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MEDIUM- AND LARGE-SIZED MAMMALS IN A PROTECTED AREA OF ATLANTIC FOREST IN THE NORTHEAST OF BRAZIL

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Abstract: This is the first survey of medium- and large-sized mammals for the Private Reserve of Natural Heritage Complex (RPPN) Serra Bonita, in southern Bahia, Brazil. RPPN Serra Bonita is one of the largest private reserves in the Central Corridor of the Atlantic Forest. This study aims to fill a knowledge gap in this area by describing the medium- and large-sized mammals species richness observed in the RPPN Serra Bonita. We installed 19 camera traps for two consecutive years, from November 2010 to November 2012 (sample effort 13.870 camera-days). In addition, some species were recorded using tracks and/or direct observations in the field. We recorded 22 species, including endemic and threatened species, distributed in seven orders: Cetartiodactyla, Carnivora, Cingulata, Lagomorpha, Pilosa, Primates and Rodentia. The crab-eating fox, *Cerdocyon thous,* was the most recorded species. We also recorded some threatened species, like *Leopardus guttulus* (VU) and *Sapajus xanthosternos* (CR). Species richness at RPPN Serra Bonita was higher than that found in other studies conducted in the Atlantic Forest of southern Bahia. The Clench model had a good fit with 96% of the expected mammals recorded in the reserve. This suggests that RPPN Serra Bonita protects a high species richness of medium- and large-sized mammals. Therefore, this small area should be considered a hotpoint within the Atlantic Forest hotspot.

Keywords: Atlantic Forest; camera trap; high diversity; inventory; mammal community.

INTRODUCTION

With 701 species, Brazil has one of the world's highest diversities of mammals. For Brazilian biomes, the Atlantic Forest has the second highest diversity with 321 species, of which 89 are endemic; only the Amazon Forest (399 species) is more diverse (Paglia *et al.* 2012). Of the 102 mammal species (excluding marine animals) categorized as threatened in Brazil, 53 are found in the Atlantic Forest (ICMBio 2018). The most diverse orders are Chiroptera (120 species), Rodentia (108 species) and Primates (26 species) (Graipel *et al.* 2017). The best preserved biogeographic subregions of this biome are the Serra do Mar (with 36.5% of its original coverage), followed by Bahia (17.7%) and

the Brejos Nordestinos (16%) (Ribeiro *et al.* 2009). However, only 1.62% of what remains falls into a conservation category, and Bahia is the state with the third highest amount of Atlantic Forest under protection (Ribeiro *et al.* 2009).

Among the subregions of Atlantic Forest, southern Bahia is one of the most important areas due to the high degree of species richness, endemism and threats (Cassano *et al.* 2017). This region still preserves large remnants of native forests that form the Central Corridor of the Atlantic Forest (CCAF) (Mesquita 2004, Ministerio do Meio Ambiente *et al.* 2006, Galetti *et al.* 2009). It is also considered a high priority region for mammal conservation because, according to the list of endangered species of Bahia State (Cassano *et al.* 2017), it houses several threatened species.

Information about medium- and large-sized mammals from southern Bahia is still scarce and represented by only a few inventories from lowland forest (Moura 2003, Falcão *et al.* 2012, Soares *et al.* 2013, Cassano *et al.* 2014)which along with the contiguous forested area of the Pau-Brasil Ecological Station, is an important part of the remaining Atlantic Forest of southern Bahia. We carried out an inventory of medium and large mammals in the Reserve during a 16-month camera trap survey, as well as conducted interviews with park rangers and searched for direct/indirect records, which revealed 33 species belonging to nine different Orders. Among the species recorded, six are categorized as threatened in the national list and four in the IUCN global list. The RPPN harbors species which are crucial to the ecosystem, many of which are in decline and threatened by high hunting pressure and reduction of habitat. The results confirm the relevance of the RPPN as a Key Biodiversity Area (KBA. The Private Reserve of Natural Heritage Complex (RPPN) Serra Bonita is a priority area of mountain Atlantic Forest for fauna and flora inventories because anthropic impact in Brazilian mountains are high and little is known about the biodiversity in these regions (Martinelli 2007). According to Galetti *et al.* (2009), Atlantic Forest remnants in mountain areas (such as Serra Bonita) should be considered priority areas for the conservation of mammals.

