



## NON-VOLANT MAMMALS IN A FRAGMENT OF CAATINGA IN NORTHEASTERN BRAZIL

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**Abstract:** The state of Paraíba is one of those with the most degraded Caatinga that presents the large gap of knowledge concerning the mammal fauna. Mammals are among the taxa most affected by this. In this sense, we evaluated non-volant mammals' richness and composition between March 2013 and February 2020 in a Caatinga fragment (121 ha). We used active search (336 hours) and camera traps (1,200 night traps). We recorded 20 species, including four threatened ones. Carnivora was the most representative order (7 species), followed by Rodentia (4 species). The richness of non-volant mammals found represents 35.6 % of the total number of such species in the Caatinga. This species richness is greater than that found in other studies in the state. The presence of these mammal species was mainly due to the recovering vegetation that resulted from the great planting effort and also due to cessation of hunt, cattle and sheep breeding that had existed on the farm for over thirty years. Our findings highlight the importance of this particular reserve due to the large number of species registered.

**Keywords:** camera trap; dry tropical forest; Private Area; water reservoirs

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The Caatinga is the largest seasonal dry tropical forest in the Americas and one of the 37 great wild regions on the planet (Mittermeier *et al.* 2002), occupying 11 % of terrestrial Brazilian territory (Silva *et al.* 2017). Only 2 % of the Caatinga territory occurs within protected areas such as parks and biological reserves (Fonseca *et al.* 2017). Further, practically half of all its original vegetative cover has already been lost due to low-tech agriculture, extensive livestock, mining, unsustainable wood extraction and poaching (Antongiovanni *et al.* 2018, Chaves *et al.* 2020). This threatens the long-term persistence of biota, including many of the

180 extant mammal species found in the area (Beisiegel 2017, Dias *et al.* 2019).

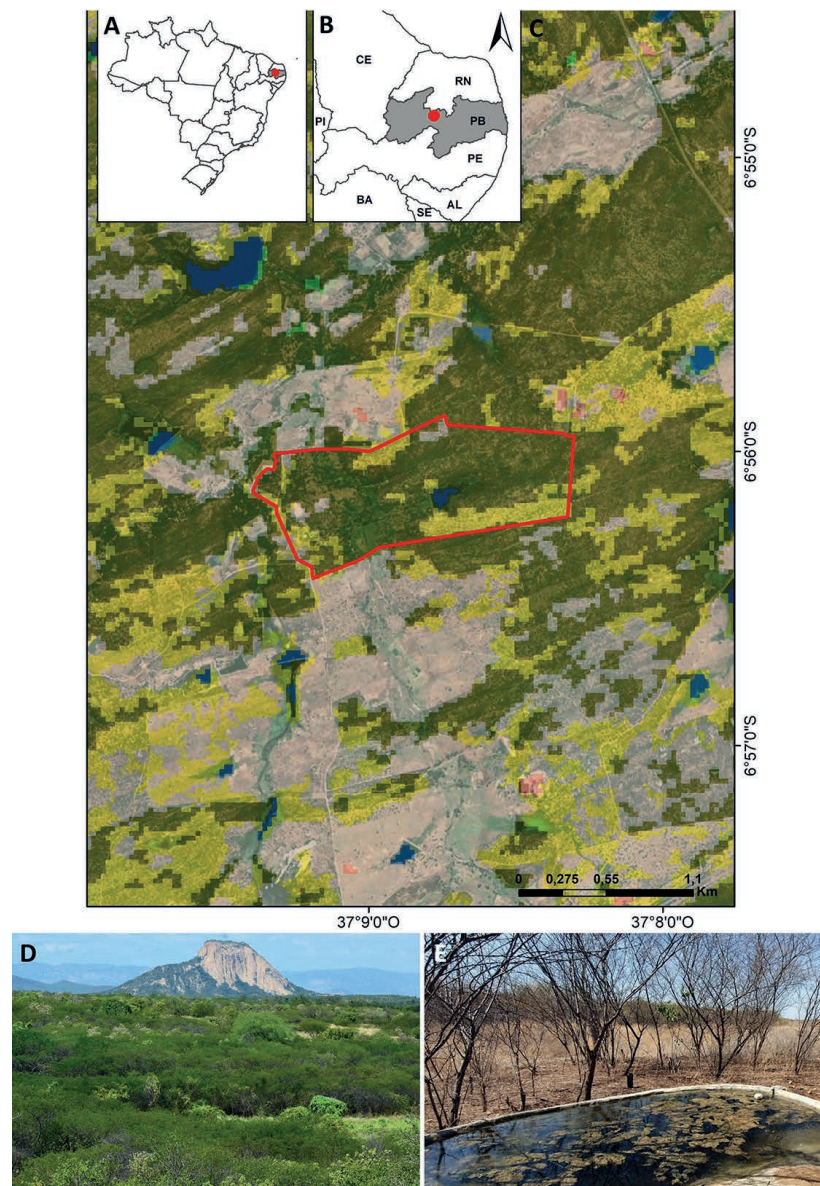
Mammals are key components of the Caatinga ecosystem as they play an important role in forest maintenance and regeneration, and the structuring and functioning of biological communities (Carmignotto & Astúa 2017). The number of mammal inventories undertaken in this biome has increased in recent years (Feijó & Langguth 2013, Delciellos 2016, Marinho *et al.* 2018, Campos *et al.* 2019, Alves *et al.* 2020). Nevertheless, knowledge on fauna and ecological processes is scarce when compared to other Brazilian

