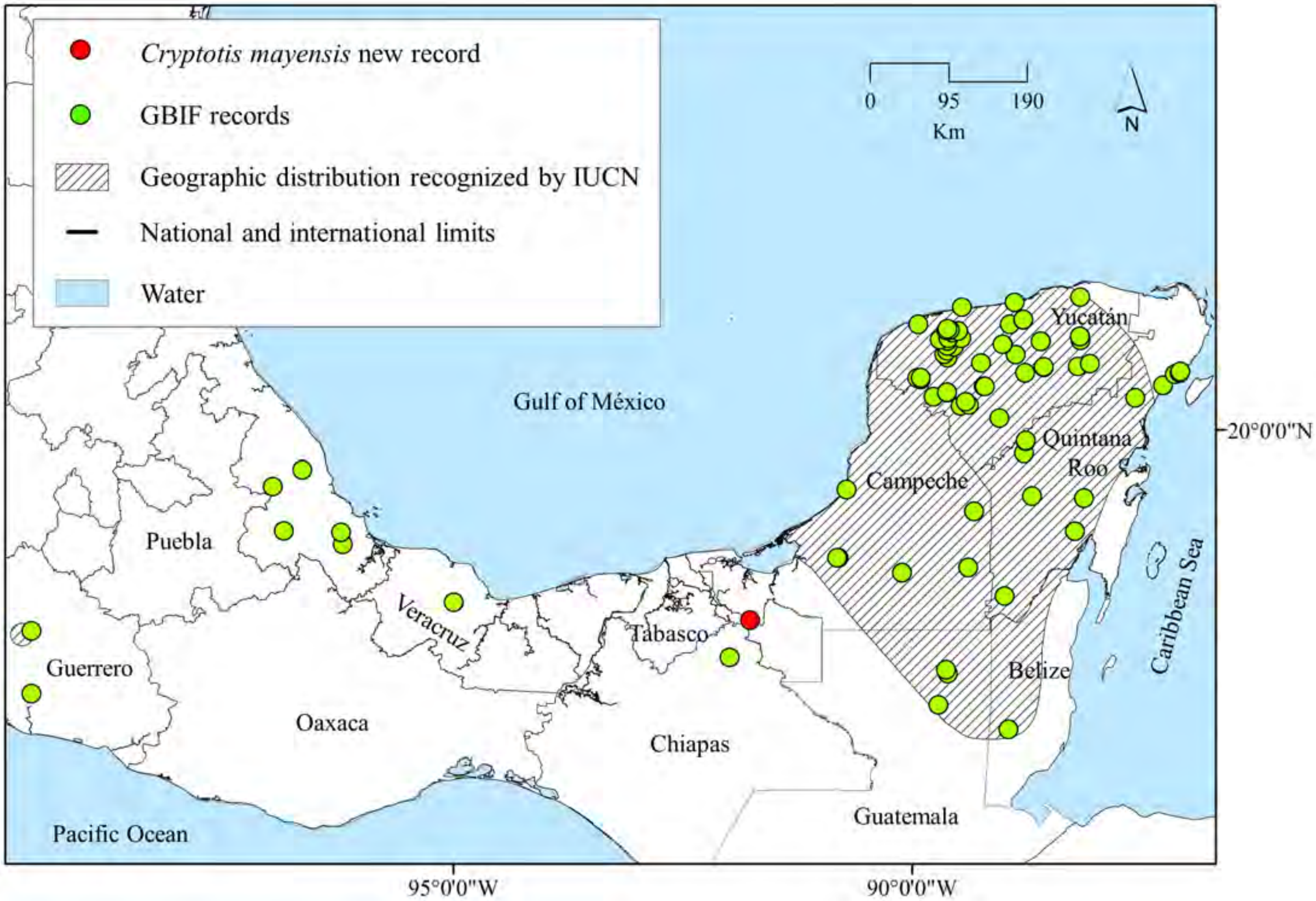

Figure 1. Geographic location of the new record of *Cryptotis mayensis* according to the distribution recognized by the International Union for Conservation of Nature (IUCN; Cuarón *et al.* 2016) and records from the Global Biodiversity Information Facility (GBIF 2023; green points).

ear length = 0 mm (Figure 2a-c). Due to the need for rapid processing to minimize handling effects, we were unable to obtain its weight and determine its sex. The specimen was identified as belonging to the *Cryptotis* genus based on its very short tail, tiny ears, and eyes. Further, it was identified as *C. mayensis* because its fur was short and dark gray on the dorsum and lighter on the ventral side, with no distinct bicolored tail (Figures 2a and b). This distinguishes it from its sympatric relatives like the small-eared shrew (*C. pueblensis*), which could also potentially inhabit the area. Unlike the specimen captured in this report, the small-eared shrew has brown dorsal fur and a slightly bicolored tail (Carraway 2007).

The *C. mayensis* specimen was photographed and subsequently released. The photographs were deposited in the "Alvar González Christen" Photographic Collection at the Instituto de Investigaciones Biológicas from Universidad Veracruzana with catalog numbers IIB-UVMam 0103f and IIB-UVMam 0103f bis (Figure 2a, and b, respectively).

To locate the records of *C. mayensis* closest to the one we obtained in the Caballitos plantation, as well as to identify records of presence beyond the reported distribution area for the species (Cuarón *et al.* 2016), we consulted the Global Biodiversity Information Facility (GBIF) using the species name "*Cryptotis mayensis*" as our search criterion. We obtained 237 records, of which 202 had reported coordinates (GBIF 2023). We projected these records onto a topographic map of the region using QGIS ver. 3.22.2 (QGIS Development Team 2021).

We found that the nearest *C. mayensis* points to the Caballitos plantation record were 3 records from the Palenque locality in Chiapas, México (GBIF ID 1895683219, 1895683206, and 1895683159), located 60 linear km to the south from this new record, and 2 records in the El Tormento locality in the municipality of Escárcega, Campeche, at 125.5 km to the east (GBIF ID 2630401870 and 2804487581; Figure 1). Additionally, we found 9 records outside the distribution area reported by Cuarón *et al.* (2016): those 3 from Palenque in Chiapas and 6 in the state of Veracruz (GBIF ID 2630469924, 2630470258, 2630470002, 2630482618, 2630482618, and 2630482983).

The record of the *C. mayensis* individual captured in the Caballitos plantation is located outside the reported distribution area for the species (Cuarón *et al.* 2016), at distances of 60 km to the north and 125.5 km to the southwest of the nearest known records. This record constitutes the first formal record of the species in the state of Tabasco (Hidalgo-Mihart *et al.* 2016). It also represents the second shrew species reported for the state. The only previously known specimen was *C. parva pueblensis* (= *C. pueblensis*), captured in Balancán, Tabasco, and deposited in the Museum of Natural Sciences at Louisiana State University (catalog number LSUMZ 8882).

Reviewing the validity of records near the *C. mayensis* record obtained in this study in the Caballitos plantation, we found that the 3 records originating from Palenque, Chiapas, can be traced back to Ocaña-Marín (1997). In his original text, Ocaña-Marín reported remains of *C. nigrescens* found during excavations at the "Templo Olvidado" in Palenque (archaeological site), Chiapas. These remains were likely derived from the regurgitations of owls and barn owls that inhabited the site while it was abandoned. Subsequently, these 3 records were reported as *C. mayensis* in reviews conducted on records of mammals at archaeological and Pleistocene sites (Arroyo-Cabrales *et al.* 2005), as well as records of mammals in the state of Chiapas (Muñoz-Alonso 2021). Despite initially being designated as *C. nigrescens*, these records are listed as *C. mayensis* in GBIF. It is important to note that since the specimens reported by Ocaña-Marín (1997) originate from archaeological samples, it is impossible to determine a specific timeframe during which the species inhabited the Palenque area.

In the case of the specimens from Escárcega, Campeche, 1 was initially determined as *C. nigrescens mayensis* (GBIF_ID 2630401870; Dowler and Engstom 1988), and the other as *C. mayensis* (GBIF_ID 280448758, deposited in the Natural History Collection of Angelo State University in Texas; ASNHC:Mamm:1286). The records of *C. mayensis* from Veracruz, as recorded in GBIF, were reported by Ceballos (2002), who cited Hall and Dalquest (1963) as the source. However, upon reviewing the original publication, we found that these authors did not mention the presence of *C. mayensis* in the state. A search in Hall and Dalquest (1963) revealed that the locations listed in the GBIF results (Teocelo, Las Vigas, Cerro Gordo, Jalapa, El Brinco, and Mecauyucan; GBIF 2023) correspond to what the authors determined as *C. micrura*, a species that, according to Choate (1970), could be synonymous with *C. parva orophila, C. parva tropicalis*, or even *C. nigrescens mayensis*. The review of historical records highlights inconsistencies between the original reports and those in GBIF for the records from Veracruz and Palenque, Chiapas. Recent studies have pointed out that these inconsistencies are primarily due to a lack of nomenclatural updating and emphasize the need for data cleaning in mammal databases, especially for poorly studied taxa like shrews (Sánchez-Cordero and Guevara 2016).

