THERYA NOTES 2023, Vol. 4 : 89-96 DOI: 10.12933/therya_notes-23-112 ISSN 2954-3614

Mammals in a cloud forest patch and a restored area in central Veracruz, México

Mamíferos en un fragmento de bosque mesófilo de montaña y una zona restaurada en el centro de Veracruz, México

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Cloud forests (CF) are home to 53 % of the mammal species recorded in México. Mammals are adversely affected by different causes, some of which are listed in a risk category. This study assessed the richness and abundance of a mammal community in a CF patch and a restoration area (RA) in Huatusco, Veracruz, México. Mammals were monitored by camera traps and track search (September 2019–May 2020). A taxonomic list was elaborated, including the risk category (NOM-059-SEMARNAT-2010 and IUCN). Species richness was compared using species accumulation curves and a similarity index between treatments. Fifteen species were recorded: 13 in camera traps and 2 through tracks. It is worth highlighting the presence of *Leopardus wiedii* (Endangered / Near Threatened), *Dasyprocta mexicana* (Critically Endangered), *Potos flavus* (Threatened), *Galictis vittata* (Special Protection), and *Mazama temama*, a species of hunting value. The CF and RA recorded 9 and 12 species with 96 % and 100 % completeness, respectively, yielding a similarity value of 63 %. The species richness in the area is complementary between treatments. We found opportunistic species in the RA and species less tolerant to disturbance in the CF. The presence of carnivores reflects the importance of this area for mammal conservation.

Key words: Camera traps; diversity; habitat; Huatusco; mammals; species richness.

En el bosque mesófilo de montaña (BMM) se reporta el 53 % de las especies de mamíferos de México. Los mamíferos han sido afectados negativamente por diferentes causas, y algunos están clasificados en categoría de riesgo. El objetivo del estudio fue conocer la riqueza y abundancia de una comunidad de mamíferos en un fragmento de BMM y una zona de restauración (ZR), en Huatusco, Veracruz, México. Se utilizó fototrampeo y búsqueda de huellas para el registro de mamíferos (septiembre 2019-mayo 2020). Se realizó un listado taxonómico incluyendo la categoría de riesgo (NOM-059-SEMARNAT-2010 y IUCN). Se comparó la riqueza de especies mediante curvas de acumulación de especies y se calculó un índice de similitud entre los tratamientos. Se registraron 15 especies: 13 mediante cámaras trampa y 2 por huellas. Destacan *Leopardus wiedii* (peligro de extinción/casi amenazada), *Dasyprocta mexicana* (peligro crítico), *Potos flavus* (amenazada), *Galictis vittata* (protección especial) y *Mazama temama* (especie cinegética). El BMM y la ZR presentaron 9 y 12 especies, con una completitud del 96 % y el 100 %, respectivamente, y una similitud de 63 %. Se determinó que la riqueza de especies en el área se ve complementada entre ambos tratamientos. En la ZR encontramos especies oportunistas, mientras que en el BMM especies con menor tolerancia a la perturbación. La presencia de carnívoros es un indicativo de la importancia de esta área para la conservación de los mamíferos.

Palabras clave: Cámaras trampa; diversidad; hábitat; Huatusco; mastofauna; riqueza de especies.

The cloud forest (CF) is one of the most diverse vegetation types in México; it is a complex biotic community located in areas with constant rainfall, fog, and high atmospheric humidity, mainly at high elevations (Rzedowsky 2006; Gual-Díaz and Rendón-Correa 2017). CF are key for biodiversity conservation and provide multiple ecosystem services, such as provision, cultural and recreational uses, environmental regulation, water collection and filtration, reduction of soil erosion, maintenance of the hydrological cycle, and ecotourism promotion (González-Espinoza *et al.* 2012; González-Ruíz *et al.* 2014; Williams-Linera 2015).

More than 50 % of the original CF coverage has been converted to other land uses, including agriculture, urban areas, and agribusiness development. Today, it covers less than 1 % of México's territory considering the associated secondary vegetation, and less than 0.4 % if only primary forests are accounted for (Gual-Díaz and Rendón-Correa 2017). Additionally, CFs are being affected by climate change, agriculture, and habitat reduction, threatening the native species (Williams-Linera *et al.* 2002; Pérez-Lustre *et al.* 2006; García-Burgos *et al.* 2014; Gual-Díaz and Rendón-Correa 2017).

