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Article

Survey and monitoring of mammals in the Serra do Tombador Natural Heritage Reserve (RPPN), Goiás, Brazil.

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ABSTRACT

The Boticário Group Foundation for Nature Protection, an organization belonging to the O Boticário cosmetics network, has been active for over three decades in initiatives focused on environmental conservation, managing two Private Natural Heritage Reserves (RPPNs): the Salto Morato Nature Reserve, located in the Atlantic Forest biome, and the Serra do Tombador Nature Reserve (RNST), located in the Cerrado. Both have as their main objective the protection of critical habitats for endangered species and ecosystems of high biodiversity.At the RNST, wildlife monitoring has been carried out since 2012 using camera traps, with records organized in databases and taxonomic identification of species. However, until the present study, this information had not been analyzed from a temporal and spatial perspective. The present study aims to evaluate the data obtained on medium and large mammals between 2012 and 2021, organizing them into three distinct monitoring phases. The analyses indicated variations in relative abundance indices between periods, suggesting the influence of changes in management and objectives established over time in the conservation unit. The results obtained, which include the recording of endangered species in all monitoring phases, reinforce the relevance of well-preserved protected areas, such as the Serra do Tombador Nature Reserve (RNST), for the maintenance of medium and large mammal populations. Furthermore, the study highlights the strategic and complementary role of the private sector in biodiversity conservation in Brazil through the creation and management of RPPNs, contributing significantly to the protection of ecosystems and endangered species.

Keywords: Cerrado; nature conservation; mammals; private natural heritage reserve.

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RESUMO

A Fundação Grupo Boticário de Proteção à Natureza, organização pertencente à rede de cosméticos O Boticário, atua há mais de três décadas em iniciativas voltadas à conservação ambiental, mantendo sob sua gestão duas Reservas Particulares do Patrimônio Natural (RPPNs): a Reserva Natural Salto Morato, localizada no bioma Mata Atlântica, e a Reserva Natural Serra do Tombador (RNST), situada no Cerrado. Ambas têm como principal objetivo a proteção de habitats críticos para espécies ameaçadas e ecossistemas de elevada biodiversidade.Na RNST, o monitoramento da fauna é realizado desde 2012 por meio de armadilhas fotográficas, com registros organizados em bancos de dados e identificação taxonômica das espécies. No entanto, até o presente estudo, tais informações não haviam sido analisadas sob uma perspectiva temporal e espacial. A presente pesquisa tem como objetivo avaliar os dados obtidos de mamíferos de médio e grande porte entre 2012 e 2021, organizando-os em três fases distintas de monitoramento. As análises indicaram variações nos índices de abundância relativa entre os períodos, sugerindo influência das mudanças no manejo e nos objetivos estabelecidos ao longo do tempo na unidade de conservação. Os resultados obtidos, que incluem o registro de espécies ameaçadas de extinção em todas as fases do monitoramento, reforçam a relevância de áreas protegidas bem conservadas, como a Reserva Natural Serra do Tombador (RNST), para a manutenção de populações de mamíferos de médio e grande porte. Ademais, o estudo evidencia o papel estratégico e complementar do setor privado na conservação da biodiversidade no Brasil, por meio da criação e gestão de RPPNs, contribuindo significativamente para a proteção de ecossistemas e espécies ameaçadas.

Palavras-chave: Cerrado; conservação da natureza; mamíferos; reserva particular do patrimônio natural.

Introduction

The Cerrado is Brazil's second largest biome and the most diverse tropical savanna in the world (Eiten, 1994). Given their high levels of biological diversity and habitat destruction, the Cerrado and the Atlantic Forest were considered the two Brazilian biodiversity *hotspots*, being priority areas for conservation (Myers et al. 2000).

Due to the rapid expansion of agriculture and livestock farming, as well as direct pressure from hunting or retaliation, countless animal species in the Cerrado are threatened with extinction (Fundação Biodiversitas 2003; IUCN 2013). However, the lack of basic biological knowledge prevents an adequate assessment of the degree of threat to most species in this biome. About 40-55% of the Cerrado has already been converted into cropland, pastures, and planted forests (Machado et al. 2004; Mantovani & Pereira, 1998; Sano et al. 2009).

Therefore, studies and actions to maintain biota in conservation units (CUs) are essential to maintaining the balance of ecosystems. According to Mattar et al. (2018), the efficient management of these areas is a key factor in promoting biodiversity conservation, and their creation is a viable alternative for mitigating the negative impacts caused by the expansion of agriculture and livestock farming in the region.

One of the categories belonging to sustainable use CUs are Private Natural Heritage Reserves (RPPNs), which are private areas, registered in perpetuity, with the objective of conserving biological diversity (Brazil, 2000). As RPPNs are private conservation units, they partially relieve the government of the burden of investing in the creation of new conservation units. In addition, although they are part of sustainable use conservation units, they have certain restrictions, bringing them closer to integral use conservation units, contributing to conservation without major human intervention (Lima & Franco, 2014).

With the aim of promoting biodiversity preservation, the Boticario Group Foundation for Nature Protection (FGBPN) maintains two Private Nature Protection Reserves in its name: the Salto Morato Reserve, located in Paraná, belonging to the Atlantic Forest biome, and the Serra do Tombador Nature Reserve (RNST), in Cavalcante-GO, located in the Cerrado biome.

Given that half of this biome has already been converted to various land uses, and that only 8.38% is protected by conservation units (MMA, 2021), the production of reliable information on which areas to protect is a factor of great importance in ensuring the effective preservation of the habitats necessary for the survival of species. However, with the exception of a few assessments, little is known about the effect of habitat protection in the Cerrado (Ferreira et al. 2020).

Information on abundance and distribution is an important tool for assessing the conservation status of a taxon (IUCN, 2012). Since 2012, RNST has been surveying and monitoring species using camera traps. By

providing knowledge about local biodiversity—the relative richness and abundance of species—camera traps can reveal the degree of conservation and guide actions to maintain or improve protection of the area.