Serra Bonita is the second largest protected area in the CCAF, 50% of the reserve is mature forest where there are threatened species, such as the harpy eagle *Harpia harpyja* (Accipitriformes, Accipitridae) (Sánchez-Lalinde *et al.* 2011) and the pink-legged graveteiro *Acrobatornis fonsecai* (Passeriformes, Furnariidae) (Pacheco *et al.* 1996). It also has a high diversity of plants (Amorim & Leme 2009, Amorim *et al.* 2009, Rocha & Amorim 2012), insects (Martins & Galileo 2010, Nemesio 2014), amphibians and reptiles (Dias *et al.* 2011, 2014, Cruz *et al.* 2014, Napoli *et al.* 2011), and birds (Damasceno 2011). It is considered an Important Bird Area (IBA) (Develey *et al.* 2009) and a Key Biodiversity Area (KBA) for vertebrates (Aguiar *et al.* 2003). Unfortunately, there is a gap of knowledge about mammals. This study aims to fill the knowledge gap in this area by describing the medium- and large-sized mammals species richness observed in the RPPN Serra Bonita.

MATERIAL AND METHODS

Study Site

The RPPN Serra Bonita is located in the municipalities of Camacan and Pau Brasil (15°23'30.9" S, 39°33'52.9" W), Bahia State, Brazil (Figure 1). The reserve protects approximately 2,000 ha of Atlantic Forest and has an altitudinal gradient ranging from 200 m to 1,080 m (Liuth *et al.* 2013). This gradient represents a transition zone between two physiognomies of the Atlantic Forest: submontane forests (< 600 m), which in the area mainly comprises secondary forest; and low montane forests (> 600 m), which includes old-growth and undisturbed forests (Oliveira-Filho & Fontes 2000, Amorim *et al.* 2009). It also has areas of cocoa plantations with native woody plants used for shade ("cabrucas") (Dias *et al.* 2014). The climate is hot and humid with an average annual rainfall between 1500 and 1750 mm and average temperature between 23 and 24°C (Peel *et al.* 2007). Six reserves form the RPPN Serra Bonita (Figure 1). Medium- and large-sized mammals were sampled in four reserves: Serra Bonita I (Fazenda Paris), Serra Bonita III (Fazenda Maria Auxiliadora), Fazenda Uiraçu and Fazenda Maria Augusta. Total sampled area was 1,080 ha.