In Veracruz, México, CF fragments are located in the transition zone between the Nearctic and Neotropical biogeographic regions, characterized by the distribution of endemic and rare mammals (Ceballos *et al.* 2002). In this area, and particularly in central Veracruz, CFs have experienced disturbances due to agriculture, urbanization, the establishment of industries, and the illegal exploitation of wild flora and fauna (Williams-Linera 1993; Williams-Linera *et al.* 2002, 2007).

Cloud forests are characterized by high mammal species richness. Some of these species are indicators of ecosystem quality due to their sensitivity to anthropic changes (Phelps and McBee 2009; Macario-Cueyactle *et al.* 2019; Willig *et al.* 2019). An example are medium and large-sized mammals whose species richness and abundance are affected by disturbance (Mezhua-Velázquez *et al.* 2022). Some mammal species with particular habitat requirements have become locally extinct while the population size of some disturbance-tolerant species has increased as top carnivores become extinct (Di Bitteti 2008; Macario-Cueyactle *et al.* 2019).

In recent decades, biodiversity loss has been observed in different regions of Veracruz. The richness of mammals has declined in different ecosystems, and populations are being decimated to the extreme of defaunation (Tlapaya and Gallina 2010). The study of mammal communities supports the conservation of these and other biological groups since several species function as "umbrellas", additionally, it allows inferring the conservation status of forests (Pérez-Irineo and Santos-Moreno 2010; González-Christen and Delfín-Alfonso 2016). However, ecological studies focused on the CFs and restored areas of central Veracruz are scarce (González-Ruíz *et al.* 2014), although this knowledge is key for decision-making concerning the protection of their populations and habitats (Zapata-Ríos *et al.* 2006; Macario-Cueyactle *et al.* 2019).

In recent years, patches of CF have been restored in central Veracruz through active and passive techniques. Seedlings of *Quercus xalapensis* and *Alnus acuminada* are planted for active restoration (RA). In contrast, passive restoration is taking place through natural succession in land owned by persons interested in the conservation and management of the ecosystem and its species (López-Barrera *et al.* 2016). This study compared the species richness and relative abundance of medium-sized mammals in a cloud forest fragment and an actively restored area within the Centro Agroecológico Las Bellotas, located in the Huatusco municipality, Veracruz.

Study area. The present study was conducted in a 100 ha land in the locality known as Centro Agroecológico Las Bellotas (19° 10' 40.123" N, 96° 58' 35.606" W), municipality of Huatusco, Veracruz, México (Figure 1). The prevailing climate is semi-warm-humid with temperature ranging between 16 ºC and 26 °C and an annual mean precipitation between 1,100 mm and 1,600 mm (INEGI 2020). The site comprises 50 ha of CF dominated by trees of more than 40 m in height (measured *in situ*), a large number of epiphytes, and a closed canopy (compared to the RA, characterized by a heterogeneous tree canopy). The soil is covered by herbaceous and shrub vegetation, and most of the ground contains organic matter derived from litter.

Adjacent to the Las Bellotas CF patch, there is the RA covering 50 ha, where restoration initiatives such as reforestation with native trees were performed approximately 20 years ago. This area is currently home to trees 25 m high on average (measured *in situ*), with an open and heterogeneous canopy, and few epiphytic plants. To note, the RA was previously used as pastureland for extensive cattle raising for over 25 years, but livestock was excluded in 2005 to implement restoration efforts (López-Barrera *et al.* 2016). However, pastures still dominate the landscape in some areas, both on the edges and within the RA.