Cryptotis mayensis is a relatively poorly known species and is considered under Special Protection according to Mexican regulations (SEMARNAT 2010), likely due to gaps in knowledge regarding its biology and ecology. Historically, the species has been associated with deciduous and semi-deciduous forests (Álvarez and Martínez 1967; Woodman and Timm 1993). However, the individual in this report was captured in an oil palm plantation and induced pastures for livestock. The remaining natural vegetation in the region consists of secondary forests smaller than 10 ha, with regeneration ages ranging from 10 to 20 years. The nearest patch of natural vegetation to the capture site is approximately 800 m away. Therefore, it is quite possible that the captured individual could inhabit the oil palm plantations, suggesting that *C. mayensis* may tolerate changes in its natural habitat.

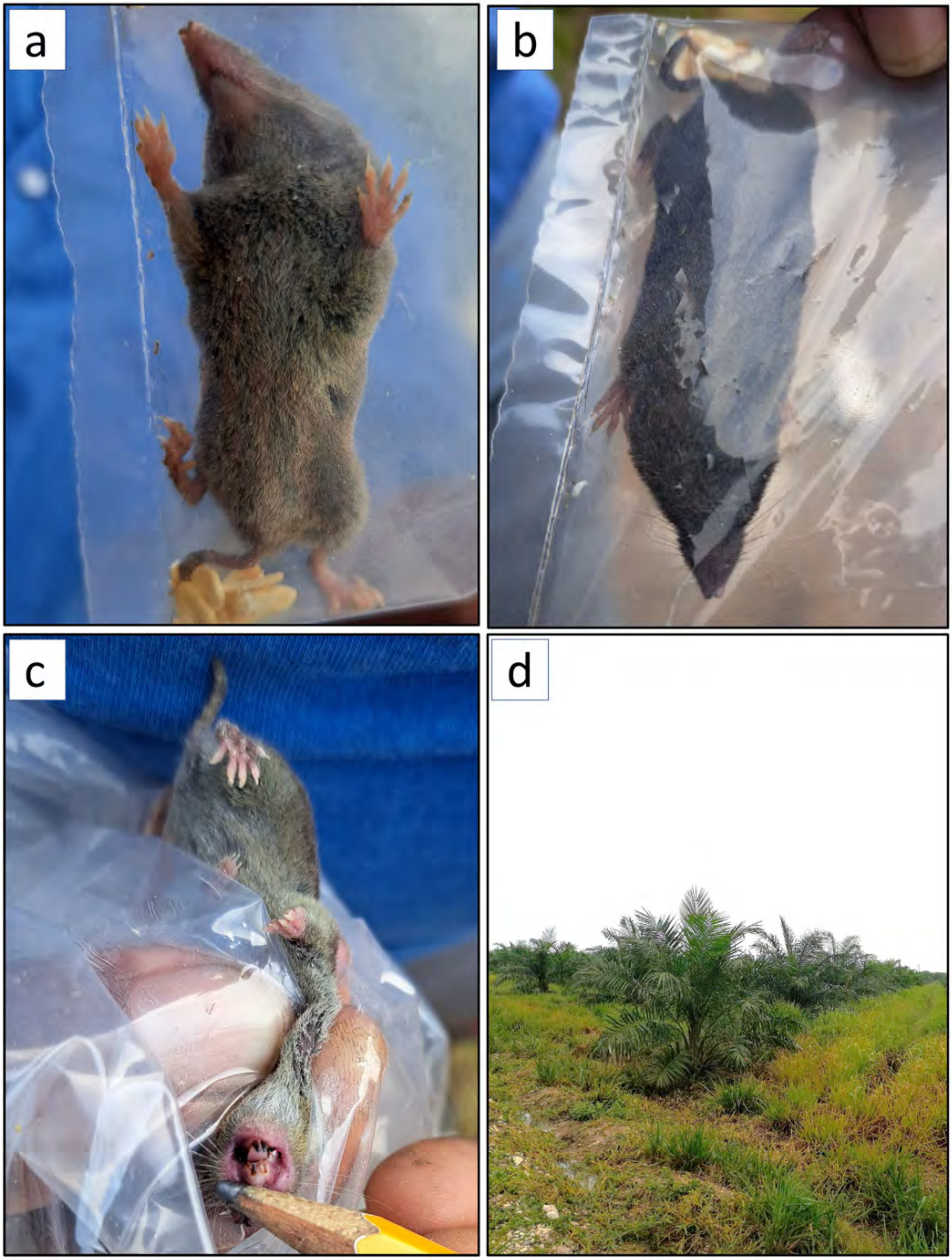

Figure 2. Characteristics of the *Cryptotis mayensis* specimen captured in the Caballitos plantation, Emiliano Zapata, Tabasco, México. a) Ventral view; b) dorsal view; c) frontal view showing dentition; d) photograph illustrating the features of the Caballitos oil palm plantation, where *C. mayensis* was captured.

The significant lack of information on Mexican shrew species has hindered a proper assessment of their conservation status and the threats facing this group in México (Guevara *et al.* 2015). Future studies in highly modified environments within the Coastal Plain of the Gulf of México region should consider the possible presence of *C. mayensis*. Therefore, sampling in these environments should include appropriate techniques for capturing shrews, such as pitfall traps (McCleery *et al.* 2022). Generally, traps designed for rodents (*e.g.*, Sherman traps) are unsuitable for capturing animals with such low body weight, making the presence of shrews easy to overlook. Appropriate techniques would help generate information to determine fundamental aspects of the species' ecology and conservation status in this region.

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Sand consumption by Hoffmann´s two-toed sloth (*Choloepus hoffmanni*) at Cahuita National Park, Costa Rica

Consumo de arena por el perezoso de dos dedos (*Choloepus hoffmanni*) en el Parque Nacional Cahuita, Costa Rica

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Mineral licking has been reported in most herbivorous mammal taxa; however, the frequency of mineral lick use by Pilosa at ground level in the wild is rare. Hoffmann's two-toed sloth (*Choloepus hoffmanni*), an herbivorous Pilosa species, is nocturnal and arboreal. We present the first case of saline sand consumption by a Hoffmann's two-toed sloth in Costa Rica. The observations occurred at Cahuita National Park, Limón, Costa Rica, on October 11, 2022, at 21:20 hr. We observed a sloth hanging from the base of a water apple tree (*Syzygium malaccense*), with its head pointing downward upon discovery. Pictures and notes were taken during the event. The sloth securely suspended itself from a lateral branch of the main tree trunk. In this position, it brought its snout nearly in contact with the ground and proceeded to lick the saline sand several times. The sequence of actions, including suspension from the branch, intermittent licking, and recommencement of climbing, transpired over a span of approximately 5 minutes. The case we present here involves the consumption of saline sand rather than licking of rocks. Our observations were conducted during the nighttime when potential sloth predators are active. Clearly, further foundational research is needed to understand these basic aspects of sloth´s natural history. Mineral licking by sloths might constitute an infrequent conduct, although essential to provide individuals with vital nutrients.

Key words: Herbivores; Megalonychidae; minerals; Pilosa; saline; salt.

El lamido de minerales ha sido reportado en la mayoría de los taxones de mamíferos herbívoros; sin embargo, la frecuencia de uso de saladeros por los Pilosa es rara. El perezoso de dos dedos (*Choloepus hoffmanni*), una especie herbívora de Pilosa, es nocturna y arborícola. Presentamos el primer caso de consumo de arena salina por parte de este perezoso en Costa Rica. Las observaciones tuvieron lugar en el Parque Nacional Cahuita, Limón, Costa Rica, el 11 de octubre de 2022, a las 21:20 hr. Observamos a un perezoso colgando de la base de un árbol de manzana de agua (*Syzygium malaccense*), con la cabeza apuntando hacia abajo al ser descubierto. Se tomaron fotografías y notas durante el evento. El perezoso se suspendió firmemente de una rama lateral del tronco principal del árbol. En esta posición, acercó su hocico casi al contacto con el suelo y procedió a lamer la arena salina varias veces. La secuencia de acciones, incluida la suspensión de la rama, el lamer intermitente y la reanudación de la escalada, transcurrió en un lapso de aproximadamente 5 minutos. El caso que presentamos aquí involucra el consumo de arena salina en vez de lamer rocas. Nuestras observaciones se llevaron a cabo durante la noche, cuando potenciales depredadores de perezosos están activos. Se necesita investigación fundamental adicional para comprender estos aspectos básicos de los perezosos. Lamer minerales por parte de los perezosos podría ser una conducta infrecuente, aunque esencial para proporcionar a los individuos nutrientes vitales.

Palabras clave: Herbívoros; Megalonychidae; minerales; Pilosa; sal; salina.

Animals require dietary salt to maintain their internal balance, and they exhibit corresponding behaviors to counteract the metabolic loss of sodium, chloride, and potassium ions (Denton 1982). This phenomenon is particularly evident among herbivores, as the naturally low-sodium content in plant tissue often fails to meet their nutritional needs (National Research Council 2005). As a result, various species such as African elephants, moose, and mountain gorillas actively seek dietary sources of additional sodium (Dudley *et al.* 2012). Mineral licking has been reported in most herbivorous mammal taxa but is especially common in ungulates and primates (Blake *et al.* 2010). The frequency of mineral lick use by sloths, or other Pilosa, at ground level in the wild is rare (Blake *et al.* 2010; Gómez-Hoyos *et al.* 2017).