The use of cameras to monitor species is particularly useful for those that use large areas of land and are rare or difficult to observe (O'Brien, 2011), especially medium and large mammals (Ahumada et al. 2011; Rovero et al. 2010). In addition, they constitute a non-invasive sampling method that allows for the collection of additional information, such as that related to animal behavior (Kays et al. 2009). In general, smaller mammals have less mobility and require less habitat when compared to larger mammals (Rocha et al. 2018).

Medium and large mammals can be considered indicators of environmental quality because, in addition to needing extensive natural areas for reproduction and refuge, they play an important role in ecological cycles (Fragoso & Huffman, 2000; Galetti et al. 2001; Rocha et al. 2004; Rovero et al. 2010). The Cerrado is home to about 194 species of mammals, organized into 30 families and nine taxonomic orders, making it the third richest biome for this group, with 22 endemic species. However, although most species have a wide distribution, a large proportion tend to be locally rare (Marinho-Filho et al. 2002; Gutiérrez & Marinho-Filho, 2017).

Knowledge of mammalian biology has highlighted the importance of species in this taxon in a number of processes in forest ecosystems. Frugivorous and/or herbivorous species appear to play an important role in seed dispersal and seedling predation, while carnivores control these populations (Pardini et al. 2006). The local extinction of top predators and their low density appear to contribute to an increase in the density of medium-sized species with generalist habits, which can cause extreme changes in small vertebrate communities (Fonseca & Robinson, 1990; Terborgh et al. 1990; Crooks & Soulé, 1999).

Due to the ecological importance of mammals, there is a need for more information and knowledge about the diversity and abundance of these species at the local level. These data are important for assessing the conservation status of the taxon (IUCN, 2009).

Thus, estimates of density or abundance indices can be used to monitor population trends. In this way, it is possible to assess the establishment, decline, or increase, as well as the rate of change in populations between years. However, the ability to detect these variations is always associated with some degree of uncertainty (Tomas & Miranda, 2003).

According to Lindenmayer & Likens (2018), monitoring can be divided into three types. The first is called passive or curiosity-driven monitoring. In this type, there are no specific questions to be answered or hypotheses, it is simply driven by curiosity, and its usefulness is limited in terms of environmental approaches. The second type is classified as mandatory, in which environmental data is collected as a requirement of government regulations or policy guidelines, focusing on identifying possible trends in occurrences. Finally, the third type of monitoring, according to the authors, is question-based. This is guided by a rigorous experimental process, in which prospective trend scenarios can be calculated and modeled. This approach can lead to predictive capabilities, allowing researchers to ask new questions, similar to adaptive monitoring, which can be of great value to ecologists, resource managers, and decision-makers.

This study focused on the analysis of data on medium and large mammals, given that some are considered key species in conservation strategies because, even though they are not as abundant, as is the case with top predators, their removal tends to destabilize ecosystems, causing habitat loss and species elimination. These species are also called "umbrella" species because by protecting sufficient habitat for their survival, several other species are automatically protected (Soulé & Noss, 1998).

Monitoring these animals is essential for understanding the composition patterns of biological communities and the changes caused by human impact. The information obtained therefore contributes to decision-making on species management and monitoring of natural habitats and protected areas (Pezzuti et al., 2022; Ponce-Martins et al., 2022).

Materials and Methods

Study area

The survey and monitoring of mammal species using camera traps was carried out in the RNST, located in the municipality of Cavalcante, Goiás (Figure 1). The reserve covers a total of 8,730 ha and is part of the Paranã-Pireneus Ecological Corridor in northeastern Goiás, which has been declared strategic for the conservation of the Cerrado biome (Fundação Grupo Boticário, 2011).

The creation of the RNST was officially published in ICMBio Ordinance No. 26, dated May 8, 2009, and according to the 2011 Management Plan, the area constitutes an important action for the conservation of the Cerrado, given the local biodiversity and proximity to the Chapada dos Veadeiros National Park (PNCV), recognized by UNESCO as a World Natural Heritage Site.

These and other conservation units are located within the Pouso Alto Environmental Protection Area (APA), created by Decree 5,419 of May 7, 2001, with a total area of 872,000 ha.

The Pouso Alto APA is considered to be of high ecological importance and is a priority for biodiversity conservation. It covers the municipalities of Cavalcante, Alto Paraíso, Colinas do Sul, Teresina de Goiás, Nova Roma, and São João D'Aliança, in the northeastern region of the state of Goiás. It encompasses a mosaic of conservation units, constituting the most preserved continuous area of the Cerrado in Goiás (SECIMA, 2016).

The RNST belongs to the group of conservation units for sustainable use and aims to conserve biodiversity, allowing scientific research and visits for tourism, recreation, and educational purposes, in accordance with Law 9.985 of July 18, 2000, which established the National System of Conservation Units (SNUC).

To date, public visitation is not permitted in the reserve. Factors such as difficulty in accessing the site, poor transportation, and lack of regional infrastructure contribute to the non-implementation of public use activities. However, in the medium and long term, the FGBPN intends to resolve these difficulties and implement visitation.

For now, the RNST structure only allows guests, consultants, FGBPN collaborators, and researchers to visit. There are also plans to build the Cerrado Conservation Center (CCC), a facility that will provide a research laboratory, library, event space, and accommodation for visitors and researchers (Fundação Grupo Boticário, 2011).

Data collection

The data for this study were obtained using Bushnell Trophy Cam HD 8 Mp and Bushnell Trophy Cam HD Essential E3 camera traps, installed at different points in the RNST between 2012 and 2021 (Figure 2).