Mammal monitoring. Six camera traps (Bushnell® and Cuddeback®) were installed at Las Bellotas to record the species richness and relative abundance of mammals, with 3 traps installed in the CF and three in the RA, leaving a separation of approximately 500 m between traps (Figure 1). Camera traps were set to capture 3 photographs per event with a minimum three-second interval between photographs; traps remained operational 24 hr a day from 5 September 2019 to 28 May 2020. Camera traps were placed in sites with characteristics previously identified as suitable to increase the success of mammal recording, such as the presence of fruit species, proximity to water bodies, and presence of tracks on paths (Hernández-Hernández *et al.* 2018; Lizcano 2018). Camera traps were affixed on tree trunks 50 cm above the ground, slightly bent towards the ground to detect small and medium-sized species, and with a separation of at least 500 m between them to avoid duplicate species counts (Chávez *et al.* 2013).

To increase the success of species richness records, mammal tracks were surveyed along 4 km of the trails set in the CF, the RA and near water bodies. Tracks were identified using the guide by Aranda-Sánchez (2012).

Analysis of mammal species richness and relative abundance. Mammal photographs and tracks were taxonomically identified and are listed according to the nomenclature of Ramírez-Pulido *et al.* (2014). This list includes the risk category of each species according to the NOM-059-SEMARNAT-2010 (SEMARNAT 2019a) and the International Union for the Conservation of Nature (IUCN 2022).

Given the area comprised by the treatments (100 ha in total: 50 ha of CF and 50 ha of RA), photographs were considered independent records when there was a three-hour difference for the same species and when more than one individual was characterized based on physical marks or traits, such as sex. Individual photographs were sorted by species, and each separate record was considered a record in each sampling zone (Moreno *et al.* 2011; Chávez *et al.* 2013).

The relative abundance was calculated using the following equation: IAR = C/EM*1,000 trap days, where C = total number of species records; EM = sampling effort (number

