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MEDIUM AND LARGE-SIZED MAMMALS IN A FRAGMENT OF CERRADO IN SERRA DOS PIRENEUS, CENTRAL BRAZIL

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Abstract: The degradation of the Cerrado ecoregion constitutes one of the greatest threats to mammals in Brazil. Effective conservation requires the identification of impacted species, particularly in unprotected areas. We report the species richness and composition of medium- and large-sized mammals in a Cerrado fragment in the state of Goiás, between July 2017 and August 2021. The sampling effort comprised 648 active search hours and 5,670 camera-trap-days. We recorded 32 species, among them, eight threatened. Rare species, such as *Leopardus wiedii,* were observed. *Tapirus terrestris* was the most frequent species (N = 34), and Carnivora was the most represented order (13 species). Species richness (36) was the highest recorded in Goiás in medium and large-sized mammal surveys. The recorded species, which include endangered and large predator species, are under anthropic pressure, requiring short-term and long-term conservation actions.

Keywords: Camera trap; Goiás; Inventory; Unprotected areas.

The Cerrado ecoregion in Brazil is severely threatened by anthropogenic pressures. Almost 80% of its original area was converted to pastures and agricultural areas, primarily soy (Strassburg *et al.* 2017, MapBiomas, 2019). Nevertheless, the Cerrado still harbors high levels of biodiversity and mammal endemism (Paglia *et al.* 2012, Gutiérrez & Marinho-Filho 2017) and has been defined as one of the 34 most relevant global hotspots for biodiversity conservation (Mittermeier *et al.* 2005). However, public protected areas cover only 8.5% of the Cerrado (Françoso *et al.* 2015).

Strict Protected areas (PAs), *i.e.*, areas that are strictly set aside to protect biodiversity, comprise only 3% of the Cerrado (Françoso *et al.* 2015, Ferreira *et al.* 2020). Large-bodied and threatened mammal species may exhibit higher occupancy in strict PAs than in multiple-use areas (Ferreira *et al.* 2020). There is, therefore, an urgent need to understand the magnitude of negative effects on biodiversity in unprotected areas of the Cerrado, where anthropogenic pressure is higher than in PAs (Rocha *et al.* 2018). For instance, medium- and large-sized mammals are threatened by habitat loss and fragmentation (Thornton *et al.* 2011, Lino *et al.*, 2018), and several species have low reproductive rates and large home ranges that make them more susceptible to local extinctions (Rocha *et al.* 2018, Oliveira *et al.* 2019).

Most studies on mammals of the Cerrado in central Brazil that used different sampling methods and efforts have apparently been carried out in public or private protected areas (see Supplementary Material). Thus, studies carried out in isolated unprotected forest fragments seem to be poorly represented in the literature, requiring immediate attention. Mammal inventories can provide fundamental data for the conservation and management of species and remnants, guiding actions to minimize population decline (Rocha *et al.* 2018). Large-bodied mammals, carnivores in particular, can act as effective umbrella species (Roberge and Anglestam 2004; but see Wang *et al.* 2021) because protecting such mammals may confer protection to other species that occur in the same area. We evaluated the species richness and composition of medium and large-sized mammals in a large cerrado fragment surrounded by degraded areas and productive areas on a private farm (geographical coordinates of the farm were not informed at the request of the property owner) in the eastern region of the state of Goiás (GO), Brazil (Figure 1).

The study area was located in a region of agricultural production farms in the Serra dos Pireneus, the second highest massif in GO, located in the municipality of Pirenópolis. The Serra dos Pireneus is one of the dividers of the Tocantins and Paraná Basins, where several streams are born, eventually forming the Rio das Almas and the Rio Corumbá, which supply several cities in the region (Salmona *et al.* 2014). Despite its importance, in recent years, the Cerrado vegetation areas in Serra dos Pireneus have decreased (2,086.94 ha), and there was an increase in both areas of agriculture (347.27 ha) and forest fire scars (1349.56 ha) (Oliveira 2018). The studied fragment comprised approximately 4,000 ha (Figure 1) located 17 Km from the northern limit of the Pireneus State Environmental Protection Area (APAEP) (15°47'48" S 48°50'37" O; 22,880 ha) (Figure 1c). The camera traps were distributed at five points within the boundaries of the farms in the following phytophysiognomies: cerradão, cerrado *sensu stricto*, *campo-rupestre*, seasonal semideciduous forest, and gallery forest (Figure 1). All the phytophysiognomies had the same sampling effort. The climate is tropical savanna (Aw), with a hot and rainy season (October to April) and a cold and dry season (May to September).