biomes. There is a historical deficit of studies and investment in research in the Caatinga, hence a large part of its area and biota remains unknown or undersampled (Santos *et al.* 2011).

We evaluated the species richness and composition of non-volant mammals on a private farm known as Verdes Pastos Ecological Reserve (VPER), located in the “Sertão Paraibano”, central region of the state of Paraíba (PB), Brazil. Knowledge about the presence and distribution of species is essential to plan and evaluate biodiversity conservation strategies. However, there are few studies and little information on

mammals of the Caatinga in PB (Cruz *et al.* 2005, Campos *et al.* 2016). Further, among the 10 Brazilian states that still contain remnants of Caatinga, PB is the second most degraded (27.7 %; LAPIS 2019). Only 3,000 ha, or 0.05 % of PB is protected in state reserves, with two of these encompassing 200 ha of Caatinga (SEMARH/PB 2019).

The VPER, is a private farm of 121.62 ha located in a rural area of the municipality of São Mamede, in the interior of PB (06°56'16"S, 37°09'10"W; 274 m). The farm's headquarters and other support infrastructures occupy 13.16 ha. The preserved area occupy over 100 ha (Figure 1). The vegetation



**Figure 1.** Location of Verdes Pastos Ecological Reserve – VPER, state of Paraíba, Brazil. Photos: A) Paraíba state (red point) in Brazil; B) São Mamede municipality (red point); C) Verdes Pastos Ecological Reserve (red polygon); D) vegetation during the rainy season; E) vegetation during the dry period and artificial water reservoir.

is largely comprised of shrubs with some cultivable areas and zones of natural regeneration (Delfino *et al.* 2020). VPER has high avian, lizard and snake reptile diversity, with 160 (Pereira *et al.* 2014), 14 and 13 species (Sousa 2018), respectively. The area is topographically flat, with some natural water bodies, dams and artificial water reservoirs, previously used in the watering of livestock. The weather is warm semi-arid (BSHW), with nine dry months and rainfall concentrated during the summer.

We carried out mammalian surveys between March 2013 and February 2020 using active searching and one camera trap (Bushnell Nature View HD). The camera trap was placed opportunistically in front of three artificial water reservoirs about 40 cm distant from the ground. The traps were inspected every two weeks, and every three months the traps were repositioned. The total sampling effort was 1,200 trap nights and 336 hours of active searching. The traps were programmed to take videos every 10 seconds and images of the same species were assumed independent when temporally separated by at least one hour. We recorded further opportunistic observations during the day. Two people in different trails of the reserve carried out these observations. To assess the accumulation of new species by sampling new individuals over time, we constructed a species accumulation curve. The total species richness was estimated by the Jackknife-1 procedure, at a significance level of 95 % ( $p < 0.05$ ), using the EstimateS program version 9.1 (<http://purl.oclc.org/estimates>).