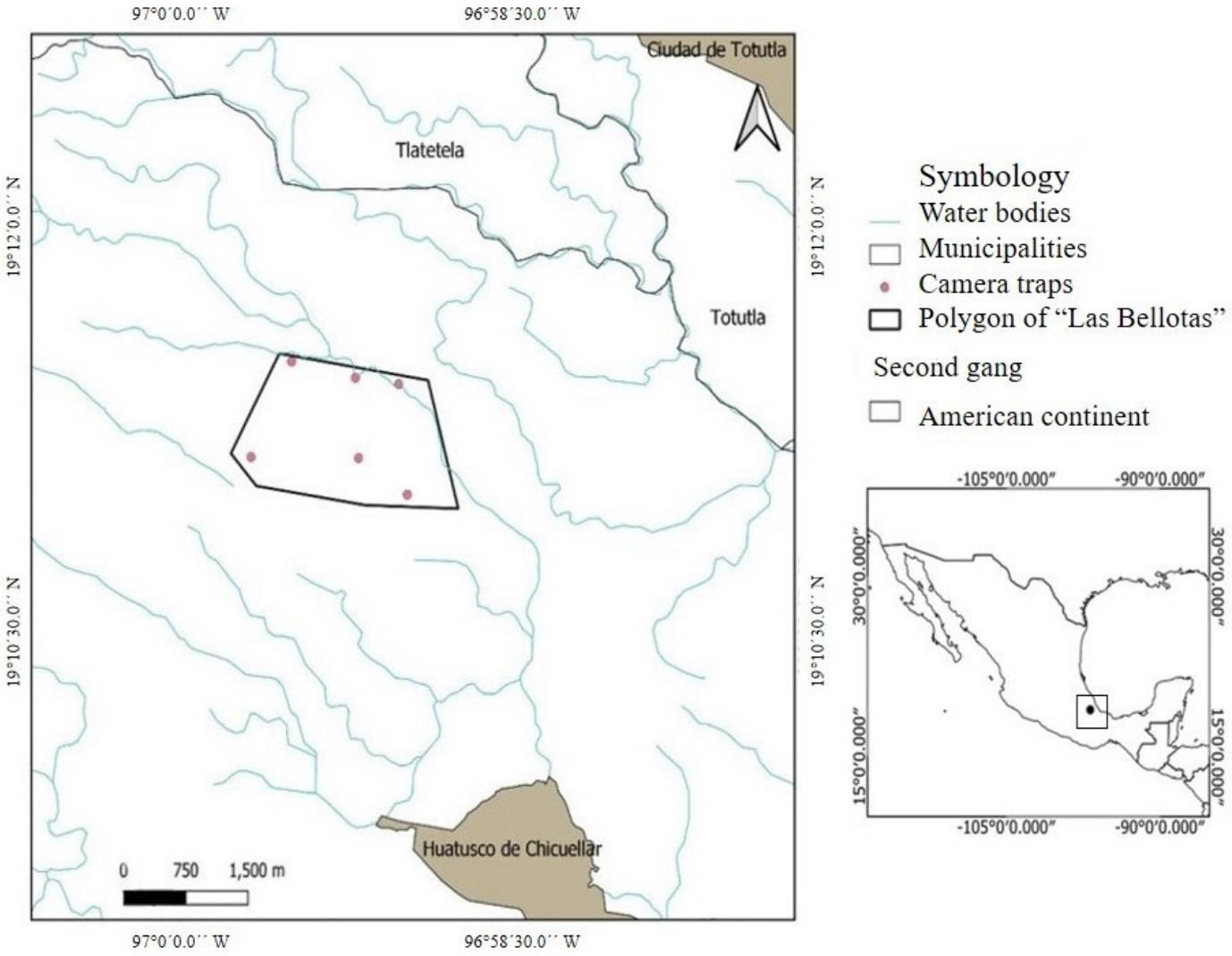

Figure 1. Centro Agroecológico Las Bellotas, Veracruz, México, indicating the camera trap sites for mammal monitoring.

of camera traps); 1,000 trap days (standard measure). IAR values were plotted by treatment and species (Lira-Torres and Briones-Salas 2012).

The species richness and total mammal records were compared between CF and RA using species accumulation curves based on individuals. These plots comparing the species richness with 95 % confidence intervals calculated through data iterations (Serna-Lagunes *et al.* 2019). These analyses were performed through the interpolation/extrapolation algorithm of the iNEXT software (Chao *et al.* 2016).

Finally, Sorensen's index was calculated using binary data (0, 1) to estimate the richness similarity between treatments using the following equation: IS = ((c)/(a+b+c)) * 100, where a = number of species in the CF, b = number of species in the RA, and c = species richness of mammals in both vegetation types (Moreno 2001).

With a sampling effort of 266 days and 1,596 trap days, we recorded 6,073 photographs and 323 separate records involving 15 mammal species, 11 families, and 6 taxonomic orders (Table 1). The following 13 species were recorded with camera traps: *Sciurus aureogaster*, *S. deppei*, *Dasyprocta mexicana*, *Cuniculus paca*, *Sylvilagus floridanus*, *Leopardus wiedii*, *Procyon lotor*, *Nasua narica*, *Potos flavus*, *Urocyon cinereoargenteus*, *Galictis vittata*, *Didelphis* spp., and *Dasypus novemcinctus* (Figure 2). *Canis latrans* and *Mazama temama* were identified based on tracks.

It is worth highlighting the presence of *Leopardus wiedii*, *Potos flavus,* and *Galictis vittata*, listed as endangered, threatened, and subjected to special protection, respectively, in the NOM-059-SEMARNAT-2010. *Sciurus aureogaster* (IAR = 78.32) and *Cuniculus paca* (IAR = 61.4) were the most abundant species (Figure 3a). Furthermore, *Mazama temama*, *P. flavus*, *Canis latrans*, *G. vittata* and *Urocyon cinereoargenteus* showed IAR values lower than 1.25 (Figure 3). Last, *Dasypus novemcinctus*, *L. wiedii*, *Sciurus deppei*, *Dasyprocta mexicana, Nasua narica*, *Didelphis* spp., *Procyon lotor*, and *Sylvilagus floridanus* attained an IAR value between 2.5 and 14.4 (Figure 3a).

Nine species and 83 individuals were recorded in the CF, with a sample completeness of 96 %. On the other hand, 12 species and 240 individuals were recorded in the RA, with a

Table 1. Taxonomic list, scientific and common name, and number of mammal records in the cloud forest (CF) and a restored area (RA) at Centro Agroecológico Las Bellotas, Veracruz, México. The conservation status is indicated according to the NOM-059-SEMARNAT-2010 (NOM-059; SEMARNAT 2019a) and the International Union for Conservation of Nature (IUCN 2022). P = Endangered; PE = Special Protection; A = Threatened; LC = Least Concern; CE = Critically Endangered; NT = Near Threatened; DD = Data Deficient.