Most frequent sightings of Hoffmann's two-toed sloth occur within the uppermost branches of trees, where it feeds on a diverse array of leaves from various plant species. This species is herbivorous, consuming fresh leaves, inflorescences, shoots, flowers, and fruits (Hayssen 2011), with apparently occasional consumption of animal material (Moraes-Barros 2018). At times, it engages in the behavior of licking and gnawing on tree trunks, possibly to feed on lichen or moss growing on the bark (Reid 2009). The digestion of plant material is even slower in sloths compared to other herbivorous mammals, despite having a notably three-chambered stomach that occupies a significant portion of the abdominal cavity (Hayssen 2011).

Hoffmann´s two-toed sloth (Megalonychidae) distributes in 2 distinct geographical regions: from southern Honduras to the northern parts of South America, encompassing Colombia, western Venezuela, and northern Ecuador, and an area extending across the Peruvian, Brazilian, and Bolivian Amazon regions (Hayssen 2011; Plese *et al.* 2016). The species inhabits various types of forests, including primary and secondary forests, as well as both lowland and montane forest ecosystems (Moraes-Barros 2018). It is predominantly observed within the canopies of continuous forests characterized by mature trees in a range of environments, such as rainforests, dry forests, and riparian forest ecosystems (Moraes-Barros 2018). The distribution of this sloth spans from sea level up to altitudes exceeding 3,000 m (Molina *et al.* 1986; Reid 2009).

Hoffmann´s two-toed sloth primarily exhibits nocturnal behavior, although it occasionally engages in diurnal activities (Reid 2009). It possesses an impressive ability to blend into its surroundings through exceptional camouflage (Suutari *et al.* 2010) and tends to prefer habitats high in the canopy or nestled in the shaded junctures of trees (Reid 2009). These attributes have contributed to the scarcity of literature exploring the activity patterns of sloths in their natural habitat (Cliffe *et al.* 2023). Despite its remarkable slowness, this sloth is equipped with swift and potent strikes when faced with a threat, making it notably dangerous due to the strength and sharpness of its claws (Hayssen 2011). It descends to the ground for defecation every 3-8 days, yet it refrains from digging cavities for this purpose (Hayssen 2011).

In this note, we present the second case of mineral consumption by Hoffmann´s two-toed sloth in Costa Rica. However, in this instance, it involves the consumption of sand rather than licking rocks, as described in the first case (Gómez-Hoyos *et al.* 2017).

The observations took place within the Puerto Vargas sector of Cahuita National Park, Limón, Costa Rica (9° 43' 55" N, 82° 48' 53" W, 10 m; Figure 1). This is a well-preserved tropical forest in the Caribbean coast, Limón Province, Costa Rica (Mora *et al.* 2020). On October 11, 2022, at 21:20 hr, we witnessed a sloth hanging from the base of a tree of the introduced water apple *Syzygium malaccense* (L.) Merr. & L. M. Perry

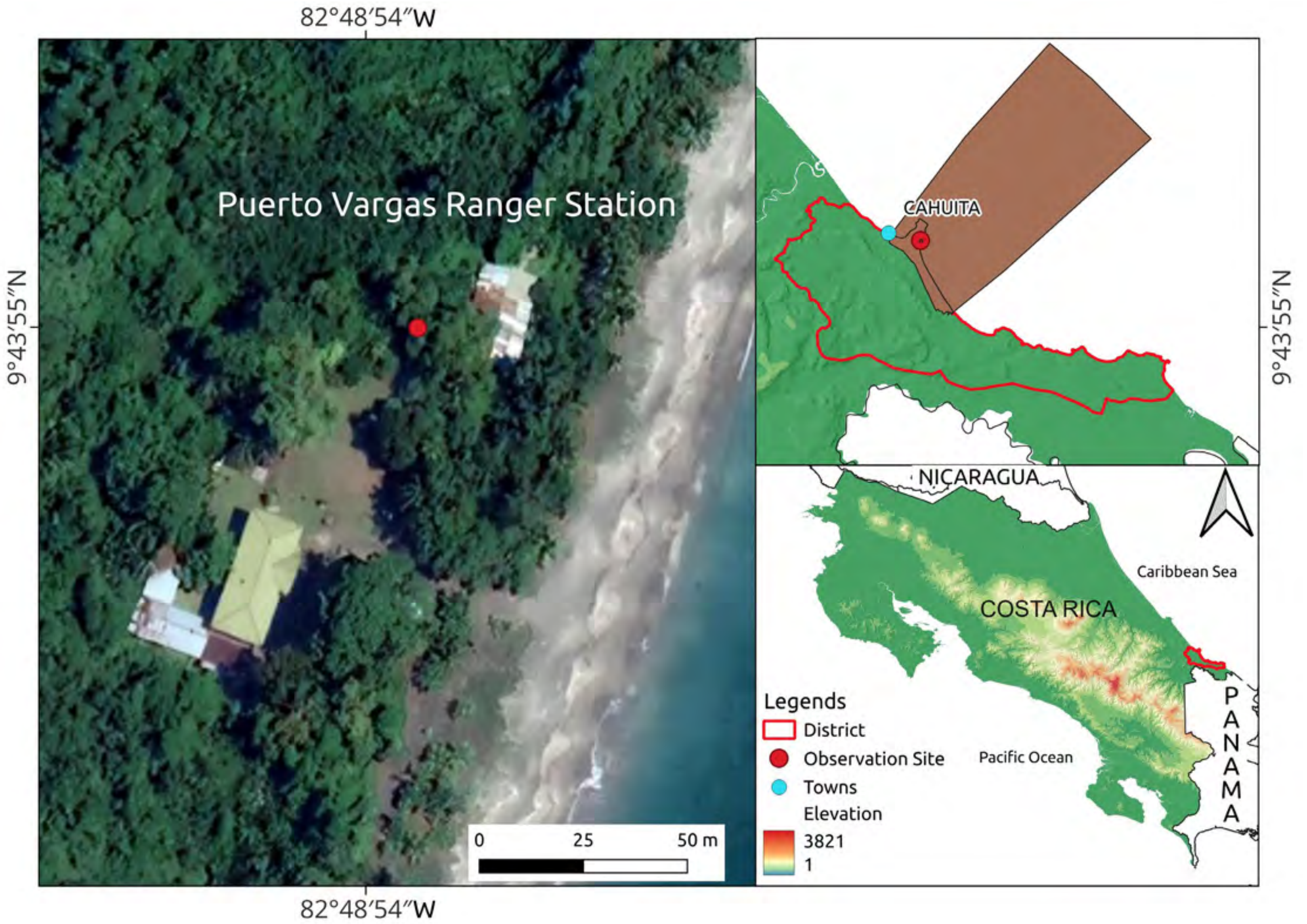

Figure 1. Location (marked with a red dot) where a Hoffmann's two-toed sloth (*Choloepus hoffmanni*) was observed consuming saline sand near the Puerto Vargas Ranger Station at Cahuita National Park, Costa Rica.

(Barrie 2007), its head pointed downward upon discovery. Our observation persisted for approximately 5 min before the sloth returned to the tree's up branches. The ground beneath the tree was sandy and devoid of vegetation, situated about 50 m from the beach (Figure 1). The tree itself exhibited a slender profile (with a diameter at breast height less than 15 cm), possessed a modest height, and featured branching near the ground, with a height measuring under 10 m.

The sloth securely suspended itself using its hind legs from a lateral branch of the main tree trunk, which it embraced effortlessly (Figure 2). It also maintained its hold on the branch with its hands, albeit less firmly. In this stance, it brought its snout nearly in contact with the ground and proceeded to lick the sand for several seconds in a series of 3 or 4 movements for at least 5 times. Following this, it turned around and initiated an ascent, with its head held aloft toward the tree's branches. This sequence of actions, involving suspension from the branch, intermittent licking, and recommencement of climbing, elapsed over a span of approximately 5 min.

In vast expanses of the continents, sodium is notably scarce due to meteorological processes, leading to a correspondingly low sodium content in plants (Lundquist and Varnedoe Jr. 2006). This situation bestows an evident evolutionary advantage upon animals capable of detecting and consuming salt from geological sources. Among these animals, herbivores are particularly in need, given the inherent low sodium content found in plants (Lundquist and Varnedoe Jr. 2006).

Numerous hypotheses, not mutually exclusive to the quest for sodium, have been proposed to elucidate these behaviors. These include the utilization of clays to aid in the detoxification of alkaloids, as well as potential medicinal functions of ingested soil (Dudley *et al.* 2012). Recent investigations have concluded that the primary driving force behind the well-known geophagy displayed by Amazonian parrots is the acquisition of sodium (Dudley *et al.* 2012).

The analyses of soil composition at Amazonian salt licks have confirmed heightened levels of sodium (and, in some instances, magnesium) relative to control sites (Brightsmith *et al.* 2008; Powell *et al.* 2009). Geophagy observed in other coexisting avian species, such as columbids and cracids (Brightsmith and Muñoz-Najar 2004), similarly aligns with sodium-seeking tendencies linked to diets predominantly reliant on plants (Dudley *et al.* 2012). All documented vertebrates that visit Amazonian salt licks have a predominantly phytophagous diet (Dudley *et al.* 2012). The herbivorous mountain tapir (*Tapirus pinchaque*) in Colombia also consumes water at salt licks that has a higher concentration of nitrogen and sodium relative to a control stream (Lizcano and Cavelier 2004).