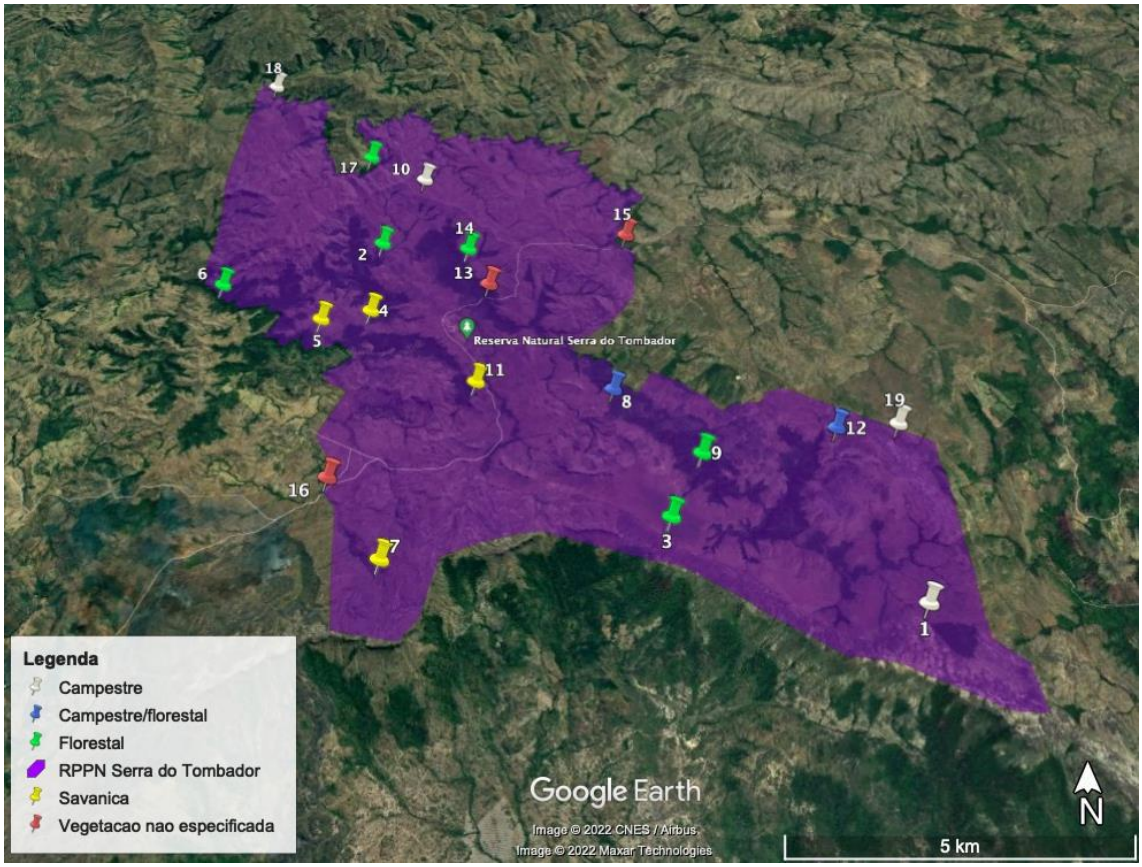

Figure 1. Location of camera traps in the Serra do Tombador RPPN from 2012 to 2021, and the types of vegetation indicated at each location. Source: Google Earth

In 2016, the FGBPN described the Protocol for monitoring medium and large mammals for biodiversity monitoring in the Salto Morato and Serra do Tombador Nature Reserves, with the aim of generating and organizing access to information on the biodiversity of these RPPNs. According to the document, traps were set up to cover the entire area of the reserves, with a sampling design of 2 to 4 km between them. To this end, the locations were chosen with the aid of a geographic information system, based on spatial data on the boundaries of the reserve and vegetation cover. The document suggests that the cameras remain in place for at least three years at each location, with the aim of obtaining long-term results for comparison.

In the RNST, the cameras were set up to capture 10-second videos at 5-second intervals. The designated field teams were responsible for installing the cameras and compiling the raw data into spreadsheets, which were later made available to us (FGBPN, 2016). A qualified person was responsible for supervising all the work, from organizing the equipment to compiling the data. The field teams consisted of two people, with at least one trained in installing and configuring the cameras in the field. Also according to the FGBPN Protocol (2016), the people responsible for compiling the data must be familiar with species identification and know how to distinguish between them.

The data spreadsheets we had access to contained the dates and times of the records, the names of the locations where the cameras were installed, and the names of the species identified. From 2012 to 2021, camera traps were installed at twenty-five different locations. However, we obtained geographic coordinates for only nineteen locations (Table 1).

Table 1. Geographic coordinates of camera traps in Serra do Tombador and the types of vegetation characterized, from 2012 to 2021. Datum: WGS84.

Camera traps	Coordinates		Vegetation
	Latitude	Longitude	
1	-13.702462	-47.758112	Countryside
2	-13.635384	-47.84425	Forest
3	-13.688837	-47.794825	Forest
4	-13.650021	-47.844949	Savanna
5	-13.651541	-47.853463	Savanna
6	-13.643504	-47.872205	Forest
7	-13.695598	-47.838791	Savanna
8	-13.666272	-47.803202	Rural/Forest
9	-13.677856	-47.7893	Forest
10	-13.621555	-47.837428	Rural
11	-13.664642	-47.825929	Savânica
12	-13.674173	-47.767789	Rural/Forest
13	-13.644719	-47.824547	Not specified
14	-13.637062	-47.828594	Forest
15	-13.634816	-47.800228	Not specified
16	-13.681571	-47.848613	Not specified
17	-13.615218	-47.848187	Forest
18	-13.595158	-47.86963	Rural
19	-13.673378	-47.757731	Campestre

Source: Prepared by the author

Data analysis

Initially, a survey was conducted of the recorded mammal species, totaling 35 different species throughout the period, divided into eight taxonomic orders. Despite the identification of all recorded species by the RNST team, we focused on the analysis of medium and large mammals. Given the degree of threat and ecological importance of medium and large mammals, it is highly relevant to obtain information on this group for environmental diagnostics (Pardini et al., 2006).