Orden	Family	Scientific name	Common name	CF	RA	NOM-059	IUCN
Rodentia	Sciuridae	*Sciurus aureogaster*	Mexican gray squirrel	24	101	-	LC
		Sciurus deppei	Deppe's squirrel	0	4	-	LC
	Dasyproctidae	*Dasyprocta mexicana*	Mexican agouti	14	0	-	CE
	Cuniculidae	*Cuniculus paca*	Spotted paca	25	73	-	LC
Lagomorpha	Leporidae	*Sylvilagus floridanus*	Eastern cottontail	0	7	-	LC
Carnivora	Felidae	*Leopardus wiedii*	Margay	1	8	P	NT
	Procyonidae	*Procyon lotor*	Northern raccoon	0	11	-	LC
		Potos flavus	Kinkajou	2	0	PE	LC
		Nasua narica	White-nosed coati	1	4	-	LC
	Canidae	*Canis latrans*	Coyote	0	1	-	LC
		Urocyon cinereoargenteus	Grey fox	0	1	-	LC
	Mustelidae	*Galictis vittata*	Greater grison	1	0	A	LC
Didelphimorphia	Didelphidae	*Didelphis* spp.	Opossum	9	9	-	LC
Cingulata	Dasypodidae	*Dasypus novemcinctus*	Nine-banded armadillo	4	19	-	LC
Artiodactyla	Cervidae	*Mazama temama*	Central American red brocket	0	2	-	DD

sample completeness of 100 %. According to the accumulation curves, there are no significant differences in species richness between the CF and the RA because confidence intervals overlap (Figure 3b).

The CF and the RA shared 6 species: *S. aureogaster*, *C. paca*, *L. wiedii*, *N. narica*, *D. novemcinctus,* and *Didelphis* spp. Only 3 species were recorded exclusively in the CF: *P. flavus*, *G. vittata,* and *D. mexicana*, and 6 species were found exclusively in the RA: *S. deppei*, *P. lotor*, *C. latrans*, *U. cinereoargenteus*, *M. temama,* and *S. floridanus* (Table 1). According to Sorensen's index, there was a 63 % similarity between the CF and the RA.

The 15 species of terrestrial mammals recorded at Centro Agroecológico Las Bellotas represent 3 % of the species reported for México (Ramírez-Pulido *et al.* 2014), 8 % of the 195 species documented for Veracruz (González-Christen and Delfín-Alfonso 2016), and 6 % of the mammal species recorded in the CFs of México (González-Ruíz *et al.* 2014). There was no previous information about mammal richness in this locality of the Huatusco municipality, but this area can be considered important due to the presence of endangered carnivores.

The richness of mammals recorded in this study is consistent with the one reported for the Las Cañadas locality in Huatusco, located approximately 2 km away from our study area. Las Cañadas also harbors a CF and a RA of more than 15 years (García-Burgos *et al.* 2014). The species richness recorded in the present study is higher than values reported for other regions of central Veracruz with CF, such as the Zongolica municipality and the Pico de Orizaba National Park (adjacent to the study area), where 11 and 10 mammal species were recorded, respectively (Macario-Cueyactle *et al.* 2019; Serna-Lagunes *et al.* 2019). However, it was lower than the richness reported for the Tequila municipality, with 16 species (Salazar-Ortiz *et al.* 2020).

The presence and abundance of 7 mammal species of the order Carnivora are indicators of the conservation level of the CF and the RA because they are species more susceptible to anthropic changes and the first to become locally extinct (Briceño-Méndez *et al.* 2017; Cruz-Bazán *et al.* 2017). The local extinction of these species may lead to an increase in rodent populations to such an extent that these are considered pests (Pérez-Irineo and Santos-Moreno 2013). This phenomenon may be occurring with *L. wiedii*, which feeds on *S. aureogaster*. In the absence of a natural predator, the latter may become a pest even in relatively well-conserved ecosystems (Cinta-Magallón *et al.* 2012; Hidalgo-Milhart *et al.* 2012) and thrives in altered sites where there are no predators (Garcés-Restrepo and Saavedra-Rodríguez 2013).