We found only 3 previous records of mineral licking by sloths, which confirm the rarity of such events. One case is from Linné's two-toed sloth *Choloepus didactylus* from Ecuador (Blake *et al.* 2010; Gómez-Hoyos *et al.* 2017), and the other 2 events are from Hoffmann´s two-toed sloth (*Choloepus hoffmanni*), 1 in the tropical rainforest of Costa Rica (Gómez-Hoyos *et al.* 2017), and 1 from Perú. Nonetheless, this last instance involved an individual that ingested human feces and urine from latrines, ostensibly in pursuit of mineral resources (Heymann *et al.* 2011). The employment of mineral licks by sloths might constitute an infrequent behavior that supplies individuals with vital nutrients required either in small quantities or during specific periods (Gómez-Hoyos *et al.* 2017).

Some studies have indicated that sloths exhibit an increased frequency of vertical movements within the canopy during the nighttime compared to the daytime (Cliffe *et al.* 2023). This trend might imply a heightened inclination to descend to the ground at night, which is somewhat unexpected given the elevated risk of predation from large nocturnal felines (Cliffe *et al.* 2023). Our own observations of Hoffmann's two-toed sloth engaging in salt licking in Costa Rica were also made during the nighttime, in alignment with other instances of this behavior. The notion that sloths descend to the ground during the night does not seem to arise from diminished visual capabilities, considering that sloth eyes function effectively under extremely low light conditions (Cliffe *et al.* 2023). Evidently, further fundamental research is necessary to delve into the core natural history aspects of Hoffmann's two-toed sloth.

Figure 2. A Hoffmann's two-toed sloth (*Choloepus hoffmanni*) consuming saline sand near the Puerto Vargas Ranger Station at Cahuita National Park, Costa Rica. Available at josemora07@gmail.com.

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Presence of Neotropical otter, *Lontra longicaudis annectens,* on Champotón River Banks, Campeche

Presencia de nutria neotropical, *Lontra longicaudis annectens,* en la ribera del río Champotón, Campeche

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Given the extensive territory inhabited by the Neotropical otter, in addition to knowing the ecological importance of this species, one annual monitoring was carried out along the Champotón River banks after 22 years of the only documented record in the study area. The aim was to confirm the presence of the Neotropical otter, *Lontra longicaudis annectens*. We navigated 30 km of the Champotón River aboard a vessel during 3 climatic seasons ("*nortes*" of 2019; dry and rainy seasons of 2020). Direct and indirect evidences of the presence of otters were recorded and properly georeferenced. Additionally, the water temperature and salinity in these sites were recorded. The recorded temperature was 30 ºC ± 3 °C, and salinity ranged between 0 ppm and 8 ppm. A total of 33 indirect evidences were recorded, including feeders and feces: 22 in the "*nortes*" season (2019), 5 in the dry season, and 6 in the rainy season (2020), plus one sighting in the 2019 "*nortes*" season. The indirect evidences analyzed confirmed the otter feeding habits based on the local crustaceans and fishes. The environmental and feeding conditions, in addition to the Champotón River flora and fauna, were favorable for the presence of *L. l. annectens*, just over 2 decades after its first record in the study area; however, attention should be paid to anthropic affectations.

Key words: Anthropic effects; Campeche; feces; feeding; Neotropical otter.

Derivado del extenso territorio en el que habita la nutria neotropical, además de conocer la importancia ecológica de esta especie, se realizó un monitoreo durante un año en la ribera del río Champotón después de 22 años del único registro documentado en el área de estudio con la finalidad de confirmar la presencia de la nutria neotropical *Lontra longicaudis annectens*. Durante 3 temporadas climáticas (nortes de 2019, secas y lluvias de 2020) se realizaron recorridos a bordo de una embarcación a lo largo de los 30 km navegables del río Champotón. Se colectaron evidencias directas e indirectas de la presencia de nutrias debidamente georreferenciadas. Adicionalmente se registró la temperatura y la salinidad del agua de estos sitios. La temperatura registrada fue de 30 ± 3 °C y la salinidad de 0-8 ppm. Se recolectaron 33 evidencias indirectas tales como comederos y heces: 22 en la temporada de nortes (2019), 5 en la temporada de secas y 6 en temporada de lluvias (2020), además de un avistamiento en la temporada de nortes (2019). Se analizaron las evidencias indirectas, confirmando los hábitos de alimentación basados en crustáceos y peces de la zona. Las condiciones ambientales, de alimentación, flora y fauna del río Champotón, fueron propicias para confirmar la presencia de *L. l. annectens*, a poco más de 2 décadas de su primer registro en el área de estudio; sin embargo, se debe poner atención a las afectaciones antrópicas.

Palabras claves: Alimentación; Campeche; efectos antrópicos; heces; nutria neotropical.

The Neotropical otter (*Lontra longicaudis annectens*) is a mustelid considered a key species because of its ecological functions within ecosystems (Miller *et al.* 1999). At the continental level, it is widely distributed from northern México to northern Argentina (Arellano *et al.* 2012). Given the current conservation difficulties from the drastic alteration of ecosystems due to the constant impact of anthropic activities on habitats, this species is protected in México by the General Law of Wildlife. The Neotropical otter is listed as Threatened in the standard NOM-059-ECOL-2010 (SEMARNAT 2010). In addition, it is listed in the Red List of Threatened Species of the International Union for the Conservation of Nature (IUCN; Rheingantz *et al.* 2021) and Appendix I of the Convention on International Trade in Endangered Species of Flora and Fauna (CITES 2018). The pollution of tributaries, habitat destruction, and altered land uses have been the main causes affecting the species. This has caused its displacement and even its eradication in historical distribution areas that no longer provide optimal conditions for its survival (Soler 2002). Other anthropogenic pressures that have influenced the decline of populations of this species are mining activities, pollution, livestock raising, urban expansion, and hydroelectric networks (Rheingantz *et al.* 2021).

In México, the Neotropical otter is distributed throughout the south to Morelos, and its distribution reaches the south of Tamaulipas on the Gulf of México slope and the north of Sonora and Chihuahua on the Pacific slope (Gallo-Reynoso and Meiners 2018). An important aspect of Neotropical otters is that in environments impacted by pollutants such as heavy metals and pesticides, there is a noticeable lack of direct and indirect evidence of the presence of Neotropical otters. Therefore, this species is considered an indicator of the conservation quality of sites (Gallo-Reynoso and Meiners 2018).

Systematic studies of the species have been conducted in the state of Campeche, such as those of Gallo-Reynoso (1997) in the Candelaria, San Pedro, Chumpan, and Samaria rivers. Guzmán-Soriano *et al.* (2013) recorded 2 skulls, 1 found in the Calakmul Biosphere Reserve and the other in the Venustiano Carranza River, in the state of Campeche. Santiago-Plata *et al.* (2013) on the road La Veleta (almost on the state border between Campeche and Tabasco) and Vázquez-Maldonado *et al.* (2021) recorded the presence of Neotropical otters in the state of Campeche. In 2022, 2 works were carried out in lagoons adjacent to the Palizada River, Campeche: "La Lagartera" lagoon (Mariano-Mendoza *et al.* 2022) and "La Sangría" lagoon (Vázquez-Maldonado and Delgado-Estrella 2022). Meanwhile, in the Champotón River, the information available regards a single record reported by Gallo-Reynoso in April 1986, observing 3 traces 3 km east of the Champotón town. This work aimed to expand the previous information, confirm the presence of this species in this tributary, and determine its food preferences to analyze the conservation issues facing the Neotropical otter.

The Champotón River is located in the central part of the state of Campeche (Figure 1); it originates near the San Juan Carpizo town, with a maximum elevation of 120 m, and runs across 48 km until its mouth to the Gulf of México. Its total area is 649 km^2, and its average depth is 4 m (Posada-Vanegas *et al.* 2013). Due to the local relief and climate, the riparian vegetation is composed of medium semi-evergreen and sub-deciduous forests, low semi-evergreen thorny forest, and mangroves composed of *Rhizophora mangrove*, *Avicennia germinans,* and *Laguncularia racemosa*. Crustaceans consumed by Neotropical otter as food include decapods, palemonids, and amphipods; for example, *Mayaweckelia yucatanensis* and *Creaseria morleyi* (INEGI 2016).

We traveled along the riverbank on an outboard motorboat, covering approximately 30 km long during the 3 climatic seasons in the region: "*nortes*" (cold-front) season of 2019 (October to January), and dry (February to May) and rainy (June to September) seasons of 2020 (Ramos-Miranda *et al.* 2006). During the surveys, we reviewed mainly trunks and mangrove trees to record indirect evidences of the presence of the Neotropical otter: feces, latrines, feeders, footprints, exudates (gelatinous excretions of the anal glands indicating the reproductive status); places that allowed walking were searched for burrows. The materials found (feces and feeders) were sampled manually using self-sealing bags with airtight closure. All the evidence was georeferenced with a GPSMAP 78s GARMIN (Taiwan), and the following characteristics of the area were recorded: surface water temperature (Seahawk manual thermosounder; Taiwan), salinity (ATAGO refractometer; U.S.A.), and presence of anthropic activities (livestock raising, agriculture, logging, fires, presence of garbage). Each indirect evidence (latrine feces, feeder, exudate, and burrow) was photographed with a Nikon DMC-LS80 digital camera. Subsequently, the percentage of occurrence (PO) on the Champotón River banks was analyzed to evaluate its representativeness by season using the modified formula for feeding habits of Macías-Sánchez and Aranda (1999):

$$PA = \frac{f_i}{ft}(100)$$

Where *fi* is the number of records of indirect evidence "*i*", and *ft* is the total number of records considering all types of indirect evidence.