Taxonomic nomenclature was based on Quintela *et al.* (2020), supplemented with the Brazilian and Global Red Lists for Endangered Species (ICMBio 2018, IUCN 2019). As a species recently separated from *Leopardus tigrinus* and considered endemic to Caatinga, *L. emiliae* was assigned the conservation status of *L. tigrinus* (see Nascimento & Feijó, 2017). The endemic species were identified according to Gutiérrez & Marinho-Filho (2017), and diets were based on Paglia *et al.* (2012).

We recorded 20 species of non-volant mammals, 16 of which were medium or large species (Table 1, Figure 2, Figure 3). Camera traps returned a total of 14 species across 189 independent detections. Sixteen species were recorded across 142 sightings

(live animal) by active searching. Four endangered species (*Leopardus emiliae*, *Puma concolor*, *Herpailurus yagouaroundi*, *Kerodon rupestris*) and three endemic being two rodents (*Wiedomys pyrrhorhinos*, *Kerodon rupestris*) and one feline (*L. emiliae*) were recorded.

The order Carnivora had the largest number of species ( $n = 7$ ), followed by Rodentia ( $n = 4$ ). Three species accounted for 42.3 % of all photographic records: *Puma yagouaroundi* ( $n = 31$ ), *Procyon cancrivorus* ( $n = 29$ ) and *Cerdocyon thous* ( $n = 20$ ). Three species were also responsible for 59.7 % of direct observation records: *Galea spixii* ( $n = 40$ ), *Callithrix jacchus* ( $n = 25$ ) and *Kerodon rupestris* ( $n = 18$ ). Three species were observed (live animal) less than 20 km from the reserve in other fragmented areas of Caatinga (*Dasypus novemcinctus*, *Puma concolor* and *Gracilinanus agilis*). Seven species were observed fewer than 10 times (Table 1). Jackknife-1 sampling of camera trap data yielded an estimate of 20 species (Figure 4). Despite the fourteen species photographed, the species accumulation curve did not stabilize. The increase in the sample effort by camera traps could add, for example, the records of six species that were only observed directly.

The number of medium and large mammalian species in the VPER ( $n = 16$ ) represents 35.6 % of the total number of large and medium size mammal species in the Caatinga, according to the most recent estimates ( $n = 45$ , Carmignotto & Astúa 2017). Only two previous studies recorded medium and large mammals in the Caatinga of PB. In a study carried out over ten days along rainy and dry seasons, Cruz *et al.* (2005) observed three species in the Pedra da Boca State Park (157 ha) in the Borborema plateau. In the Serra de Santa Catarina (> 10000 ha), located near the eastern border of the state, Campos *et al.* (2016) recorded 12 species between August 2012 to January 2014. These two protected areas have the same vegetation type as the study area. Recent mammal inventories carried out in the Caatinga in neighboring states indicated the occurrence between seven and 24 medium and large species (Deiciellos, 2016, Dias *et al.* 2017, Marinho *et al.* 2018, Alves *et al.* 2020).

In addition to presenting the highest number of species, Carnivora was represented by three of the four endangered species recorded in our study: *Leopardus emiliae*, *Herpailurus yagouaroundi*

**Table 1.** Frequency of mammal records in the Verdes Pastos Ecologica Reserve - VPER, municipality of São Mamede, state of Paraíba, Brazil. Captions: Method: PT = Photo Trap, DO = Direct Observation; Records: N - number of records; Threat: Brazil = ICMBio 2018, GLOBAL = IUCN 2018. EN: endangered, VU: vulnerable. Diet according to Paglia *et al.* 2012: C - Carnivore, H - Herbivore, M - Mirmecophage, O – Omnivore, \* = endemic.