Another abundant rodent in the study area was *C. paca*. The populations of this species can be more abundant in sites with fewer predators and competitors such as *D. mexicana* (Santos-Moreno and Pérez-Irineo 2013). In this sense, this study recorded no predators of this species, such as jaguars or ocelots (which have been reported for the CF). However, it has been documented that *L. wiedii* occasionally feeds on *C. paca* hatchlings. *Leopardus wiedii* and *C. latrans* (potential predators of *C. paca*) were recorded with low abundances (Martínez-Ceceñas *et al.* 2018). The abundance of *C. paca* indicates that it is not impacted by activities such as hunting (Martínez-Ceceñas *et al.* 2018), which is prohibited in the study area.

The recorded abundance of *M. temama* may be due to its cryptic behavior, elusive habits, and susceptibility to human presence since it prefers well-preserved forested areas (Contreras-Moreno *et al.* 2016; Muñoz-Vázquez and

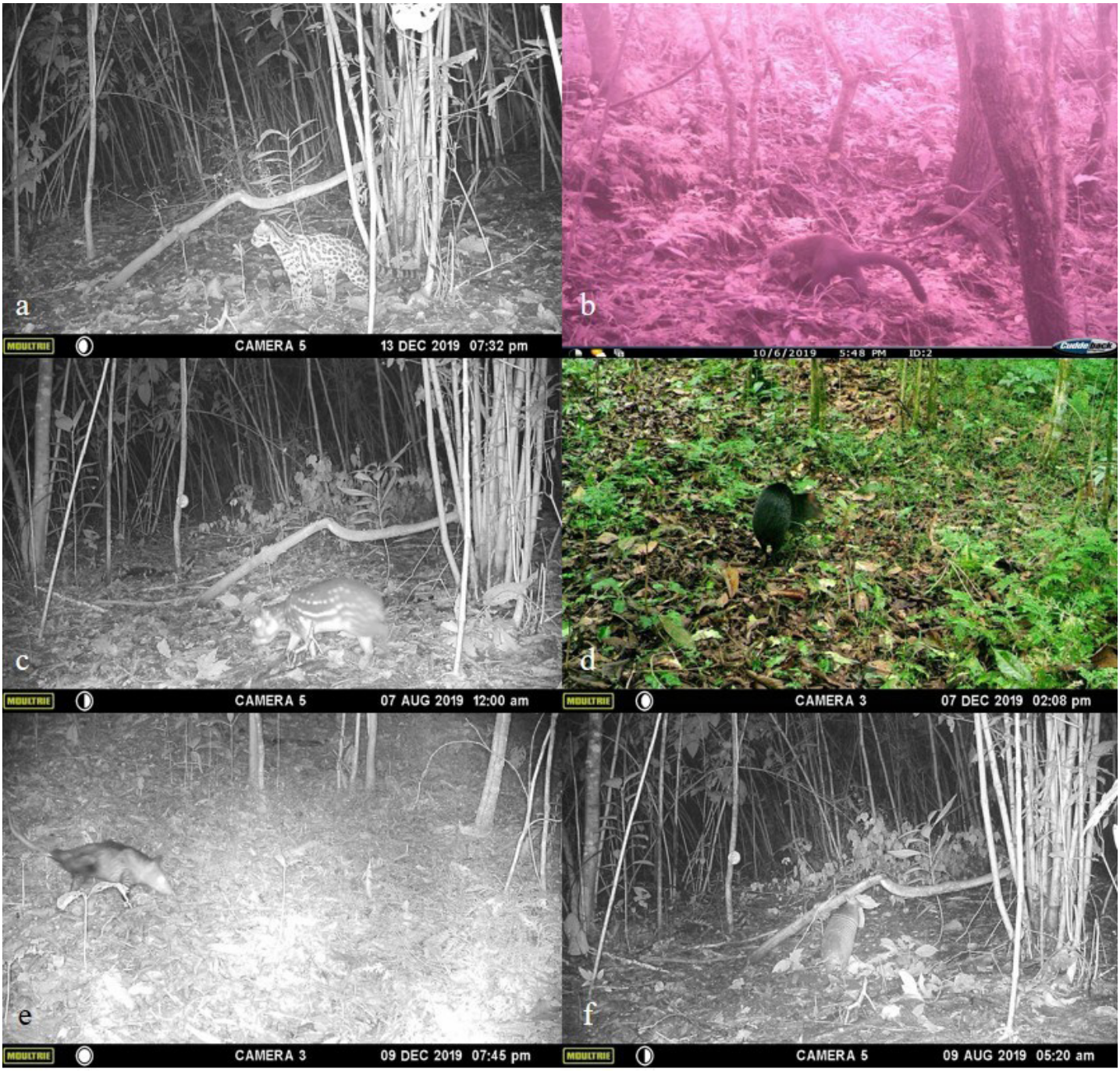

Figure 2. Main records of mammals at Centro Agroecológico de las Bellotas, Huatusco, Veracruz, México: a) *Leopardus wiedii*; b) *Nasua narica*; c) *Cuniculus paca*; d) *Dasyprocta mexicana*; e) *Didelphis* spp.; f) *Dasypus novemcinctus*.

Gallina-Tessaro 2016). In this sense, it is likely that the study site with CF and RA lacks the minimum surface area required for this species or that the habitat conditions are unsuitable to sustain high abundances. The presence of this species may be due to the fact that it occasionally uses the area as a corridor and refuge from threats in surrounding areas (Salazar-Ortiz *et al.* 2022).

Only a single record of the grison, *G. vittata*, was obtained, which was expected as it is considered a scarce species (Lucas-Juárez *et al.* 2021). However, it could also be because this species is usually found in the proximity of water bodies (Hidalgo-Milhart *et al.* 2006). The present study did not consider water bodies due to their difficult access and because some were close to human settlements.