Feces were analyzed using the method by Santiago-Plata *et al.* (2013) modified by Vázquez-Maldonado *et al.* (2021). This consisted of washing and drying the collected samples. Non-digestible components were identified using a stereo microscope (Iroscope model ES-24PLIT). Biomass was calculated from the dry weight of the remains; once the sample was separated, it was weighed on an electronic scale (Ohaus PA214, China).

Crustacean species were identified based on specialized literature: Guzmán and Sánchez (1992), Álvarez *et al.* (2014), and García and Ramírez (2015).

On the other hand, the feeding habits of the Neotropical otter were determined by calculating the percentage of occurrence (PO) with the formula:

$$PA = \frac{f_i}{ft}(100)$$

Where *fi* is the number of feces containing the prey category "*i*", and *ft* is the total number of records of all prey categories in all feces (Macías-Sánchez and Aranda 1999).

The location and spatial distribution of indirect evidences of the Neotropical otter (feces, latrines, exudates, and feeders) by climatic season were recorded using the program Qgis version 2.0, which produced the respective spatial distribution maps.

During the 2019 "*nortes*" season, the mean surface water temperature was 33.70 °C, and salinity was 7.91 ppm. In the 2020 rainy season, mean surface water temperature was 30.25 °C, and salinity was 0. Besides, the 2020 dry season recorded a mean surface water temperature of 33.50 °C and salinity of 6 ppm.

Figure 1. Location of the study area in Champotón River, Campeche, México.

We obtained 33 records of indirect evidence of the presence of *L. l. annectens* along the Champotón River banks (22 in the "*nortes*" season, 6 in the rainy season, and 5 in the dry season). Of these, 16 corresponded to feces, 12 to feeders, 2 to latrines, 3 to exudates (gelatinous excretions from the anal glands), and 1 sighting. In the latter, an individual was observed sunbathing on a dead tree trunk in the 2019 "*nortes*" season; this otter could not be photographed because it ran away, but its location was recorded (see the map in Figure 2a). Differences in the ecosystem between seasons were observed during the period studied, reflected as variations in the number of direct and indirect evidences in the study area by season. Besides, in the dry and rainy seasons of 2020, a greater impact of anthropic activities was observed, such as livestock farming, cane fishing, deforestation, fires, and agriculture carried out by villagers living near the river (Figure 2b, 2c).

Regarding the percentage of occurrence of indirect otter traces, a higher incidence was recorded in the "*nortes*" season (68 %), followed by the rainy season (17 %), and the lowest in the dry season (15 %). Concerning non-digestible remains in feces and feeders, crustaceans showed the highest percentage of occurrence (PO) in the 3 seasons (80 %), followed by a minor presence of fish remains (12 %) and mollusks (8 %). The main crustacean species consumed by otters in the study area belong to 3 genera (*Uca* sp., *Sesarma* sp., and *Callinectes* sp.). The genus *Uca* had the highest biomass (60.04 g), followed by *Sesarma* (21.73 g), and *Callinectes* (14.36 g). These 3 genera were recorded in the 3 climatic seasons. Also were found remains of fish spines and scales, which were scarce compared to crustaceans; as no structures allowing their identification were found, we only recorded their consumption. The presence of mollusks was also recorded; however, the very small fragments of exoskeletons (shells) found were unsuitable for identification.

The presence of *L. longicaudis* on the Champotón River banks was confirmed with a sighting and the record of 3 anal excretions (exudates), which indicate the reproductive stage of the species, in the 2019 "*nortes*" season. Similarly, several indirect evidences confirm the presence of this species in the study area.

The distribution of indirect traces of Neotropical otter in the study area in the 3 climatic seasons was analyzed, revealing that the presence of the species may also be influenced by seasonal variations in resource availability. This is consistent with the observations for *L. longicaudis* reported by Arellano *et al.* (2012) in Tlacotalpan, Veracruz; Grajales-García *et al.* (2019) in the coastal area of Tuxpan, Veracruz, and Vázquez-Maldonado and Delgado-Estrella (2022) in La Sangría lagoon, Ciudad del Carmen, Campeche, México. Our findings also agree with those reported by Carrasquilla and Trujillo (2004) for the giant river otter of the Amazon River (*Pteronura brasiliensis*), who stated that annual variations in the hydrological regime and prey availability are among the drivers of the spatial distribution of otters.

The area studied in the present work is composed of habitats and physicochemical parameters similar to those in the areas where the Neotropical otter thrives, described by Gallo-Reynoso in this same region (1991). That is, the species can adapt to live in areas of forests (mountain cloud forest, tropical sub-deciduous forest), mangroves, and

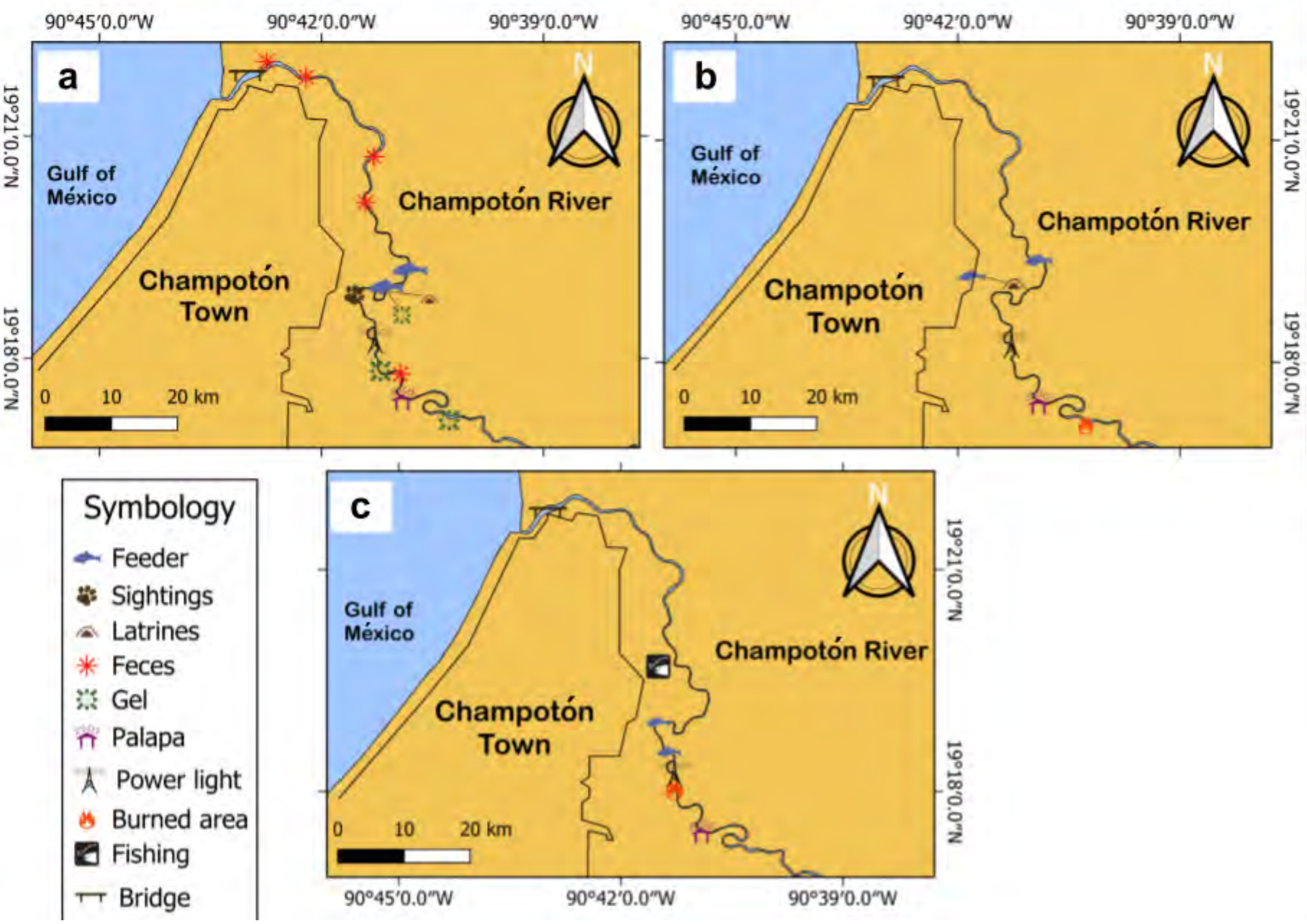

Figure 2. Record of indirect and direct evidences of the presence of the Neotropical otter (*Lontra longicaudis annectens*), as well as of anthropic activities, by climatic season in the Champotón River, Campeche. a) "*nortes*" season (2019), b) dry season (2020), c) rainy season (2020).

low deciduous forests with well-defined climatic seasons, in addition to brackish and even completely saline water ecosystems. The Champotón River comprises medium subdeciduous and semi-evergreen forests, low thorny semi-evergreen forests, and mangroves, presenting well-defined climatic seasons and influenced by brackish water. These features make Champotón River a suitable habitat for *L. longicaudis,* as documented in the present study.