Táxon	Nome popular	Records			Status		
		DO	PT	Total	Diet	ICMBio	IUCN
DIDELPHIMORPHIA							
Didelphidae							
<i>Didelphis albiventris</i> Lund, 1840	White-eared opossum	10	15	25	O		
<i>Gracilinanus agilis</i> (Burmeister, 1854)	Gracile mouse opossum	1	0	1	O		
<i>Monodelphis domestica</i> (Wagner, 1842)	Short-tailed opossum	1	4	5	O		
PILOSA							
Myrmecophagidae							
<i>Tamandua tetradactyla</i> (Linnaeus, 1758)	Southern Tamandua	1	0	1	M		
CINGULATA							
Dasypodidae							
<i>Dasypus novemcinctus</i> Linnaeus, 1758	Nine-banded Armadillo	1	0	1	O		
Chlamyphoridae							
<i>Euphractus sexcinctus</i> (Linnaeus, 1758)	Yellow Armadillo	12	18	30	O		
PRIMATES							
Callitrichidae							
<i>Callithrix jacchus</i> (Linnaeus, 1758)	Common marmoset	25	5	30	O		
Cebidae							
<i>Sapajus libidinosus</i> (Spix, 1823)	Bearded capuchin monkey	2	0	2	O		
CARNIVORA							
Canidae							
<i>Cerdocyon thous</i> (Linnaeus, 1766)	Crab-eating fox	12	20	32	C		
Felidae							
<i>Leopardus pardalis</i> (Linnaeus, 1758)	Ocelot	0	2	2	C		
<i>Leopardus emiliae</i> (Thomas, 1914)*	Northern Tiger Cat	1	18	19	C	EN	VU
<i>Puma concolor</i> (Linnaeus, 1771)	Puma	1	0	1	C	VU	
<i>Herpailurus yagouaroundi</i> (É. Geoffroy Saint-Hilaire, 1803)	Jaguarundi	5	31	36	C	VU	

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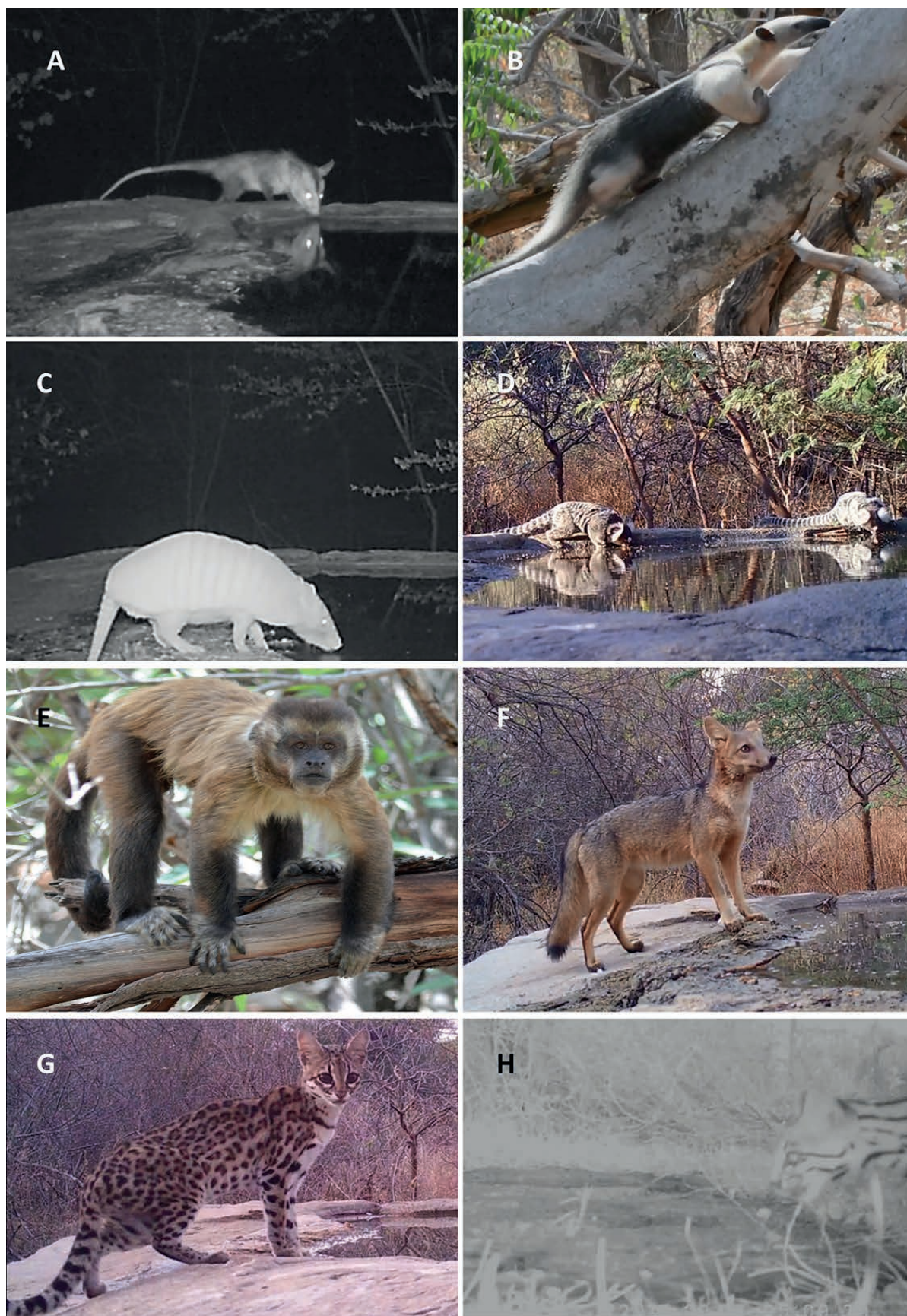
Táxon	Nome popular	Records			Status		
		DO	PT	Total	Diet	ICMBio	IUCN
Mephitidae							
<i>Conepatus amazonicus</i> (Lichtenstein, 1838)	Hog-nosed Skunk	1	0	1	O		
Procyonidae							
<i>Procyon cancrivorus</i> (Cuvier, 1798)	Crab-eating raccoon	1	29	30	O		
ARTIODACTYLA							
Cervidae							
<i>Mazama gouazoubira</i> (Fischer, 1814)	Gray Brocket Deer	1	5	6	H		
RODENTIA							
Echimyidae							
<i>Thrichomys apereoides</i> (Lund, 1839)	Punaré rat	7	15	22	H		
Cricetidae							
<i>Wiedomys pyrrhorhinos</i> (Wied-Neuwied, 1821)*	Red-nose mouse	2	5	7	H		
Caviidae							
<i>Galea spixii</i> (Wagler, 1831)	Spix's cavy	40	10	50	H		
<i>Kerodon rupestres</i> (Wied-Neuwied, 1820)*	Rock cavy	18	12	30	H	VU	
Total		142	189	331			