We used the average weights of the species described by Paglia et al. (2012) and considered species with a body weight between 5 and 20 kg to be medium-sized and species weighing over 20 kg to be large. Based on the results related to relative abundance indices, we analyzed population dynamics throughout the monitoring period in order to understand the temporal and spatial variation in the size of a population of one or more species (Begon et al., 1990).

According to Tomas and Miranda (2003), density or abundance indices using cameras can be expressed in relation to the number of nights of exposure, number of cameras, detections per hour/camera or per day/camera, and if detections are rare, the number of records per week or a longer period can also be used. Given the wide variation in body size, lifestyle, and habitat preferences among mammals (Pardini, et al., 2006), we opted to use a 24-hour interval as an independent record for each species.

According to the types of monitoring proposed by Lindenmayer & Likens (2018), we divided the RNST monitoring data from 2012 to 2021 into three phases, according to the evolution of the applied methodology

observed. Thus, we considered the first period from 2012 to 2015, the second from 2016 to 2018, and the third from 2019 to 2021.

Based on the survey of recorded species, the occurrence of each species throughout the monitoring period was verified, in addition to the threat status and the presence of exotic or domestic species.

To observe the population structure, the relative abundance index (RAI) was calculated (n*[100/N], where "n" is the number of independent records for each species and "N" is the total number of records. The index was calculated only for species with more than five records.

Results

With regard to monitoring types, from 2012 to 2015, camera traps were placed at arbitrary points, in very different numbers, with 3, 5, 6, and 10 cameras for each year, respectively. In addition, some geographic coordinates related to the trapping points for this period were not made available, which corroborates monitoring driven by curiosity, without a specific method being applied.

From 2016 to 2018, there was greater similarity in relation to the trapping points and the number of cameras, with 9, 8, and 7 each year, thus enabling the grouping of data for this period. The FGBPN monitoring protocol, initiated in 2016, established a methodological plan and defined criteria for camera installation, data collection, and compilation, and is considered a transition period between the first and third periods.

In 2019, a partnership agreement was signed between the FGBPN and the PCMCV, involving the exchange of information and site visits, in order to apply a scientific methodology that would enable a more assertive analysis of the data. Thus, the third period analyzed grouped the data set from 2019 to 2021, with 13, 17, and 15 traps for each year, respectively. The geographic coordinates of the trapping points common to all periods are shown in Table 1.

For the species found during the analysis period, we first listed the presence of medium and large mammal species identified in the Serra do Tombador Nature Reserve, based on monitoring using camera traps from 2012 to 2021 (Table 2). The threat status for each species was also described, according to the Red List of Threatened Species (IUCN, 2016) and the ICMBio Red Book of Brazilian Fauna Threatened with Extinction (2018). In the list presented, the species were grouped according to the taxonomic orders and families described in the literature.

As with the number of camera traps, the number of mammal species recorded also varied across all years of monitoring (Figure 3).

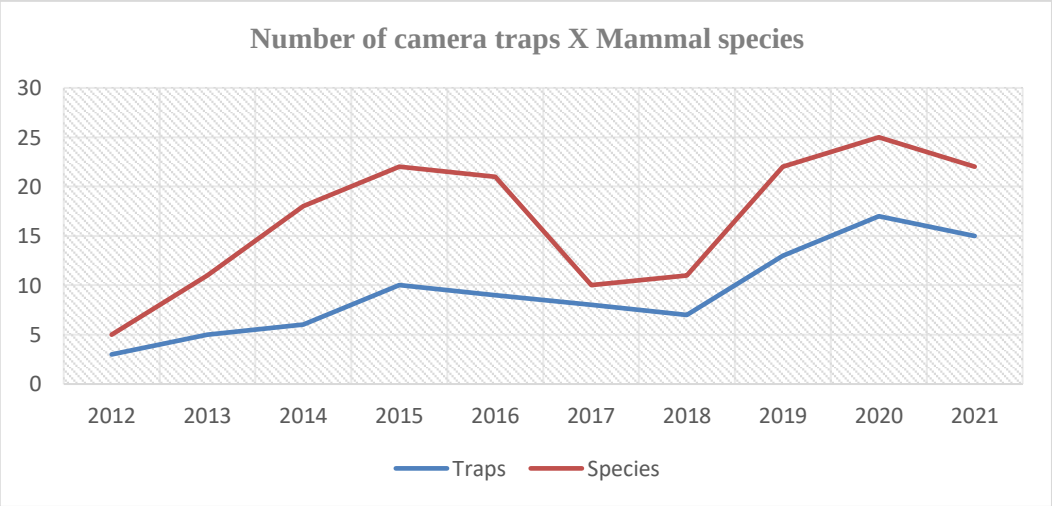

Figure 2. Number of camera traps and mammal species recorded during the entire monitoring period in the RNST. Source: Prepared by the author

Table 2 . Presence of medium and large mammal species in the RNST from 2012 to 2021, based on camera trap records, and threat status according to the IUCN Red List (2016) and the ICMBio Red Book (2018). Abbreviations: LC – least concern, NT – near threatened, VU – vulnerable, and EN – endangered