Different anthropic activities were observed on the Champotón River banks during the study period. These differ in each climatic season as the resources provided by the river are used: the approach of cattle to the river bank, incidence of fishing boats, agri-food crops on the river margins, logging, and, in particular, induced fires in the dry season. These were reflected in the low incidence of direct and indirect evidences reflecting the sporadic use of this site by Neotropical otters, confirming the reports of Gallo-Reynoso and Meiners (2018), and highlighting that anthropic activities influence the presence of the species.

With regard to the diet of Neotropical otter (*L. longicaudis*) in this area, crustaceans were the most abundant prey in their diet, followed by fishes, although in a low proportion. These results are similar to those recorded by Macías-Sánchez and Aranda (1999), Macías-Sánchez (2003), Botello *et al.* (2006), Ramírez-Bravo (2010), Duque-Dávila *et al.* (2013), and Grajales- García *et al.* (2019), but differ from the reports by Gallo-Reynoso (1986, 1991, 1996), Parera (1993), Parera (1993), Cruz-García *et al.* (2017), Barrientos *et al.* (2018), Juárez-Sánchez *et al.* (2019), Mariano-Mendoza *et al.* (2022), and Vázquez-Maldonado and Delgado-Estrella (2022), who mention that fishes are the most important prey in their study areas. Several authors (Gallo-Reynoso 1991, 1996; Macías-Sánchez and Aranda 1999; Arellanes-Licea and Briones-Salas 2003; Díaz-Gallardo *et al.* 2007; Santiago-Plata *et al.* 2013; Grajales-García *et al.* 2019; García-Silva *et al.* 2021) indicate that otters are generalist carnivores that feed preferentially on abundant and slow species. Accordingly, *L. longicaudis* has been defined as a generalist species feeding on any potential food available. The incidence of the prey group with the highest percentage of occurrence (PO) in the samples supports the idea that crustaceans (*Uca* sp., *Sesarma* sp., and *Callinectes* sp.) were the most available prey in the area. Rheingantz *et al.* (2017) note that flexibility in feeding patterns of the Neotropical otter may contribute to explaining the wide distribution of the species, as it depends on the broad range of conditions in the aquatic systems where it thrives.

This work, a follow-up of the study by Gallo-Reynoso (1997), confirms the presence of this species in the Champotón River, Campeche, after approximately 2 decades. For this reason, we consider it important to continue with studies in the region, preferably addressing the current condition of the native carcinofauna and ichthyofauna, as well as the population dynamics and abundance of the Neotropical otter, to gain a deeper insight into the biological and ecological aspects of its population in this region. Based on the observations made, we also recommend conducting environmental education workshops targeting the local inhabitants. This activity would contribute to conserving the otter and mitigating any ecosystem disruptions in general. Additionally, these workshops would inform municipal and state environmental institutions aimed at setting plans for the monitoring and conservation of the Neotropical otter in the Champotón River.

The environmental conditions of the Champotón River (physicochemical, flora, and fauna) allowed us to confirm the presence of the Neotropical otter since the analysis of indirect and direct evidences is consistent with the observations recorded in other studies. However, the various anthropic activities in human settlements on the Champotón River banks could be drivers of the low presence of *L. longicaudis annectens* during the 3 climatic seasons covered by our research work. The prey consumed by *L. longicaudis* included mainly crustaceans and a low percentage of fish; crustaceans were represented by the genera *Uca* sp., *Sesarma* sp., and *Callinectes* sp.

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Puma concolor: First photographic record in the El Jilguero Reserve Water Production Zone, Honduras

Puma concolor: Primer registro fotográfico en la Zona Productora de Agua Reserva El Jilguero, Honduras

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The puma (*Puma concolor*) is the second largest felid in Honduras, whose geographic distribution in the departments bordering El Salvador has been the subject of controversy. Two photographs of puma were captured in the El Jilguero Reserve Water Production Zone of the Guajiquiro-El Jilguero Biological Corridor on March 21, 2023 using camera traps installed in the mountain cloud forest at 2,092 m. The capture site of the puma is located 30.4 km northwest of the previous record at La Paz and 32.2 km northeast of the nearest record in the Sapo River Basin, El Salvador. The puma is a priority species for conservation since it is listed as Endangered in Honduras. Therefore, it is necessary to strengthen long-term monitoring programs and implement conservation actions to prevent and reduce its threats.

Key words: Biological corridor; Felidae; Guajiquiro; La Paz; Opatoro.

El puma (*Puma concolor*) es el segundo mayor félido en Honduras, cuya distribución geográfica en los departamentos fronterizos a El Salvador, había sido objeto de controversia. En la Zona Productora de Agua Reserva El Jilguero del Corredor Biológico Guajiquiro-El Jilguero, el 21 de marzo 2023, se obtuvieron 2 fotografías de puma en trampas cámara instaladas en el bosque mesófilo de montaña a 2,092 m. El sitio de ocurrencia del puma se encuentra ubicado a 30.4 km al noroeste del registro previo en La Paz y 32.2 km al noreste del registro más cercano en la Cuenca del Río Sapo, en El Salvador. El puma es una especie prioritaria para la conservación, dado que está categorizado en Peligro de extinción en Honduras. Por lo tanto, es necesario fortalecer los programas de monitoreo a largo plazo e implementar acciones de conservación con la finalidad de prevenir y reducir sus amenazas.

Palabras clave: Corredor biológico; Felidae; Guajiquiro; La Paz; Opatoro.

Felids have been reported in several regions of Honduras, including 5 species: jaguar (*Panthera onca*), puma (*Puma concolor*), jaguarundi (*Herpailurus yagouaroundi*), ocelot (*Leopardus pardalis*), and margay (*L. wiedii*; Reid 1997; Marineros and Martínez-Gallegos 1998). After the jaguar, the puma is the second largest feline living in the major biomes of América, from northern Canadá to southern Chile and Argentina, from sea level to above 5,800 m (Currier 1983; Nowell and Jackson 1996; Sunquist and Sunquist 2002; Beck *et al.* 2005). It lives in forests, rainforests, or near wetlands, plains, arid areas, sierras, and mountains (Currier 1983; Nowell and Jackson 1996). In addition, it adapts to altered environments and areas subjected to heavy anthropogenic pressure (Ernest *et al.* 2014; Meyer *et al.* 2020).

The puma is a priority species for conservation at the country level because it is listed as Endangered (EN) by the Wildlife Conservation Society (WCS 2021). In Honduras, as in the rest of its range in America, its populations are believed to be declining due to habitat loss and fragmentation, depletion of its prey, and conflicts with humans due to livestock predation (Ernest *et al.* 2014; Nielsen *et al.* 2015; Meyer *et al.* 2020; WCS 2021).

According to the Global Biodiversity Information Facility (GBIF 2023), in 1946, a female puma was collected in the department of Lempira, municipality of San Francisco, in western Honduras adjacent to El Salvador. This specimen was deposited in the Museum of Comparative Zoology at Harvard University (MCZ 43013). Marineros and Martínez-Gallegos (1998) reported the observation of a skull in Guajiquiro and a limb in Opatoro, both municipalities of the department of La Paz (Figure 1); however, this evidence is not available in a scientific collection for review and verification. Later, Portillo-Reyes and Elvir-Valle (2022) reported one indirect photographic record collected at the municipality of Aguanqueterique in La Paz, western Honduras, and mentioned another record supported by an unverified television news from Colomoncagua, Intibucá. Separately, the puma has been recently recorded at localities in El Salvador near Honduras through camera traps (Morales-Rivas *et al.* 2020). There are no systematic studies aimed at obtaining specific records, *i.e.*, supported by photographs or skulls of specimens deposited in scientific collections and available for consultation. For this reason, the inclusion of the western region of Honduras in the geographic range of puma has been the subject of controversy, specifically in the departments bordering El Salvador (Table 1). It was believed that the puma could be highly restricted to some protected areas in the central and eastern regions, mainly on the northern coast and the Honduran Moskitia (Gonthier and Castañeda 2013; Midence 2019; Portillo- Reyes and Elvir-Valle 2018, 2022; Castañeda *et al.* 2023). This study documents the first photographic record of puma in the El Jilguero Reserve Water Production Zone (ZPARJ, in Spanish), consisting of 2 photographs captured with a camera trap as recent evidence of their presence in this protected area. This evidence suggests that the forested areas of this region probably function as corridors for Felidae.