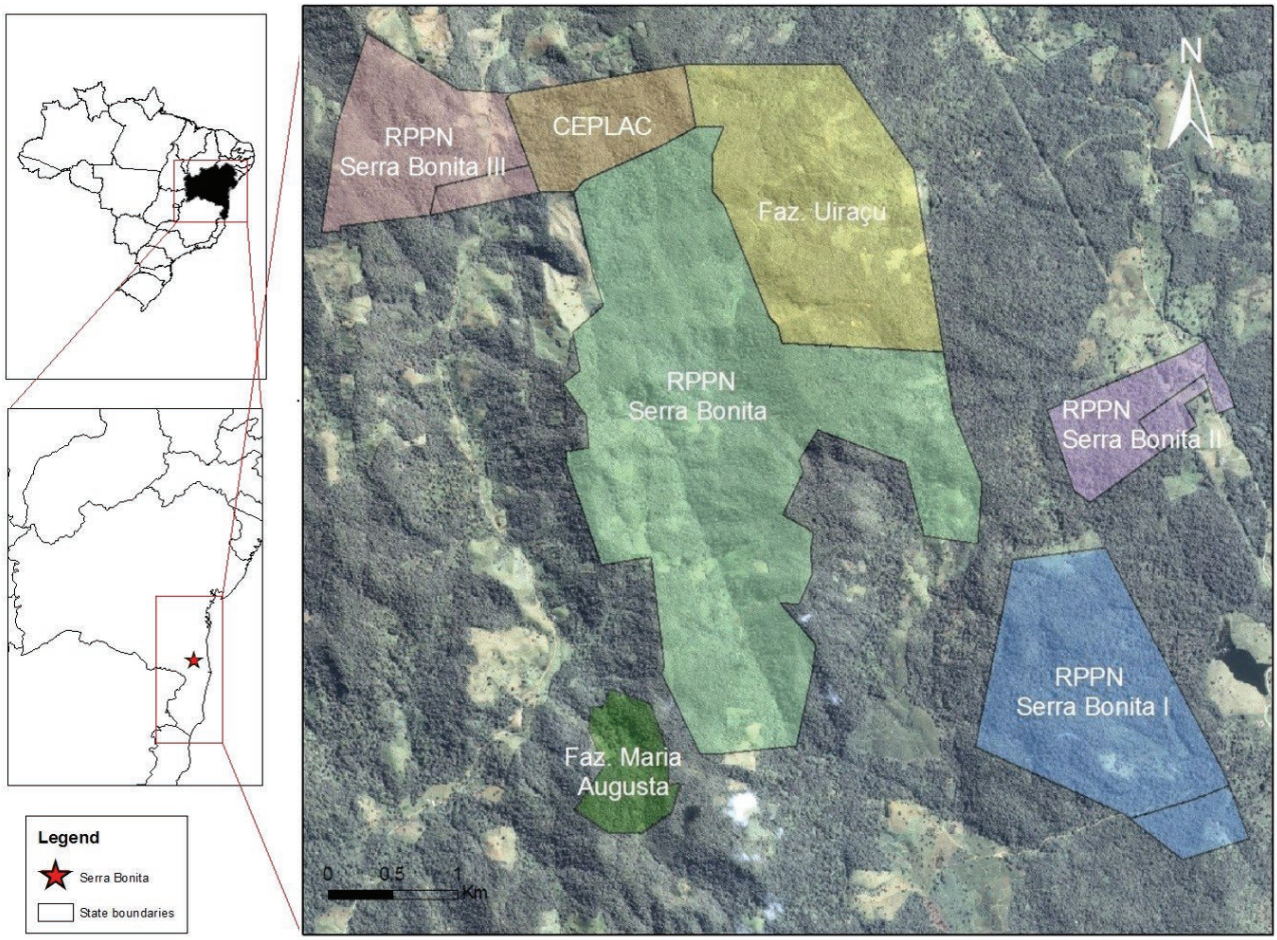

Figure 1. Location of the Private Reserve of Natural Heritage Complex Serra Bonita, Bahia state, Brazil. Medium- and large-sized mammal species were sampled in four reserves: Serra Bonita I (Fazenda Paris), Serra Bonita III (Fazenda Maria Auxiliadora), Fazenda Uiraçu and Fazenda Maria Auguta.

Data Collection

We distributed nineteen camera traps (Tigrinus Conventional v 4.0 c) proportionally throughout the size of the sampled areas. On preexisting trails, we installed the cameras and were at least 500 m apart from each other. We used 200 ASA color film (Fuji/Kodak) with 36 exposures. The cameras operated 24 h for two years (November 2010 to November 2012). The total camera trap sample effort was 13.870 camera-days. We also considered indirect records like tracks, footprints and/or direct observations during camera trap maintenance (*i.e.*, replacement of film and batteries every month) as a secondary method for data collection. According to Oliveira & Cassaro (2005), Borges & Tomás (2008) and Reis *et al.* (2011) we identified the indirect records and the primate species. The nomenclature followed the International Union for Conservation of Nature (IUCN 2019).

Identification of the species of genus *Leopardus* were based on the description of the species (*L. guttulus*, *L. emilieae* and *L. tigrinus*) made by Nascimento & Feijó (2017). They used external characteristics, such as the color and the spot pattern of the pelage for the species diagnosis (Nascimento & Feijó 2017), once in the state of Bahia, both *L. tigrinus* and *L. guttulus* can be found (Cassano *et al.* 2017). To identify the species, we considered fur characteristics, such as dorsal, ventral and lateral coloration, plus the size and color of the rosettes (*i.e.*, if the rosettes were or not forming oblique bands). In relation to fur color, *L. tigrinus* is dark and orangish to yellowish and grayish brown, with medium sized rosettes on the sides of the body forming oblique bands in scapularinguinal direction (Nascimento & Feijó 2017). In addition, *L. guttulus* is dark yellowish brown to ochraceous, rosettes smaller, dark, and rarely coalesce to form oblique bands (Nascimento & Feijó 2017). We also had the collaboration of small felines experts, Tadeu Gomes de Oliveira (Universidade Estadual de Maranhão), Fábio Nascimento (Universidade

de São Paulo) and Anderson Feijó (Universidade Federal de Paraíba).

According to Emmons & Feer (1997), we classified medium- and large-sized mammals as species with a body mass > 1 kg that can be registered using the same sampling protocol.