and *Puma concolor*. Almost half of the carnivores found in Brazil are threatened (ICMBio 2018). The visual record of the *P. concolor* was recorded out on a dirt road that crosses the Serra de Santa Luzia, located close to VPER (about 20 km). Few studies have recorded this species in the Caatinga in PB and neighboring states (Feijó & Langguth 2013, Campos *et al.* 2016, Dias *et al.* 2017, Marinho *et al.* 2018). This species requires extensive territories and has a low reproductive rate, which makes them more susceptible to environmental changes and anthropic pressures (Astete *et al.* 2017, Beisiegel 2017).

*Herpailurus yagouaroundi* was the most commonly observed species in photographic records (n = 36; 16.4 % of the total). Our results contrast sharply to the literature on the species, which suggests that this small felid occurs in low densities and yields few records (Almeida *et al.* 2013, Dias *et al.* 2017, Marinho *et al.* 2018). Data are lacking on the relationship between

detection rate and density for *Herpailurus yagouaroundi*, yet our observations present an important opportunity for further research. The main threats to this species are habitat loss and fragmentation, sport hunting, fur trade, collisions with vehicles, transmission of diseases from domestic carnivores, breeding for domestication, and retaliation against livestock predation (Almeida *et al.* 2013, Delciellos 2016, Giordano *et al.* 2016, Marinho *et al.* 2018). The identification of a population that may occur at relatively high density has important implications for the conservation of this threatened species.