The Guajiquiro-Jilguero Biological Corridor (CBGJ, in Spanish) comprises 3 protected areas (Figure 1): ZPARJ, Guajiquiro Biological Reserve (RBG), and Montecillos Biological Reserve, in addition to other protected forest areas, such as micro-basins, based on the delimitation of the corridors of southwestern Honduras of the Secretariat of State's Office of Natural Resources and Environment (SERNA 2023). The ZPARJ

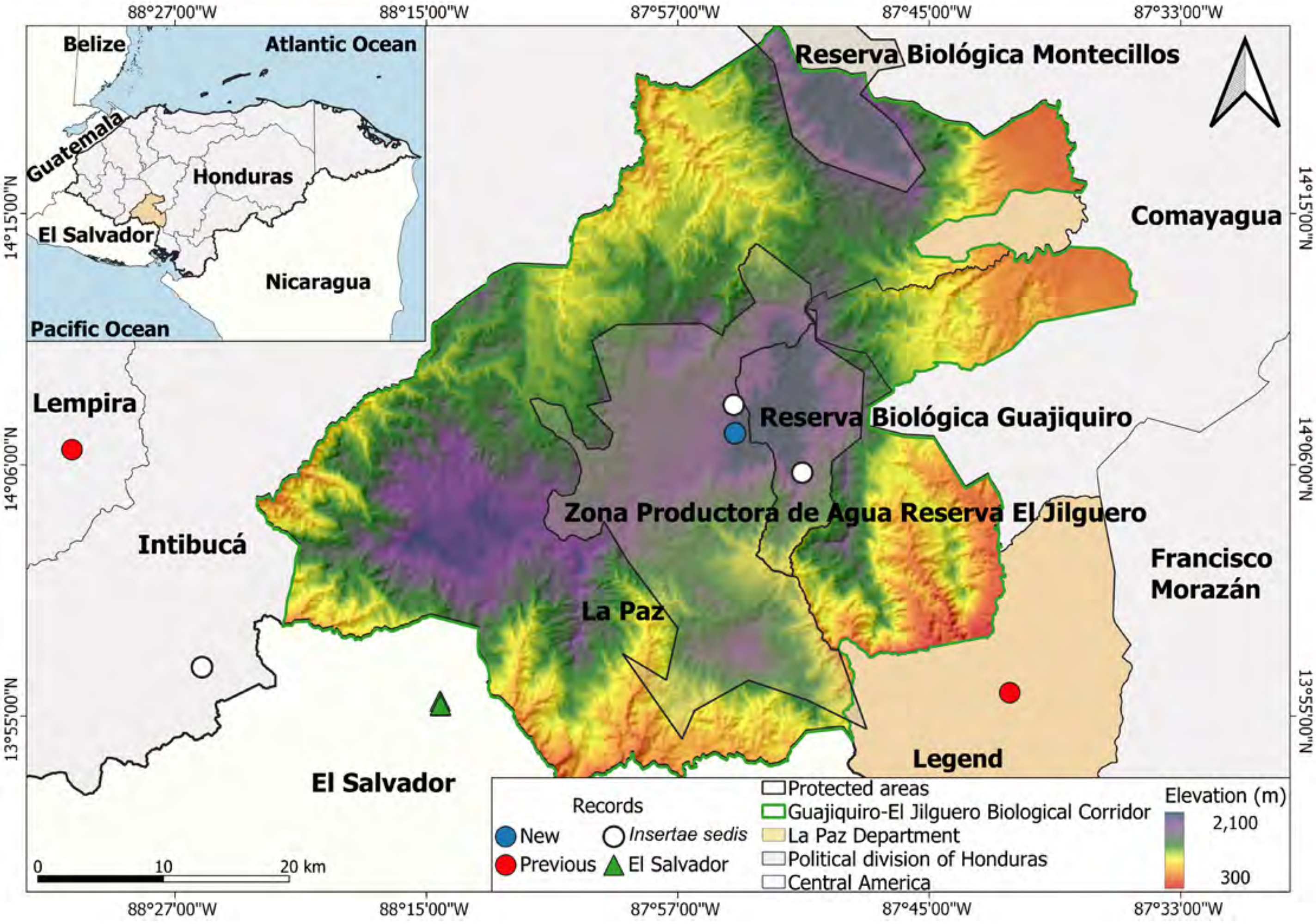

Figure 1. Geographic location of the sites of occurrence of puma (*Puma concolor*) in the Guajiquiro-El Jilguero Biological Corridor and adjacent areas. In addition, records in the Honduras-El Salvador border are indicated. Geographic coordinates and other details are included in Table 1.

stretches across 44,108.01 ha, with jurisdiction in 8 municipalities in the department of La Paz. According to the National Institute for Forest Conservation and Development, Protected Areas, and Wildlife (ICF 2016), 93.72 % of the area corresponds to subtropical humid forests and 6.28 % to low mountain cloud forests. Besides, 11.97 % of the area comprises the core zone and 88.03 % the buffer zone, which, in turn, includes 5 sub-zones: sustainable natural resource management, recovery, urban, restricted use, and protected forests. In ZPARJ, the main issues affecting biodiversity are associated with deforestation from different anthropogenic activities, especially migratory agriculture of basic grains (maize and beans), monoculture coffee plantations, and forest fires. These have led to the decline of forest areas; for example, 18 ha were lost between 2018 and 2020 (SERNA 2023).

On March 20, 2023, the mammal monitoring program was launched at ZPARJ, installing 5 camera traps (Moultrie®), 1 per station, separated by 400 m. On May 2, 2023, 2 additional camera traps (Stealth Cam®) were installed following the same protocol. To maximize the probability of capture, we sought evidence of the presence of mammals, *e.g.*, footprints, feces, and burrows. The cameras were set at a distance not less than 2 m (ideally 3 to 4 m) from the expected trajectory of the animal, either perpendicular or at 45°, and at between 30 cm and 80 cm from the ground, depending on the local topography and slope. These traps were set to operate for 24 hr; 1 camera trap was set to capture 3 photographs, and 6 camera traps to capture 15-sec videos (Appendix Video). The field sampling effort at the time of the review was 170 camera trap-days.

We deposited the photographs and videos in the mammalian photographic collection of the Natural History Museum at Universidad Nacional Autónoma de Honduras (National Autonomous University of Honduras; MUVS-V; see collection numbers in Figure 2). Capture sites were georeferenced with a manual geopositioner (Garmin eTrex®). The map (Figure 1) was produced in the Geographic Information System v3.26.3 (QGIS 2023). All coordinates are in the datum WGS84.

On March 21, 2023, 2 photographs of puma (*Puma concolor*) were captured during the night (20:17 hr) at 2,092 m in the ZPARJ broadleaf forest (14° 8' 16.19" N, 87° 52' 58.40" W), municipality of Opatoro, CBGJ, La Paz (Figures 1, 2a, 2b). This site is located 30.4 km northwest of the record at Aguanqueterique, La Paz (Portillo-Reyes and Elvir-Valle 2022) and 32.2 km northeast of the nearest camera trap record on the Sapo River Basin, department of Morazán, El Salvador (Morales-Rivas *et al.* 2020; Table 1).

As the first results of the ZPARJ monitoring, records of other mammal species (Figure 2c-l) were obtained: margay (*L. wiedii*), coyote (*Canis latrans*), white-tailed deer (*Odocoileus virginianus*), white-nosed coati (*Nasua narica*), rabbit (*Sylvilagus gabbi*), Central American agouti (*Dasyprocta punctata*), armadillo (*Dasypus novemcinctus*), opossum (*Didelphis marsupialis*); the birds captured include Highland guan (*Penelopina nigra*) and white-faced quail-dove (*Zentrygon albifacies*).

Previous records, the potential distribution, and comments from local inhabitants on puma sightings partially supported the hypothesis of its presence in ZPARJ (Reid 1997; Marineros and Martínez-Gallegos 1998; Portillo-Reyes and Elvir-Valle 2022), which was confirmed by this first photographic record using camera traps. Despite likely being present in the area, the species had not been previously recorded due to the limited or absent sampling effort in the western Honduras protected areas. On the other hand, Castañeda *et al.* (2023) have carried out sampling in some protected areas of western Honduras, as well as the Mancomunidad Mapance monitoring program in the Montaña de Celaque National Park, without having recorded

Table 1. Records of puma (*Puma concolor*) indicated in Figure 1, including unverified *incertae sedis* observations, because of lack of evidence such as a photograph record, or voucher specimen deposited in a museum or collection. Museum of Comparative Zoology, Harvard University (MCZ). Elevation in m. Coordinates and elevation data provided by H. Portillo-Reyes, May 16, 2023 (indicated with superscripts[1,2]).