Data Analysis

For the analysis, we considered the camera trap records, as well as the direct and indirect records. We considered only records of the same species with 1h interval in order to respect the statistical independency.

With the recorded data we constructed a species accumulation curve and used the Clench model to estimate species richness and sample adequacy. The Clench model is an asymptotical model recommended for large-area sampling and for sampling protocols in which the researcher's experience increases over time, increasing the likelihood of recording new species during the inventory (Soberon & Llorente 1993, Moreno 2001, Jiménez-Valverde & Hortal 2003, Díaz-Francés & Soberón 2005). In addition, this model, unlike other asymptotic models, is less complex and does not underestimate species richness in exhaustive sampling (Gonzalez-Oreja *et al.* 2010).

The model is expressed as:

$$Sn = \frac{a * n}{\left(1 + (b * n)\right)}$$

Where: a is the rate of increase of new species and b is a parameter related to the shape of the curve. The asymptote of the curve represents the expected species richness and is calculated as a/b. This assumption considers that if the inventory carried out is very accurate, it can override this value by the total species observed in the field (Jiménez-Valverde & Hortal 2003). To determine the adequacy of the model to the species accumulation curve, we used the coefficient of determination (R^2). This coefficient indicates the percentage of variation of species richness in relation to the sampling effort. The coefficient takes values between 0 and 1. Values close to 1 represent a better fit of the model. A slope value of less than 0.1 indicates a good sampling effort (Jiménez-Valverde & Hortal 2003).

RESULTS

We recorded 22 species of medium- and large-sized mammals, belonging to seven orders, and distributed in 13 families and 20 genera. Were registered 18 species with the camera traps, 12 by indirect observation (tracks) and nine by direct observation in the field (Table 1, Figure 2). *Lontra longicaudis* was the only species reported exclusively by tracks (Table 1). One exotic species, the domestic dog *Canis lupus familiaris* (Linnaeus, 1758), was recorded but not considered in the analysis. Carnivora was the order with the most recorded species (47.6%), followed by Cingulata (14.3%) (Table 1). *Cerdocyon thous* was the most recorded species (Figure 3).

The species accumulation curve approached an asymptote after eight months of sampling (Figure 4). The Clench model shows good fit to the species accumulation curve (R^2 = 0.97) considering the 22

Table 1. List of medium- and large-sized mammal species registered in four reserves that are part of the Private Reserve of Natural Heritage Complex Serra Bonita, Bahia state, Brazil. Methods: Ct = camera trap; Tr = tracks; Obs = observation. Reserve: Mag = Maria Augusta; Max = Fazenda Maria Auxiliadora; Fu = Fazenda Uiracu; Fp = Fazenda Paris. Species nomenclature follows IUCN (2019), except for *Leopardus guttulus* that follows Trigo *et al.* (2013) and *Sapajus xanthosternos* that follows Alfaro *et al.* (2012).

Species	Method	Reserve
Order Cetartiodactyla		
Family Cervidae		
Mazama americana (Erxleben, 1777)	Ct, Tr	Fp
Family Tayassuidae		
Pecari tajacu (Linnaeus, 1758)	Ct, Tr, Obs	Max, Fp, Fu