Taxon	Common name	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Status (IUCN)	Status (MMA)
Order ARTIODACTYLA													
Family Bovidae													
Bos taurus	Ox		X	X	X	X							
Family Tayassuidae													
Pecari tajacu (Linnaeus, 1758)	Collared peccary			X		X	X	X	X	X	X	LC	LC
Family Suidae													
Sus domesticus	Domestic pig		X			X							
Order CARNIVORA													
Family Canidae													
Canis lupus familiaris	Domestic dog	X	X	X	X	X	X		X				
Cerdocyon Thous (Linnaeus, 1766)	Feral dog	X	X	X	X	X	X		X	X	X	LC	LC
Chrysocyon brachyurus (Illiger, 1815)	Maned wolf		X	X	X	X	X	X	X	X	X	NT	VU
Lycalopex vetulus (Lund, 1842)	Pampas Fox									X	X	LC	VU
Speothos venaticus (Lund, 1842)	Vulture									X		NT	VU
Family Felidae													
Herpailurus yagouaroundi (É. Geoffroy, 1803)	Jaguarundi Musk cat			X	X		X	X		X	X	LC	VU
Puma concolor (Linnaeus, 1771)	Cougar			X	X	X	X		X	X	X	LC	VU

Panthera onca (Linnaeus, 1771)	Jaguar		X	X	X	X	X		X	X	X	NT	VU
Leopardus pardalis (Linnaeus, 1758)	Ocelot			X	X	X	X	X	X	X	X	LC	LC
Leopardus cf.tigrinus (Schreber, 1775)	Wildcat				X					X			
Family Mephitidae													
Conepatus semistriatus (Boddaert, 1785)	Jaritataca			X						X		LC	LC
Mustelidae family													
Eira barbara (Linnaeus, 1758)	Irara		X			X	X			X	X	LC	LC
Family Procyonidae													
Nasua nasua (Linnaeus, 1766)	Yellow-tailed coati				X	X	X					LC	LC
Order CETARTIODACTYLA													
Family Cervidae													
Mazama sp.	Deer	X	X	X	X	X	X	X	X	X	X	LC	LC
Ozotoceros bezoarticus	Pampas deer								X			NT	VU
Order CINGULATA													
Family Dasypodidae													
Dasypus novemcinctus (Linnaeus, 1758)	Nine-banded armadillo			X				X	X		X	LC	LC
Priodontes maximus (Kerr, 1792)	Giant armadillo			X	X		X		X	X		VU	VU
Family Chlamyphoridae													
Cabassous tatouay (Desmarest, 1804)	Soft-tailed armadillo						X		X			LC	LC

Philander opossum (Linnaeus, 1758)	Tatu-peba											LC	LC
Order PERISSODACTYLA Family Equidae													
Equus caballus (Linnaeus, 1758)	Horse	X	X	X	X	X							
Tapiridae family													
Tapirus terrestris (Linnaeus, 1758)	Tapir		X	X	X	X	X	X	X	X	X	VU	VU
Family Cuniculidae													
Cuniculus paca (Linnaeus, 1766)	Paca		X	X	X	X	X	X	X	X	X	LC	LC
Order PILOSA													
Family Myrmecophagidae													
Myrmecophaga tridactyla (Linnaeus, 1758)	Giant anteater			X	X	X	X	X	X	X	X	VU	VU
Tamandua tetradactyla (Linnaeus, 1758)	Southern tamandua				X							LC	LC
Order RODENTIA *Family Caviidae*													
Hydrochoerus hydrochaeris (Linnaeus, 1766)	Capybara				X							LC	LC

Source: Prepared by the author

Of the eight taxonomic orders identified throughout the monitoring period in the RNST, Carnivora had the highest number of species, thirteen in total, belonging to five families, namely - Family Canidae: domestic dog (*Canis lupus familiaris)*, bush dog (*Cerdocyon thousand)*, maned wolf (*Chrysocyon brachyurus)*, pampas fox (*Lycalopex vetulus)*, bush dog (*Speothos venaticus)*; Felidae family: jaguarundi (*Herpailurus yagouaroundi)*, cougar (*Puma concolor)*, jaguar (*Panthera onca)*, ocelot (*Leopardus pardalis)*, margay (*Leopardus cf.tigrinus)*; Mephitidae family: jaritataca (*Conepatus semistriatus)*; Mustelidae family: irara (*Eira barbara)*; and Procyonidae family: quati (*Nasua nasua)*. Of these, seven species are threatened with extinction (IUCN, 2016; ICMBio, 2018).

Based on the analysis of the data, considering all orders of large and medium-sized mammals, eleven endangered species were confirmed. Of these, three were only recorded in the third monitoring phase: the pampas deer (*Ozotoceros bezoarticus)*, the bush dog (*Speothos venaticus)*, and the pampas fox (*Lycalopex vetulus)* (Table 3).

Table 3 . Presence of endangered species in the Serra do Tombador RPPN during different monitoring periods and threat status according to the IUCN Red List (2016) and the ICMBio Red Book (2018). Abbreviations: LC – least concern, NT – near threatened, VU – vulnerable, and EN – endangered.

Taxon	Common	2012 to	2016 to	2019 to	Threat status	Threat status
Order CARNIVORA						
Family Canidae						
Chrysocyon brachyurus (Illiger, 1815)	Maned wolf	X	X	X	NT	VU
Lycalopex vetulus (Lund, 1842)	Pampas Fox			X	LC	VU
Speothos venaticus (Lund, 1842)	Vulture dog			X	NT	VU
Family Felidae						
Herpailurus yagouaroundi (É. Geoffroy,	Jaguarundi/	X	X	X	LC	VU
Puma concolor (Linnaeus, 1771)	Cougar	X	X	X	LC	VU
Panthera onca (Linnaeus, 1771)	Jaguar	X	X	X	NT	VU
Leopardus cf. tigrinus (Schreber, 1775)	Wildcat	X		X	VU	EN
Order CETARTIODACTYLA						
Family Cervidae						
Ozotoceros bezoarticus (Linnaeus, 1758)	Pampas deer			X	NT	VU
Order CINGULATA						
Family Dasypodidae						
Priodontes maximus (Kerr, 1792*)*	Giant armadillo	X	X	X	VU	VU
Order PERISSODACTYLA						
Family Tapiridae						
Tapirus terrestris (Linnaeus, 1758)	Tapir	X	X	X	VU	VU
Order PILOSA						
Family Myrmecophagidae						
Myrmecophaga tridactyla (Linnaeus,	Giant anteater	X	X	X	VU	VU

Source: Prepared by the author

As the number of exotic species decreased during monitoring in the RNST, we compared their presence with that of some native species. Due to the fact that the number of independent records in our study was low (n<5) for the three-banded armadillo, we did not include this species in our comparative study (Figure 4).