The presence of these mammal species in VPER was mainly due to the recovering vegetation that resulted from the great planting effort and also due to cessation of hunt, cattle and sheep breeding that had existed on the farm for over thirty years. Other areas of the Caatinga, even protected areas, continue to suffer from the synergistic impacts of human activities



**Figure 2.** Selected mammal species recorded in the Verdes Pastos Ecologica Reserve - VPER, state of Paraíba, Brazil. Photos: A) *Didelphis albiventris*, B) *Myrmecophaga tridactyla*, C) *Euphractus sexcinctus*, D) *Callithrix jacchus*, E) *Sapajus libidinosus*, F) *Cercopithecus thous*, G) *Leopardus emiliae*, H) *Leopardus pardalis*.





**Figure 3.** Selected mammal species recorded in the Verdes Pastos Ecologica Reserve - VPER, state of Paraíba, Brazil. Photos: A) *Herpailurus yagouaroundi*, B) *Conepatus amazonicus*, C) *Procyon cancrivorus*, D) *Mazama gouazoubira*, E) *Thrichomys apereoides*, F) *Wiedomys pyrrhorhinos*, G) *Galea spixii*, H) *Kerodon rupestres*.

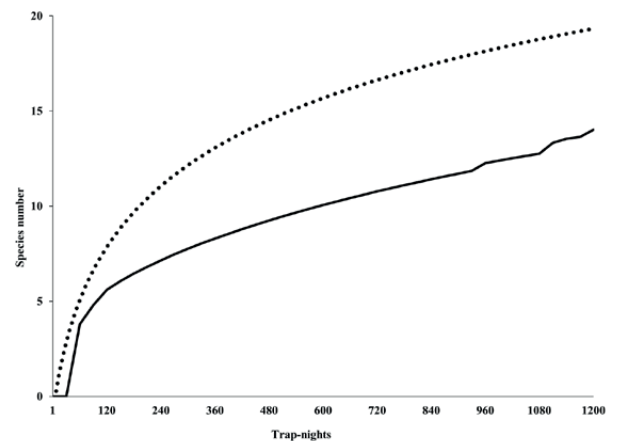


that negatively affect the diversity of mammals (Beisiegel 2017, Dias *et al.* 2019). For example, in the Catimbau National Park (62,294 ha), in the Pernambuco state, only 8 native species and 7 non-native species were recorded during camera trap surveys. The authors suggested that the recent history of livestock farming, hunting activities, fire, forest loss and fragmentation in the region is insufficient to pay off the extinction debt (Alves *et al.* 2020).

The construction of artificial water reservoirs guarantees the availability of this scarce resource for wildlife throughout the year. In semi-arid environments, the availability of water is one of the primary factors limiting biological diversity (Campos *et al.* 2019, Weiler *et al.* 2020). Hence, permanent artificial bodies of water provide a critical resource for resident species, especially during prolonged droughts (Astete *et al.* 2017, Dias *et al.* 2019, Weiler *et al.* 2020). In our study, the probabilities of occupancy of species such as *Mazama gouazoubira*, as well as the large carnivores, were almost certainly greater with increased abundance of and proximity to water sources (Giordano 2016, Astete *et al.* 2017, Campos *et al.* 2019).

Several of the recorded species, such as *Sapajus libidinosus* and *M. goazoubira*, are little known in PB (Feijó & Langguth 2013, Campos *et al.* 2016). Both acts as important seed dispersers and, despite being dependent on forested environments, they are ecologically flexible and not restricted to primary habitats (Moura & Mcconkey 2006, Duarte *et al.* 2012). Further, the great pressure of hunting has led *M. gouazoubira* to decline or even to local extinction in more disturbed areas of the Caatinga (Duarte *et al.* 2012, Chaves *et al.* 2020). Our records therefore add important additional data on poorly-studied and infrequently-recorded species in PB.

Our findings suggest the habitat amount hypothesis, which predicts that forest-dependent species density increases with increasing forest cover availability (Watson *et al.* 2018). The positive effects of restoring forest cover, controlling non-native species, eradicating of hunting and ceasing livestock farming are evident in the number of species, including endangered and endemic species, recorded in the study area. We emphasized the need for ongoing protection



**Figure 4.** The species accumulation curve (black line) and estimated species richness (dotted line) curves for observed medium and large mammalian species of the Verdes Pastos Ecológica Reserve - VPER, state of Paraíba, Brazil.

and regular monitoring of remaining Caatinga fragments, with a particular focus on endangered species.

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