Table 1. *Continued on next page…*

Table 1. *...Continued*

Species	Method	Reserve
Order Carnivora		
Family Canidae		
Cerdocyon thous (Linnaeus, 1766)	Ct, Tr, Obs	Mag, Max, Fp, Fu
Family Felidae		
*Leopardus guttulus (*Henzel, 1872)	Ct	Mag, Fp, Fu
Leopardus pardalis (Linnaeus, 1758)	Ct, Tr	Max, Fu
Leopardus wiedii (Schinz, 1821)	Ct	Mag, Fp, Fu
Puma concolor (Linnaeus, 1771)	Ct, Tr	Mag, Max, Fp, Fu
Family Mephitidae		
Conepatus semistriatus (Boddaert, 1785)	Ct	Fp
Family Mustelidae		
Eira barbara (Linnaeus, 1758)	Ct, Tr, Obs	Mag, Max, Fp, Fu
Lontra longicaudis (Olfers, 1818)	Tr	Fp
Family Procyonidae		
Nasua nasua (Linnaeus, 1766)	Ct, Tr, Obs	Mag, Max, Fp, Fu
Procyon cancrivorous (Cuvier, 1798)	Ct, Tr	Mag, Fp, Fu
Potos flavus (Scheber, 1774)	Obs	-
Order Cingulata		
Family Chlamyphoridae		
Cabassous tatouay (Desmarest, 1804)	Ct, Obs	Mag, Fp, Fu
Euphractus sexcinctus (Linnaeus, 1758)	Ct, Obs	Fp
Family Dasypodidae		
*Dasypus novemcintus (*Linnaeus, 1758)	Ct, Tr, Obs	Mag, Max, Fp, Fu
Order Lagomorpha		
Family Leporidae		
Sylvilagus brasiliensis (Linnaeus, 1758)	Ct	
Order Pilosa		
Family Myrmecophagidae		
Tamandua tetradactyla (Linnaeus, 1758)	Ct	Mag, Fp, Fu
Order Primates		
Family Callithricidae		
Callithrix kuhlii (Coimbra-Filho, 1985)	Obs	Fp, Fu
Family Cebidae		
Sapajus xanthosternos (Wied-Neuwied, 1826)	Ct, Obs	Max
Order Rodentia		
Family Cuniculidae		
Cuniculus paca (Linnaeus, 1766)	Ct, Tr	Mag, Max, Fp, Fu
Family Hydrochaeridae		
Hydrochoerus hydrochaeris (Linnaeus, 1766)	Tr, Obs	Fp