Given the difficulty in identifying the species *Mazama americana* (Erxleben, 1777) and *Mazama gouazoubira* (G. Fischer, 1814), we chose to group them as Mazama sp.

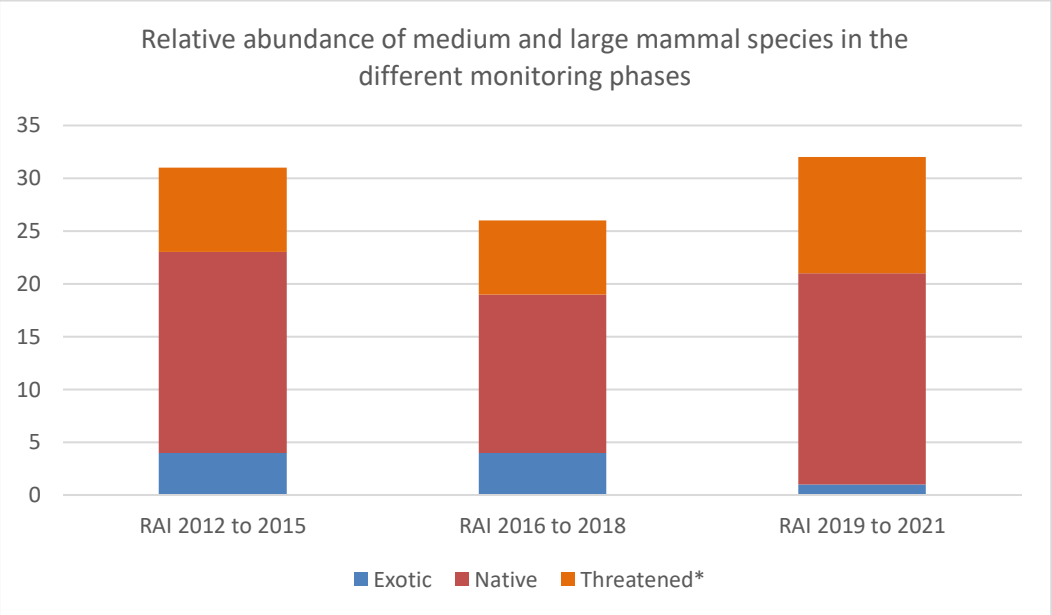

Figure 3 . Relative abundance index RAI (n*(100/N) of exotic species (*Bos taurus*, *Sus domesticus*, *Canis l. familiaris*, and *Equus caballus*), native species ( ), and threatened species* (among native species). Source: Prepared by the author

The population structure during monitoring was observed based on the calculation of the relative abundance index for species with more than 5 records (n > 5) out of the total number of records for each of the three monitoring phases (Table 5).

Table 4 . Relative abundance index RAI (n*(100/N) for species with more than 5 records (n>5) for each sampling period.

Taxon	Common name	RAI 2012 to 2015	RAI 2016 to 2018	RAI 2019 to 2021
Order ARTIODACTYLA				
Family Bovidae				
Bos taurus	Ox	2.61	-	-
Tayassuidae family				
Pecari tajacu (Linnaeus, 1758)	Collared peccary	-	1.36	9.11
Family Suidae				
Sus domesticus	Domestic pig	-	2.21	-
Order CARNIVORA				
Family Canidae				
Canis lupus familiaris	Domestic dog	5.10	2.55	-
Cerdocyon Thous (Linnaeus, 1766)	Wild dog	15.05	-	2.88
Chrysocyon brachyurus (Illiger, 1815)	Maned wolf	17.27	1.36	2.79
Family Felidae				
Herpailurus yagouaroundi (É. Geoffroy, 1803)	Jaguarundi/ Musk cat	0.91	-	-
Puma concolor (Linnaeus, 1771)	Cougar	3.14	4.25	1.39
Panthera onca (Linnaeus, 1771)	Jaguar			0.93
Leopardus pardalis (Linnaeus, 1758)	Ocelot	4.84	1.36	2.51
Mustelidae family				
Eira barbara (Linnaeus, 1758)	Irara	-	-	0.55
Procyonidae family				
Nasua nasua (Linnaeus, 1766)	Coati	-	-	2.79
Order CETARTIODACTYLA				
Family Cervidae				
Mazama sp.	Deer	6.80	14.96	11.44
Order CINGULATA				
Family Dasypodidae				
Dasypus novemcinctus (Linnaeus, 1758)	Nine-banded armadillo	-	-	0.93
Order PERISSODACTYLA				
Family Equidae				
Equus caballus (Linnaeus, 1758)	Horse	6.67	1.19	-
Tapiridae family				
Tapirus terrestris (Linnaeus, 1758)	Tapir	2.61	12.92	10.41
Family Cuniculidae				
Cuniculus paca (Linnaeus, 1766)	Paca	3.66	10.54	6.04
Order PILOSA				
Family Myrmecophagidae				
Myrmecophaga tridactyla (Linnaeus, 1758)	Giant anteater	-	2.72	3.25
Order RODENTIA				
Family Caviidae				
Hydrochoerus hydrochaeris (Linnaeus, 1766)	Capybara	1.04	-	-

Source: Prepared by the author

Discussion

The distinct population structures recorded in the Serra do Tombador Nature Reserve (RNST) during the three monitoring phases (2012–2015, 2016–2018, and 2019–2021) can be attributed to variations in the management of the Private Natural Heritage Reserve (RPPN), as well as changes in data collection methods between the periods analyzed. However, such variations may also reflect natural ecological processes. Changes in population sizes over time in a given area may occur as a result of species birth, mortality, emigration, and immigration rates (Turchin, 1998).