Mammalian surveys were carried out between July 2017 and June 2021 using active searching and five camera traps (four Bushnell Nature View HD and one DSLR camera trap). Camera traps (Bushnell Thophy Cam HD) were placed in close proximity to animal trails, close to river crossings, and in front of armadillo pits, at approximately 40 cm high. The traps were programmed to take still images (day and night). Baits were not used to attract the animals (Aximoff *et al.* 2022). The traps were inspected every two weeks, and repositioned every three months. The minimum criterion for image independence was one hour (Scotson *et al.* 2017).

The total sampling effort comprised 5,670 camera-trap-days and 648 hours of active searching. A species accumulation curve was constructed based on the detections of new individuals of species over time. 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 (Colwell 2019). Species identification was based on external characters according to Reis *et al.* (2011). Field guides were used to aid the identification of footprints and feces (Becker and Dalponte 1999, Mamede and Alho 2008). Taxonomic nomenclature was based on Abreu-Junior *et al.* (2020), supplemented with the Brazilian and Global Red Lists for Endangered Species (ICMBio 2018, IUCN 2019).

We recorded 32 species across 234 independent detections. A total of 28 species were identified from camera trap photos while only four species were recorded exclusively by active searching (Table 1, Figure 2). Eight species were categorized as endangered according to the Brazilian Red List (ICMBio 2018) and three (*Myrmecophaga tridactyla*, *Priodontes maximus*, *Tapirus terrestris*) were categorized as endangered according to the Global Red List (IUCN 2019). The order Carnivora had the highest number of species recorded (N = 13), followed by Rodentia (N = 5). Four species accounted for 43.2% of all photographic records (Figure 3A): *Tapirus terrestris* (N = 34 photos), *Dicotyles tajacu* (N = 29), *Panthera onca* (N = 20) and *Cerdocyon thous* (N = 18) (Table 1). Twenty-one species were detected fewer than 10 times in total (Table 1). The species accumulation curve did not

Figure 1. Location of the study area, a Cerrado fragment located in the Serra de Pirenópolis, state of Goiás, Brazil. Photos: A) Goiás state (red point) in Brazil; B) Pirenópolis municipality (red point); C) Cerrado Fragment 1 (blue polygon) and Pirenópolis State Environment Protected Area (yellow polygon); D) agricultural field around the fragments, (E) Cerrado vegetation; (F) Estacional Forest and (G) Gallery Forest.

Figure 2. Threatened species registered in the Serra de Pirenópolis, state of Goiás, Brazil. Photos: (A) *Myrmecophaga tridactyla*, (B) *Priodontes maximus*, (C) *Chrysocyon brachyurus*, (D) *Leopardus wiedii*, (E) *Herpailurus yagouaroundi*, (F) *Puma concolor*, (G) *Panthera onca*, (H) *Tapirus terrestris*.

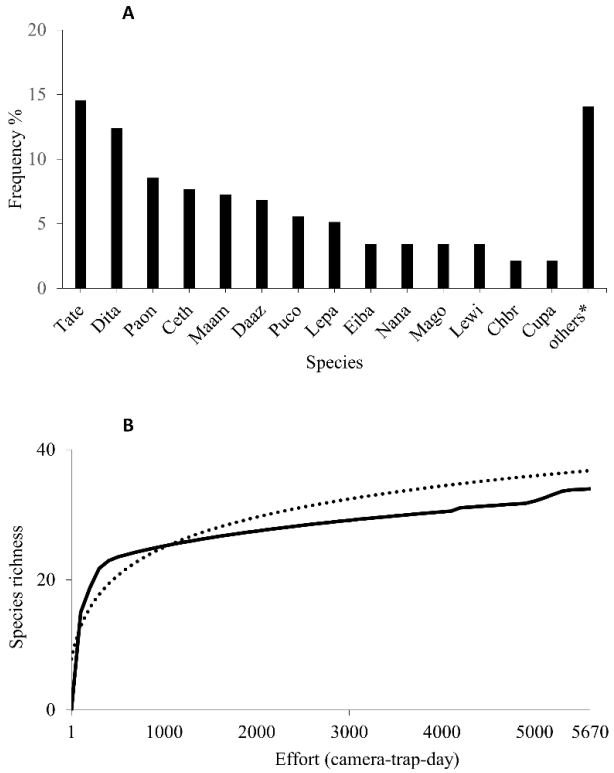

Figura 3. Frequency (%) for species (A), and the observed species accumulation curve (black line) and the estimated species accumulation curve (dotted line) (B) for medium and large-sized mammalian species in the Serra de Pirenópolis, state of Goiás, Brazil. Legend: *Tapirus terrestris* = Tate, *Dicotyles tajacu* = Dita, *Panthera onca* = Paon, *Cerdocyon thous* = Ceth, *Mazama americana* = Maam, *Dasyprocta azarae* = Daaz, *Puma concolor* = Puco, *Leopardus pardalis* = Lepa, *Leopardus wiedii* = Lewi, *Eira barbara* = Eiba, *Nasua nasua* = Nana, *Mazama gouazoubira* = Mago, *Chrysocyon brachyurus* = Chbr, *Cuniculus paca* = Cupa.

reach an asymptote (Figure 3B). The estimated species richness was 36 using the Jackknife-1 method for camera trap data (Figure 3B).