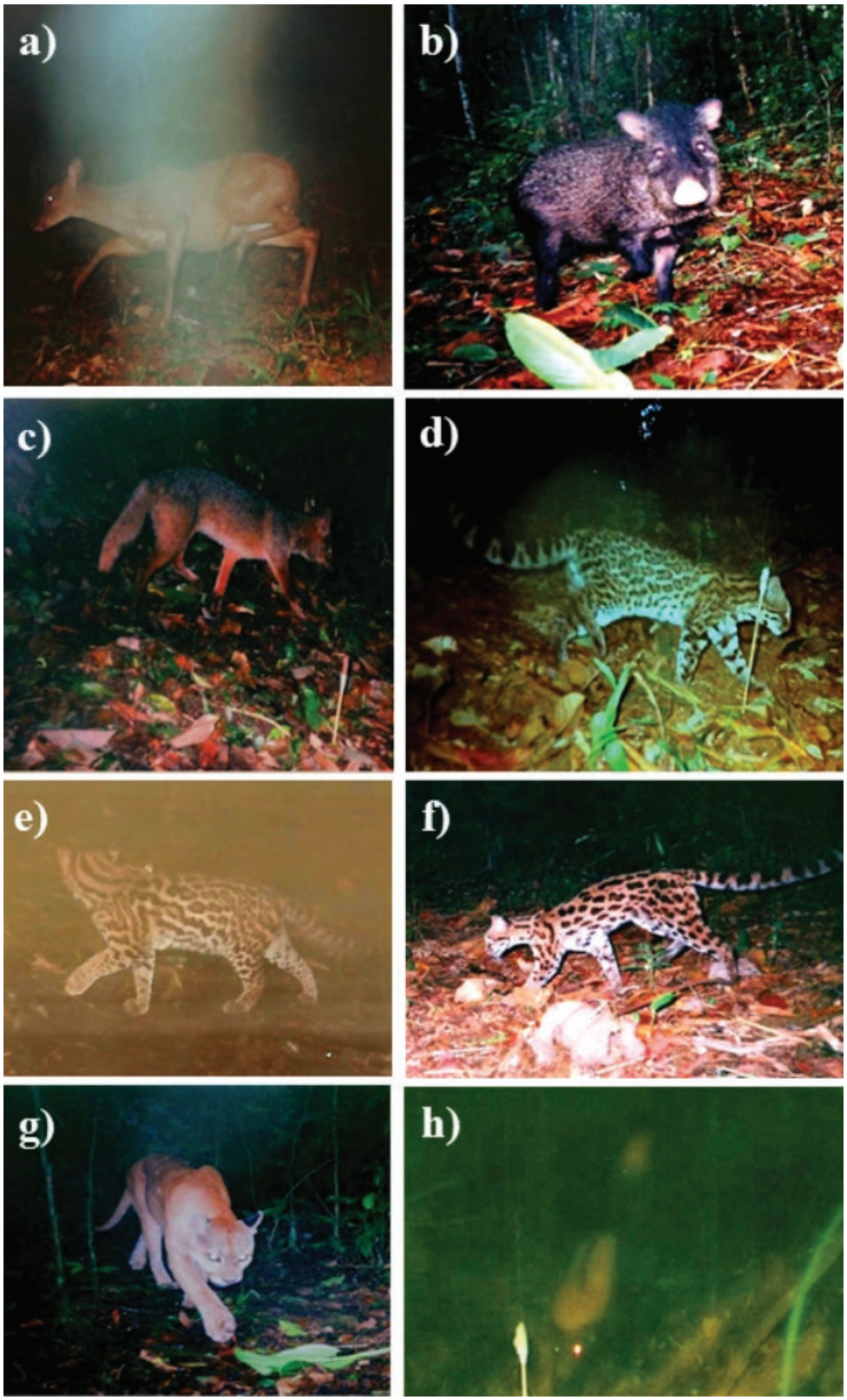

Figure 2. Mammals recorded in the Private Reserve of Natural Heritage Complex Serra Bonita, Bahia state, Brazil. a) *Mazama americana*, b) *Pecari tajacu*, c) *Cerdocyon thous*, d) *Leopardus guttulus*, e) *Leopardus pardalis*, f) *Leopardus wiedii*, g) *Puma concolor*, h) *Conepatus semistratus*.