Although the data for the period from 2012 to 2015 were collected in a more exploratory manner or motivated by an initial interest in local biodiversity, the records obtained during this interval reveal the occurrence of relevant species, including large mammals and endangered species. These findings reinforce the importance of continuing monitoring efforts, even if in early or less structured stages, as a way to support effective conservation and management strategies.

Since 2017, there has been a significant reduction in domestic dogs (Canis lupus familiaris), as well as other exotic species, which can be explained by the FGBPN Protocol (2016), when the management of the RNST began to take better care and greater concern with the presence of these species in the area.

Although some species have notable ecological requirements, they can persist even in fragmented environments, as they adapt to the food supply available in places that have suffered anthropogenic pressures (Juarez & Marinho-Filho, 2002). However, despite persisting in these anthropized environments, they are threatened by the presence of domestic animals (Bagatini, 2006).

Except for 2018, there were records of jaguars (*Panthera onca*) in all years, with the highest number in 2021. They were found in all types of vegetation characterized in the RNST: forest, grassland, and savanna.

The pampas fox (*Lycalopex vetulus*), with records in 2020 and 2021, was present in grassland and forest vegetation. The bush dog, with a single record in 2020, occurred in forest vegetation. The location of its record had a camera installed only in 2020, which may explain why it was only recorded in the third monitoring phase.

This study identified 24 native species of medium and large mammals, contrasting with only 14 in Cabral et al. (2017), for the same RPPN, with monitoring carried out from April to June 2012. This difference may be related to the difference in monitoring time, which reinforces the importance of doing so in the long term. However, both studies recorded a higher number of species for the order Carnivora, with 13 and 9, respectively.

Final considerations

The analysis of the data obtained highlights the importance of effective management in conservation units, especially with regard to the control of exotic species, whose presence can compromise the free movement and ecological balance of native species. The variations in the records throughout the different monitoring phases indicate that more rigorous management actions can have a positive impact on the results obtained.

The significant diversity of species recorded in the Serra do Tombador Nature Reserve (RNST), including endangered specimens, highlights the importance of the private sector's role in biodiversity conservation actions. The maintenance of the reserve by the Boticário Group Foundation for Nature Protection (FGBPN) shows how private initiatives can play a complementary and essential role in environmental conservation in Brazil.

Considering the strategic location of the RNST, close to other conservation units, the results obtained indicate the importance of a network of well-maintained protected areas for the maintenance of medium and large mammal populations. Although more in-depth analysis of the data collected is necessary, the evidence points to the effectiveness of proper management of these areas in preserving local biodiversity. Additionally, the study highlights the fundamental role of partnerships between non-governmental organizations and higher

education institutions, which prove to be valuable strategies for strengthening and expanding nature conservation efforts, promoting an integrated approach between science, management, and civil society.

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References

Ahumada JA, Silva CEF, Gajapersad K, Hallam C, Hurtado J, Martim E, McWilliam A, Mugerwa B, O'Brien T, Rovero F, Sheil D, Spironello WR, Winarni N, Andelman SJ 2011. Community structure and diversity of tropical forest mammals: data from a global camera trap network. *Philosophical Transactions of the Royal Society* B 366: 2703–2711.

Begon M, Harper JL, Townsend CR 1990. *Ecology: Individuals, populations, and communities.* Blackwell Scientific Publications, Boston MA, 1068 pp.

Brazil 2000. Law No. 9,985, of July 18, 2000. Regulates Article 225, §1, items I, II, III, and VII of the Federal Constitution, establishes the National System of Nature Conservation Units, and provides other measures.

Cabral R, Zanin M, Porfírio G, Brito D 2017. Medium-sized to large mammals of Serra do Tombador, Cerrado of Brazil. *Check list* 13 (3): 1-6.

Crooks KR, Soulé ME 1999. Mesopredator release and avifaunal extinction in fragmental system. *Nature* 400: 563-566.

Eiten G 1994. Vegetation of the Cerrado. In: MN Pinto -. *Cerrado: Characterization, Occupation, and Perspectives.* University of Brasília Press, Brasília, pp. 17-73.

Ferreira GB, Collen B, Newbold T, Oliveira MJR, Pinheiro MS, Pinho FF, Rowcliffe M, Carbone C 2020. Strict protected areas are essential for the conservation of larger and threatened mammals in a priority region of the Brazilian Cerrado. *Biological Conservation* 251: 108762.

Fonseca GAB, Robinson JG 1990. Forest size and structure: competitive and predatory effects on small mammal communities. *Biological* Conservation53: 265-294.

Fragoso JMV, Huffman JM 2000. Seed-dispersal and seedling recruitment patterns by the last Neotropical megafaunal element in Amazonia, the tapir. *Journal of Tropical Ecology* 16(3):369–385.

Boticário Group Foundation for Nature Protection 2011. *Management Plan for the Serra do Tombador Nature Reserve, Cavalcante - Goiás.* Curitiba.

Boticário Group Foundation for Nature Protection 2016. *Monitoring Protocol for Medium and Large Mammals: Description of the methodology for monitoring biodiversity in the Salto Morato and Serra do Tombador Nature Reserves*. Curitiba.

Galetti M, Keuroghlian A, Hanada L, Morato MI 2001. Frugivory and seed dispersal by the lowland tapir (*Tapirus terrestris*) in Southeast Brazil. *Biotropica*, 33(4): 723-726.

International Union for Conservation of Nature (IUCN) 2012. IUCN *Red list categories and criteria.* Version 3.1, second edition, Gland, Switzerland and Cambridge, UK, 32 pp.