The observed species richness represents 68% of the 47 medium and large-sized mammals known to occur in the state of GO (Hannibal *et al.* 2021) and more than 60% of the species found in the Cerrado ecoregion (Marinho-Filho *et al.* 2002, Paglia *et al.* 2012). Our results showed high species richness in the study area compared to 20 other published inventories from the Cerrado ecoregion in GO (range = 8-33, $\bar{x}$ = 23; see Supplementary Material). Only two studies showed similar species richness: one in the Serra do Falcão Dam (33 species; Gomes *et al.* 2015) and another in Emas National Park (PNE) (33 species; Giozza *et al.* 2017). Among them, only the latter had a sampling effort greater than the current study, with 13,869 camera trap nights.

The greatest number of species and detections came from camera traps located in gallery forests, corroborating studies that demonstrate the importance of forest vegetation for the conservation of the Cerrado biodiversity (Oliveira *et al.* 2019). In addition to acting as biological corridors for faunal movement, gallery forests also constitute environments of climatic and microclimatic stability, high structural complexity and provide shelter, food and water during long periods of drought (Ali 2019, Resasco 2019). Forested areas are of primary concern regarding management and conservation, given the ongoing destruction and degradation of the Cerrado. However, monitoring of open areas of Cerrado *sensu stricto* might lead to the detection of additional species and the accumulation of important additional data.

We obtained photographic records of particularly rare species for the area, including *Cabassous tatouay, Galictis cuja*, and *L. wiedii*, all of which have been recorded fewer than three times in Cerrado areas in the state of GO (Hannibal *et al.* 2021, Calaça *et al.* 2010, Gomes *et al.* 2015). *L. wiedii* is a vulnerable felid (ICMBio 2018) that is rare in the Cerrado (< 0.01 individuals/ Km^2), occurs almost exclusively in gallery forests, and has broadly nocturnal habits (Oliveira *et al.* 2013). There is still little information on the biology, ecology and social characteristics of this species, limiting the development of effective conservation strategies. We also detected *P. maximus* and *Tapirus terrestris,* both of which are threatened species (ICMBio 2018). *P. maximus* is highly sensitive to altered environments (Lemos *et al.* 2020), and is considered rare in the state of GO (Hannibal *et al.* 2021). *Tapirus terrestris* plays important roles in the regeneration of vegetation (Giombini *et al.* 2016) and in the maintenance of carnivore populations, which are the predominant group in the Cerrado (Barbosa *et al.* 2021, Aximoff *et al.* 2022).

The presence of the largest Brazilian carnivore, the endangered *Panthera onca,* which is considered rare in the Cerrado of GO (Hanibal *et al.* 2021), is of great importance in the region. The species is

Table 1. The number of animals recorded of medium and large-sized mammal records in the Serra de Pirenópolis, state of Goiás, Brazil. Method: CT = Camera Trap; DO = Direct Observation. Threat: BR = ICMBio 2018; IUCN = IUCN Red List (2021). Threat categories: - = not listed; VU = Vulnerable; EN = Endangered.

Taxon	Common name	Method		Status	
		CT	DO	BR	IUCN
DIDELPHIMORPHIA					
Didelphidae					
Didelphis albiventris Lund, 1840	Brazilian White-eared Opossum	4		-	-
PILOSA					
Myrmecophagidae					
Tamandua tetradactyla (Linnaeus, 1758)	Southern anteater		x	-	-
Myrmecophaga tridactyla Linnaeus, 1758	Giant anteater	4		VU	VU
CINGULATA					
Chlamyphoridae					
Euphractus sexcinctus (Linnaeus, 1758)	Six-banded Armadillo		x	-	-
Priodontes maximus (Kerr, 1792)	Giant Armadillo	2		VU	VU
Cabassous tatouay (Desmarest, 1804)		2			
Dasypodidae					
Dasypus novemcinctus Linnaeus, 1758	Nine-banded Armadillo	1		-	-
PRIMATES					
Cebidae					
Sapajus libidinosus (Spix, 1823)	Bearded Capuchin	2	x	-	-
Atelidae					
Alouatta caraya (Humboldt, 1812)	Black-and-Gold Howler Monkey	2	x	-	-
Callitrichidae					
Callithrix penicillata (É. Geoffroy, 1812)	Black-tufted marmoset		x	-	-
CARNIVORA					
Canidae					
Cerdocyon thous (Linnaeus, 1766)	Crab-eating Fox	18		-	-
Chrysocyon brachyurus (Illiger, 1815)	Maned Wolf	5		VU	-
Felidae					
Leopardus pardalis (Linnaeus, 1758)	Ocelot	12		-	-
Leopardus wiedii (Schinz, 1821)	Margay	8		VU	-
Herpailurus yagouaroundi (E. Geoffroy Saint-Hilaire, 1803)	Eyra Cat	4		VU	-
Puma concolor (Linnaeus, 1771)	Cougar	13		VU	-
Panthera onca (Linnaeus, 1758)	Jaguar	20		EN*	-
Mustelidae					
Eira barbara (Linnaeus, 1758)	Tayra	8		-	-
Lontra longicaudis (Olfers, 1818)	Neotropical otter	3		-	-
Galictis cuja (Molina, 1782)	Lesser Grison	1		-	-