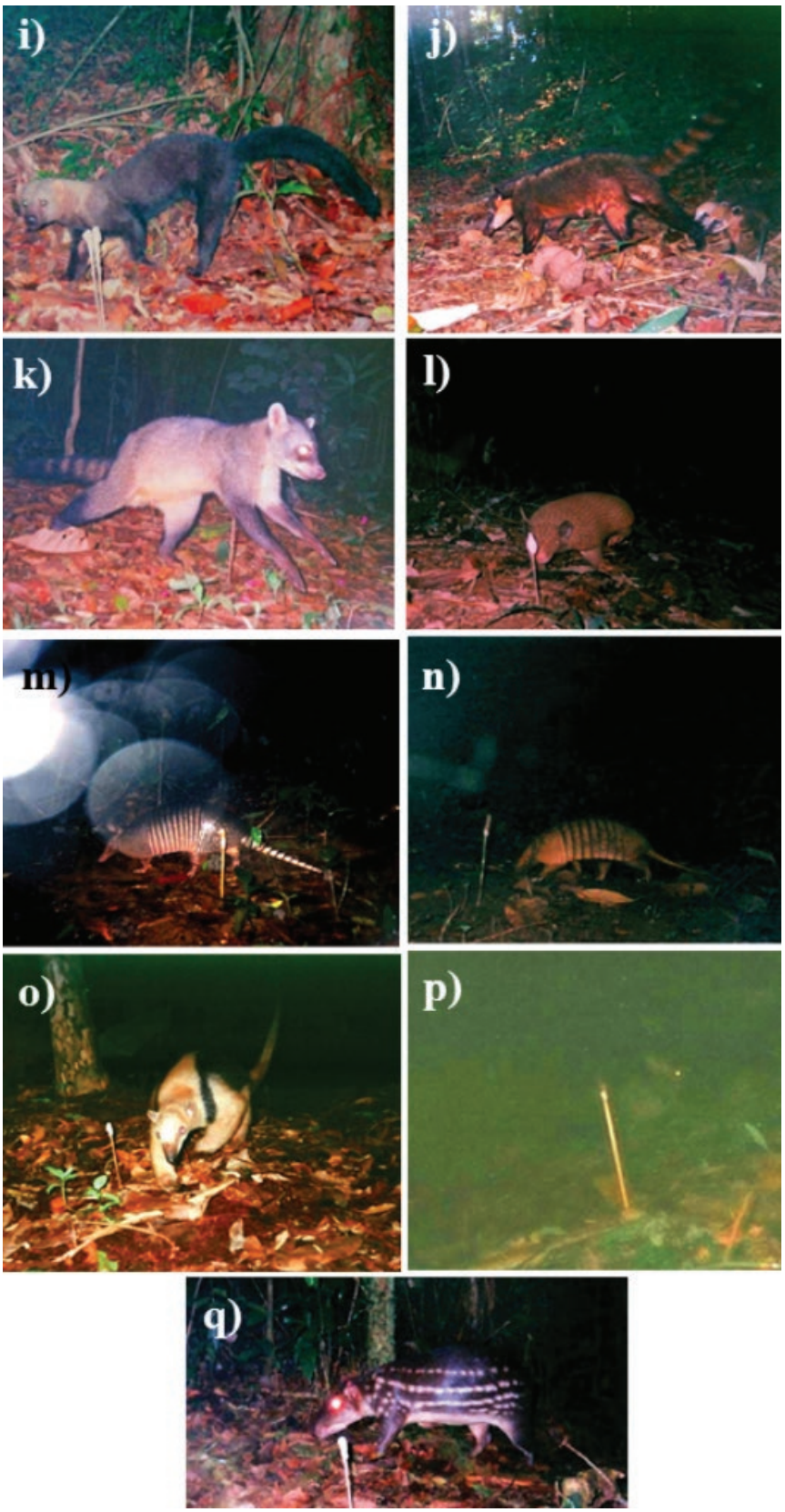

Figure 2 (Continuation). Mammals recorded in the Private Reserve of Natural Heritage Complex Serra Bonita, Bahia state, Brazil. i) *Eira barbara*, j) *Nasua nasua*, k) *Procyon cancrivorous*, l) *Cabassous tatouay*, m) *Dasypus novemcinctus*, n) *Euphractus sexcinctus*, o) *Tamandua tetradactyla*, p) *Sylvilagus brasiliensis*, q) *Cuniculus paca*.

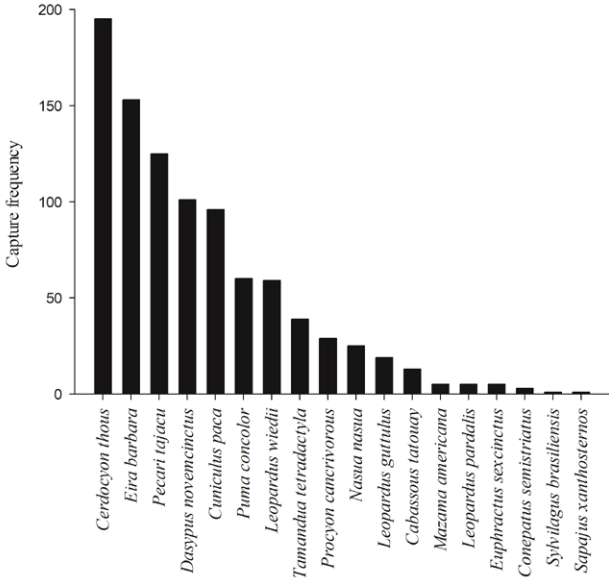

Figure 3. Frequency of capture for medium- and large-sized mammal species in the Private Reserve of Natural Heritage Complex Serra Bonita, Bahia state, Brazil.

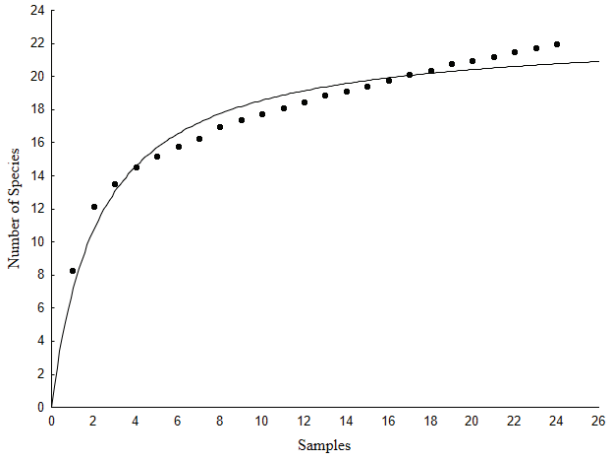

Figure 4. Species accumulation curve of medium- and large-sized mammal species recorded in the Private Reserve of Natural Heritage Complex Serra Bonita, Bahia state, Brazil. Random curve (one in every 20 samples) in circles and line represents the expected richness (Clench model).

species recorded and the 24 months of sampling. The asymptote of the model (*a/b*) predicted 22.7 species, suggesting that 96% of all medium and large mammals that could occur in the study area were recorded. The slope at the end of the curve was 0.074, which indicates a complete and reliable sampling (Figure 4).