Locality	Latitude (N)	Longitude (W)	m	Evidence	Reference
San Francisco, Lempira	14° 7' 4.78"	88° 22' 22.10"	790	MCZ 43013	GBIF (2023)
Aguanqueterique, La Paz[1]	13° 56' 45.58"	87° 40' 52.69"	320	Photograph record	Portillo-Reyes and Elvir-Valle (2022)
ZPARJ, Opatoro, La Paz	14° 7' 55.37"	87° 53' 3.49"	2,092	Photograph/Camera trap	This study
	13° 56' 06.70"	88° 06' 01.62"	705		
Sapo River Basin, Morazán, El Salvador	13° 56' 18.94"	88° 06' 02.42"	716	Photograph/Camera trap	Morales-Rivas *et al*. (2020)
	13° 56' 08.71"	88° 06' 01.61"	706		
Incertae sedis					
Altamira, Guajiquiro, La Paz					Marineros and Martinez-Gallegos (1998)
Las Trancas, Opatoro, La Paz					Marineros and Martinez-Gallegos (1998)
Colomoncagua, Intibucá[2]	13° 57' 43.19"	88° 16' 34.33"	860		Portillo-Reyes and Elvir-Valle (2022)

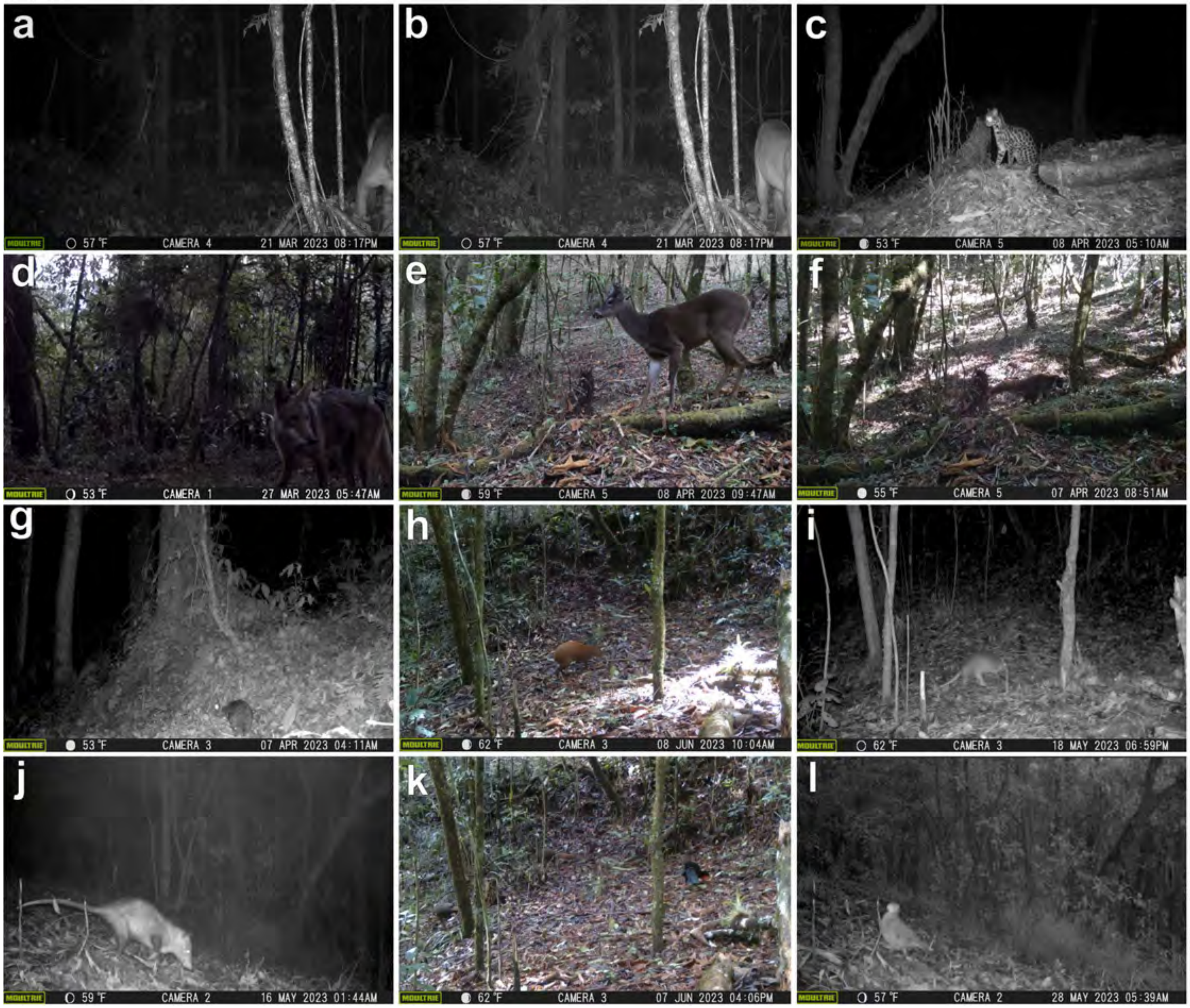

Figure 2. Fauna recorded during the monitoring with camera traps in the El Jilguero Reserve Water Production Zone, Guajiquiro-El Jilguero Biological Corridor, Honduras, Central America. Mammals: a, b) *Puma concolor* (MUVS-F-0001); c) *Leopardus wiedii* (MUVS-V-0001); d) *Canis latrans* (MUVS-F-0002); e) *Odocoileus virginianus* (MUVS-V-0002); f) *Nasua narica* (MUVS-V-0003); g) *Sylvilagus gabbi* (MUVS-F-0003); h) *Dasyprocta punctata* (MUVS-V-0004); i) *Dasypus novemcinctus* (MUVS-V-0005); j) *Didelphis marsupialis* (MUVS-F-0004). Birds: k) *Penelopina nigra* (MUVS-V-0006); l) *Zentrygon albifacies* (MUVS-V-0007).

pumas (H. Vega, pers. comm., July 20, 2023). Besides, the puma photograph we report probably corresponds to a dispersed individual from nearby regions, *e.g.*, Sapo River basin in El Salvador, as the puma requires extensive areas to move, generally greater than 100 km^2, with notable records exceeding 450 km^2 (Ruiz-García *et al.* 2009). Puma dispersal movements usually occur through preserved habitats; however, they can also move through landscapes dominated by anthropic activities, *e.g.*, crops and grasslands (Hornocker and Negri 2010).

The presence of carnivores such as *P. concolor*, *C. latrans,* and *L. wiedii* at the top of the ecological pyramid may indicate that CBGJ forested areas such as ZPARJ, RBG, and the micro-basins of Quebrada Honda, Río León, and Cimarrón still maintain a good state of conservation, connectivity, and ecological integrity. In turn, the present report is one of the few records of puma in mountain cloud forests in Honduras. This is a positive indication of efforts focused on conservation to address the effects of habitat fragmentation pressures on Felidae populations. ZPARJ also yielded photographic records of *O. virginianus, N. narica, S. gabbi, D. punctata, D. novemcinctus, D. marsupialis,* and *P. nigra*, all of which are potential prey of puma (Branch *et al.* 1996; Beck *et al.* 2005; Novack *et al.* 2005; Cascelli de Acevedo 2008; Monroy-Vilchis *et al.* 2009). The records of species such as *P. nigra*, *O. virginianus*, *L. wiedii*, *N. narica*, and *P. concolor* are relevant because they are a warning call for conservation actions, given that all of them are on the Red List of Endangered Species in Honduras, with the first 4 species in the Vulnerable category (VU; WCS 2021).

CBGJ is a priority area for conservation due to its location, rugged topography, and altitudinal strata, ideal to function as a potential corridor for puma dispersal as it borders El Salvador (Morales-Rivas *et al.* 2020; SERNA 2023). In this sense, the conservation of puma and its prey poses numerous challenges and opportunities to focus actions based on strengthening the connectivity of protected areas of the CBGJ with Honduras and El Salvador. The ZPARJ is contemplated in collaborative efforts between different actors for the management and governance of forest areas (*e.g.*, ASOMAINCUPACO, Conecta+/SERNA, International Union for Conservation of Nature, IUCN, water councils and boards, civil organizations) involving the participation of the Lenca indigenous people. The Lenca communities are essential to preserving the natural heritage of the CBGJ, as they have a good knowledge of biodiversity. Values such as respect and admiration for nature are part of their culture and worldview, thus providing opportunities to boost protection actions involving key species such as the puma. A close relationship has been demonstrated between indigenous territories and areas of high biological diversity, where deforestation is generally lower because native communities manage their lands sustainably (McElwee *et al.* 2020). Undoubtedly, the RBG adjacent to ZPARJ (Figure 1) is fundamental for connectivity. Therefore, the Conecta+ project initiatives include developing the first management and conservation plan for the protected area; besides, it is being strengthened at the local organizational level to assume shared management of the reserve.

Given that a network of forested areas is needed in the CBGJ, micro-basins are being decreed, agroforestry coffee systems implemented, and degraded areas reforested (SERNA 2023). Protected under decree 98-2007 of the Protected Areas and Wildlife Forestry Act, Opatoro government authorities recently (2023) issued an ordinance prohibiting the use of fire in agriculture. Monitoring efforts are carried out under an inclusive governance approach, with the participation of indigenous people and the local community as the key players in conservation. It is necessary to continue environmental education and long-term monitoring, in addition to implementing payment for environmental services and training community monitoring committees on livestock predation conflicts that may occur in ZPARJ and CBGJ.

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Appendix

Mammal and bird species recorded by video during the monitoring with camera traps in the El Jilguero Reserve Water Production Zone, Guajiquiro-El Jilguero Biological Corridor, Honduras, Central America.

https://drive.google.com/file/d/1KkBPaSndApj0DMcxowg-suZB4jr4wyeX/view?usp=sharing

In order of appearance: Margay (*Leopardus wiedii*), white-tailed deer (*Odocoileus virginianus*), white-nosed coati (*Nasua narica*), central American agouti (*Dasyprocta punctata*), armadillo (*Dasypus novemcinctus*), highland guan (*Penelopina nigra*), and white-faced quail-dove (*Zentrygon albifacies*).