Additionally, *C. latrans* showed low abundance values because this species prefers open areas bordered by vegetation, even being better adapted to anthropic areas and avoiding CFs (Peña-Mondragón *et al.* 2014). By contrast, the two records of kinkajou, *P. flavus*, indicate that CFs provide the tree cover that favor its presence (Monterrubio-Rico *et al.* 2013; Cruz-Bazán *et al.* 2017).

The species richness recorded in this study could be explained because mammal species use complementary

resources, thus being distributed in both vegetation types (Macario-Cueyactle *et al.* 2019). There were more records per species in the RA, maybe due to a higher abundance of resources. However, each area has unique biotic and abiotic conditions that favor the presence of different species (Gardner *et al.* 2009). The RA showed more records of opportunistic species (Hidalgo-Milhart *et al.* 2013; Pérez-Irineo and Santos-Moreno 2013; Peña-Mondragón *et al.* 2014).

Considering that low values of the similarity index indicate less similarity (Moreno 2001), we can conclude that these vegetation types complement each other. These differences may be related to the fact that opportunistic species or those that are more active in open sites were recorded in the RA, such as *C. latrans*, *U. cinereoargenteus*, and *P. lotor* (Hidalgo-Milhart *et al.* 2013; Pérez-Irineo and Santos-Moreno 2013; Peña-Mondragón *et al.* 2014). On the other hand, we recorded species more susceptible to habitat changes in the CF, which are found in more densely forested areas because they require more specific habitat resources (Jiménez-Alvarado *et al.* 2016). For instance, *P. flavus* is able to feed in any strata and is usually found in the forest canopy, preferring trees with fruits throughout the year (Hernández-Flores *et al.* 2018). Species of the genus *Didelphis* and *D. novemcinctus* can adapt to habitat changes and have been reported inhabiting both vegetation types (López-Ramírez *et al.* 2020).

Some mammals reported in this study play central ecological roles in the CF, including the dispersal of large seeds by *C. paca* and *D. mexicana* and of smaller seeds by species of the genus *Sciurus* (Rojas-Robles *et al.* 2012; Bonilla-Morales *et al.* 2013). A carnivore species, the gray fox *U. cinereoargenteus*, is an incidental disperser (Villalobos-Escalante *et al.* 2014).