Table 1: Continues on next page...

Table 1: ...continued

Taxon	Common name	Method		Status	
		CT	DO	BR	IUCN
Procyonidae					
Procyon cancrivorus (G. Cuvier, 1798)	Crab-eating Raccoon	1		-	-
Nasua nasua (Linnaeus, 1766)	South American Coati	8		-	-
Mephitidae					
Conepatus amazonicus (Lichtestein, 1838)	Striped hog-nosed skunk		x	-	-
PERISSODACTYLA					
Tapiridae					
Tapirus terrestris (Linnaeus, 1758)	Tapir	34		VU	VU
ARTIODACTYLA					
Cervidae					
Mazama americana (Erxleben, 1777)	South American Red Brocket	17		-	-
Mazama gouazoubira (G. Fischer, 1814)	South American Brow Brocket	8		-	-
Tayassuidae					
Dicotyles tajacu (Linnaeus, 1758)	Collared Peccary	29		-	-
RODENTIA					
Caviidae					
Hydrochoerus hydrochaeris (Linnaeus, 1766)	Capybara	4		-	-
Cuniculidae					
Cuniculus paca (Linnaeus, 1766)	Spotted Paca	5		-	-
Dasyproctidae					
Dasyprocta azarae Lichtenstein, 1823	Azara's Agouti	16		-	-
Erethizontidae					
Coendou prehensilis (Linnaeus, 1758)	Brazilian Porcupine	2		-	-
LAGOMORPHA					
Leporidae					
Sylvilagus minensis Thomas, 1901	Brazilian Cottontail Rabbit	1		-	EN

experiencing an ongoing decline in Brazil, and has been extirpated from most of its historical range (Morato *et al.* 2013). Subpopulations of this species are decreasing in size and increasing in isolation, leading to a loss of genetic diversity (Srbek-Araujo *et al.* 2018). It is likely that *P. onca* territories in the study area overlap those of individuals in other fragments in Serra dos Pireneus due to their resource requirements and spatial ecology (Rocha *et al.* 2019). However, the discrete, site-specific behavior of this species in the study area is unknown and would be worthy of further study so that appropriate conservation and habitat management actions can be implemented.

Most species identified in this study are impacted by various anthropogenic threats that are recurrent throughout the Cerrado, including habitat loss and fragmentation due to agricultural activities, an increase in livestock in particular, hunting pressure, retaliation due to human-wildlife conflicts, and the presence of exotic species (*e.g.*, Beisiegel 2017, Rocha *et al.* 2019). Livestock can have a substantial ecological and economic impact, mainly for the conversion of native areas into pasture, and for their predation by large felines (Beisiegel *et al.* 2017). Furthermore, according to farm worker reports, hunting, which likely resulted in the local extinction of some species, such as peccary, and the decline of other species, was considered common until a few years ago.

Land use change in proximity to natural areas

has consequences for ecosystems. However, this relationship has rarely been studied (Rocha *et al*. 2018), and the implications of changing land management for Cerrado fragments, such as those described in this study, are unknown. The high species richness and the presence of rare and threatened species observed in the study area reveal the importance of species surveys in these Cerrado fragments. This study enphasizes the need for landscape-scale protection and monitoring, with a particular focus on threatened species. Our results reveal the importance of forest fragments within unprotected areas for the conservation of medium- and large-sized mammals. On a short-term scale, we suggest that the impacts of anthropogenic threats in such areas should be quantified and mitigation actions implemented. On a medium- to long-term scale, we recommend the creation of a municipal protected area covering the studied fragment.

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SUPLEMENTARY MATERIAL

Table S1. Number of medium and large-sized mammal species recorded by study carried out along the Brazilian Cerrado in Goias state.

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