Kays R, Kranstauber B, Jansen P, Carbone C, Rowcliffe M, Fountain T, Tilak S 2009. Camera traps as sensor networks for monitoring animal communities. In: *The 4th IEEE International Workshop on Practical Issues in Building Sensor Network Applications*, Zürich, Switzerland, p. 811-818.

Lima PCA, Franco JLA 2014. RPPNs as a strategy for biodiversity conservation: The case of Chapada dos Veadeiros. *Soc. & Nat.* 26 (1): 113-125.

Lindenmayer D, Likens G 2018. *Effective Ecological Monitoring***.** Second edition. Csiro Publishing, Australia, 225 pp.

Machado RB, Neto MBR, Pereira PGP, Caldas EF, Gonçalves DA, Santos NS, Tabor K, Steininger M 2004. *Estimates of loss of Brazilian Cerrado area*. Unpublished technical report. Conservation International, Brasília, DF, 25 pp.

Mantovani JE, Pereira LA 1998. Estimation of the integrity of Cerrado vegetation cover using TM/Landstat data. In: *IX Brazilian Symposium on Remote Sensing, INPE*. p. 1455-1466.

Marinho-Filho J, Rodrigues FHG, Juarez KM 2002. The Cerrado Mammals: Diversity, Ecology and Natural History. In: PS Oliveira -, RJ Marquis. *The Cerrados of Brazil,* Columbia University Press, New York, pp. 266-284.

Mattar EPL, Barros TTV, Cunha BB, Souza JF, Silva AMC 2018. Federal Conservation Units in Brazil: The Situation of Biomes and Regions. *Floresta e Ambiente*. 25 (2). https://doi.org/10.1590/2179-8087.005115

MMA. Ministry of the Environment, 2021. Brazilian Conservation Units Panel. Available at: <https://app.powerbi.com/view?r=eyJrIjoiMGNmMGY3NGMtNWZlOC00ZmRmLWExZWItNTNiNDhkZDg0MmY4IiwidCI6IjM5NTdhMzY3LTZkMzgtNGMxZi1hNGJhLTMzZThmM2M1NTBlNyJ9&pageName=ReportSectione0a112a2a9e0cf52a827> Accessed on: May 2, 2022.

Myers N 1988. Threatened Biotas: "Hot Spots" in Tropical Forests. *The Environmentalist* 8 (3): 187-208.

Myers N, Mittermeier RA, Mittermeier CG, Fonseca GAB, Kent J 2000. Biodiversity hotspots for conservation priorities. *Nature* 403: 853–858. https://doi.org/10.1038/35002501.

O'Brien TG 2011. Abundance, Density and Relative Abundance: A Conceptual Framework. In: AF O'Connell, JD Nichols, KU Karanth. *Camera Traps in Animal Ecology – Methods and Analyses*. Ed. Springer, p. 71-96.

Paglia AP, Fonseca GAB, Rylands AB, Herrmann G, Aguiar LMS, Chiarello AG, Leite YLR, Costa LP, Siciliano MCMK, Mendes SL, Tavares VC, Mittermeier RA, Patton JL 2012. *Annotated list of mammals of Brazil*. Conservation International. 2nd Edition. Occasional Papers in Conservation Biology, 6, Arlington, 76 pp.

Available at: https://www.conservation.org/docs/default-source/brasil/annotated_checklist_of_brazilian_mammals_2nd_edition.pdf

Pardini R, Ditt EH, Cullen Jr. L, Bassi C, Rudran, R 2006. Rapid survey of medium and large terrestrial mammals. In: L Cullen Jr., R Rudran, C Valladares-Pádua. *Methods of study in conservation biology and wildlife management.* Ed. Federal University of Paraná, Curitiba, pp. 181-201.

Pezzuti JCB, Oliveira T, Pantoja-Lima J, Rebêlo GH, Félix-Silva D 2022. Temporal and spatial stability on the population structure of consumed and illegally traded big-headed Amazon River Turtle in the Negro River Basin, Central Amazon, Brazil. *Front. Ecol. Evol.* 10 (308). https://doi.org/10.3389/fevo.2022.640961

Ponce-Martins M, Lopes CKM, Carvalho-Jr EAR, Castro FMR, Paula MJ, Pezzuti JCB 2022. Assessing the contribution of local experts in monitoring Neotropical vertebrates with camera traps, linear transects and track and sign surveys in the Amazon. *Perspectives in Ecology and Conservation* 20: 303–313.

Rocha EC, Brito D, Silva PM, Silva J, Bernardo PVS, Juen L 2018. Effects of habitat fragmentation on the persistence of medium and large mammal species in the Brazilian Savanna of Goiás State. *Biota Neotropica* 18(3). https://doi.org/10.1590/1676-0611-BN-2017-0483

Rovero F, Tobler M, Sanderson J 2010. Camera trapping for inventorying terrestrial vertebrates. In: J Eymann J Degreef, C Hauser, JC Monje, Y Samyn, D VandenSpiegel. *Manual on field recording techniques and protocols for All Taxa Biodiversity Inventories and Monitoring.* Ed. Belgian Development Cooperation, p. 100-128.

Sano EE, Rosa R, Brito JLS, Ferreira LG 2009. Land cover mapping of the tropical savanna region in Brazil. *Environmental Monitoring Assessment* 166: 113–124.

Soulé ME, Noss R 2014. Rewilding and Biodiversity: Complementary Goals for Continental Conservation. In: ME Soulé , RL Peters 1998. *Collected Papers of Michael E. Soulé - Early Years in Modern Conservation Biology*, Island Press, Washington, pp. 233-254.

Tomas WM, Miranda GHB 2003. Use of camera traps in population surveys. In: L Cullen Jr. , R Rudran, C Valladeres-Padua. *Methods of Study in Conservation Biology and Wildlife Management.* Ed. Federal University of Paraná, Curitiba, p. 243-267.