About 44 % of the mammals recorded in this study belong to the order Carnivora. This group is more susceptible to anthropic changes and is one the first groups of species to become locally extinct (Briceño-Mendéz *et al.* 2017). In this sense, the Centro Agroecológico Las Bellotas should be certified as an Área Destinada Voluntariamente a la Conservación (ADVC) y el Programa de Acción para la Conservación de Especies prioritarias (PACE): small felines (SEMARNAT 2019b). This certification would support the study, management, and conservation of the wildlife populations inhabiting this area by research and education institutions, along with the owners of this and adjacent land. Additionally, an environmental awareness program should be implemented aimed at the ecological restoration of the CF in the region.

Fifteen mammal species were recorded in the Centro Agroecológico Las Bellotas. The Mexican gray squirrel (*S. aureogaster*) showed the highest abundance of all the mammals in the CF and the RA, indicating that it is a markedly modified area. The CF harbors species that depend on well-preserved sites or the tree stratum, such as *P. flavus* and *G. vittata*. On the other hand, the RA had a higher richness of opportunistic species that prefer disturbed sites, such as

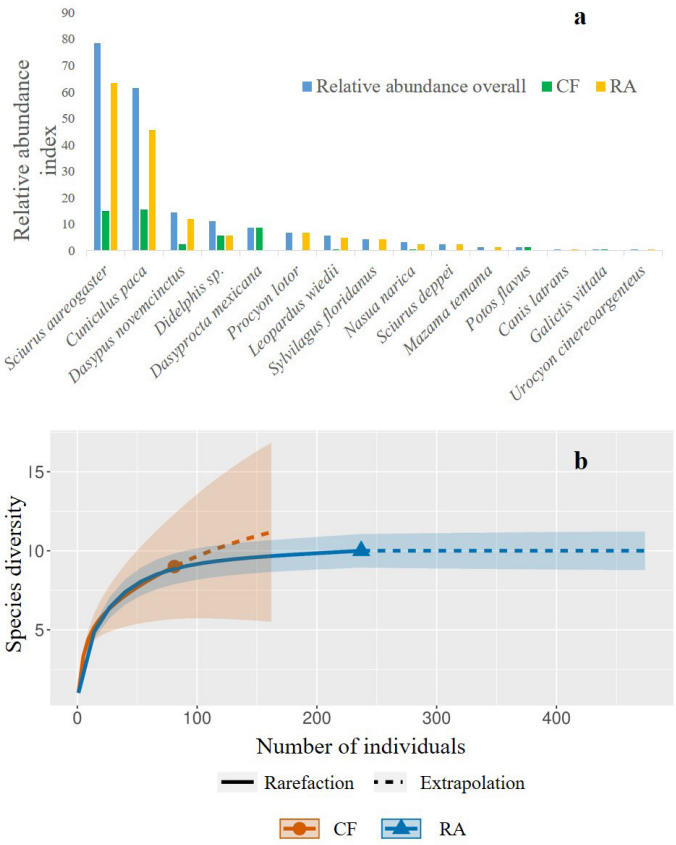

Figure 3. a) Combined relative abundance index by zone of the mammal species recorded in the CF and the RA; b) Interpolation/extrapolation curve of the mammal community in the CF and the RA at Centro Agroecológico Las Bellotas, Veracruz, México.

P. lotor, *U. cinereoargenteus*, and *C. latrans*. Both sites can be considered complementary, providing habitat to species with different ecological requirements. Protection measures for the species recorded in the study area, such as *L. wiedii*, *P. flavus,* and *G. vittata*, should focus on increasing reforestation with native trees that provide food for wildlife, implementing corridors between the different patches of CF, avoiding the entry of poachers and cattle, and conducting population studies.

Acknowledgements

The authors wish to thank the Centro Agroecológico Las Bellotas for its support in the conduct of this study. Thanks also to the anonymous reviewers whose contributions considerably improved the article. M. E. Sánchez-Salazar translated the manuscript into English.

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Associated editor: Cristian Kraker Castañeda.
Submitted: August 5, 2022; Reviewed: June 20, 2023.
Accepted: July 10, 2023; Published on line: August 4, 2023.