DISCUSSION

This is the first medium to large-sized mammals list of RPPN Serra Bonita, which demonstrated high species richness in this area compared to other areas in southern Bahia (Falcão *et al.* 2012). However, despite the record of a small spoted-cat, which we know is *L. guttulus*, all species were expected to occur in the area. The species richness previous recorded for this group in the region seems to vary according to the sampling method used, however, as long the mammals species list are still scarce for southern Bahia, we associated species recorded in the RPPN Serra Bonita with the studies founded. Based on interviews, Moura (2003) reported 44 species in 21 forest fragments along the central corridor of the Atlantic Forest. Studies using camera traps reported 20 (Cassano *et al.* 2012, Cassano *et al.* 2014) , 14 (Falcão *et al.* 2012) and eight species (Soares *et al.* 2013). In all cited cases, the areas are larger than RPPN Serra Bonita is, and are located in areas with lower altitudes.

Species reported in other studies in Atlantic forest fragments of southern Bahia but not recorded in the present work include: *Herpailurus yagouaroundi, Mazama gouazoubira, Cabassous unicinctus, Bradypus variegatus, Callithrix geoffroyi, Sapajus robustus, Dasyprocyta leporina* and *Tapirus terrestris* as stated by Falcão *et al.* (2012), and *Leontopithecus chrysomelas*, *Chaetomys subspinosus*, *Dasyprocta* cf. *leporina*, *Coendou insidiosus*, *Bradypus torquatus*, *Callicebus melanochir* and *H. yagouaroundi* according to Cassano *et al.* (2012, 2014). Most of the absence of these records might be related to our camera placement in study area; only one record is known for H. yagouaroundi in the RPPN Serra Bonita (J. C. D. Passos, unpublished data).

The three species of felines reported in this study are included on both the national (Ministério do Meio Ambiente 2014) and the regional (Cassano *et al.* 2017) threatened species lists (Table 1). As top predators, they are considered flagship species (Caro *et al.* 2004, Clucas *et al.* 2008) for conservation areas because they require large areas for survival (Oliveira & Cassaro 2005). We also registered *S. xanthosternos,* an endemic primate of the Atlantic Forest in southern Bahia, which is critically endangered (CR) (Ministério do Meio Ambiente 2014, Cassano *et al.* 2017). Their populations are

in decline and it is known that they occur in small protected areas (Kierulff *et al.* 2015, Cassano *et al.* 2017).

Cerdocyon thous was the most recorded species in our study, as well as in other studies focusing on medium- and large-sized mammals in other Atlantic Forest regions in Brazil when the species is very abundant (Prado *et al.* 2008, Goulart *et al.* 2009, Dotta & Verdade 2011, Soares *et al.* 2013, Bogoni *et al.* 2016). *Cerdocyon thous* frequently uses pre-existing trails in the area. We evidenced tracks along the forest trails where the cameras were installed, which may explain the high records of the species.

In this work, we assume that the record of the little spotted cat is from *L. guttulus* due to its estimated area of occurrence that approaches our study area and for characteristics of the fur (Nascimento & Feijó 2017). Nevertheless, the taxonomy of this species is currently under review because it was treated as a subspecies of *Leopardus tigrinus* until Trigo *et al.* (2013) demonstrated with a comprehensive molecular study that *L. tigrinus* and *L. guttulus* are clearly distinct species. Further research is needed to establish the geographic distribution and morphology of *L. guttulus*. The record in our study may represent a northern extension in the distribution area of *L. guttulus*. According to Trigo *et al.* (2013), *L. guttulus* is distributed in southeastern Brazil and *L. tigrinus* in northern and northeastern Brazil. Our record shows the presence of the species above the previous most northern record in the Atlantic Forest, which is in Espirito Santo State. Therefore, our results should contribute to the knowledge of the distribution of this species; although, molecular and morphological studies are needed for taxonomic confirmation, which is possible only if a specimen is captured.

Hunting activities are not common in RPPN Serra Bonita, but there are records of this activity in surrounding areas. The reserve hires park rangers, which favors the maintenance and perpetuation of the local fauna. A relationship between an abundance increase in large mammals and the support of park ranger services has been reported for other areas of Atlantic Forest in Bahia (Flesher & Laufer 2013).

Most of the species recorded use the cocoas plantations, increasing their occurrence area. We recorded the highest richness of medium- and large-sized mammals in southern Bahia so far, with 22 species, including endemic and threatened species. The RPPN Serra Bonita may be acting as a core area for the conservation of these species in the Central Corridor of the Atlantic Forest, making this small area a biodiversity hotpoint within the Atlantic Forest hotspot.

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