Composition of medium and large-sized mammals in two protected areas of the Atlantic Forest in the central western mesoregion of Paraná state, Brazil

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Abstract: There is a significant lack of information on the diversity of medium- and large-sized mammal species in heavily anthropologically altered regions, such as the Atlantic Forest of Southern Brazil. Biodiversity inventories play a crucial role in developing conservation and mitigation strategies at the local and regional scales. In this study, we conducted the first assessment of medium- and large-sized mammal species in two protected areas of the Atlantic Forest in the Central Western Mesoregion of Paraná State, Brazil. Sampling took place between September 2021 and September 2022 in Estação Ecológica Municipal de Roncador (EEMR) and Parque Municipal Miguel Pereira (PMMP) in Roncador City, PR. Using 180 h of active research and 64,800 h of camera trapping, we identified 27 species from 15 families and seven orders, with 40% of the recorded mammal species being endangered at the state, national, or international level. We also found two exotic and one domestic species in the protected areas. Our results improve our understanding of the southern Brazilian fauna, highlighting the importance of the protected areas EEMR and PMMP as refuges for medium- and large-sized mammals in the Central Eastern-Western Mesoregion of Paraná State.

Keywords: biodiversity inventories, conservation strategies, Mixed Ombrophilous Forest.

Composição de mamíferos de médio e grande porte em duas áreas protegidas da Mata Atlântica na mesorregião centro ocidental do Paraná, Brasil

Resumo: Existe uma significativa falta de informação sobre a diversidade de espécies de mamíferos de médio e grande porte em regiões fortemente alteradas pela atividade humana, como a Mata Atlântica do Sul do Brasil. Inventários da biodiversidade desempenham um papel crucial no desenvolvimento de estratégias de conservação e mitigação em nível local e regional. Neste estudo, conduzimos a primeira avaliação de espécies de mamíferos de médio e grande porte em duas áreas protegidas da Mata Atlântica na Mesorregião Centro Ocidental do Estado do Paraná, Brasil. As amostragens ocorreram entre setembro de 2021 e setembro de 2022 na Estação Ecológica Municipal de Roncador (EEMR) e no Parque Municipal Miguel Pereira (PMMP) na cidade de Roncador, PR. Utilizando 180 horas de pesquisa ativa e 64.800 horas de armadilhamento fotográfico, identificamos 27 espécies de 15 famílias e sete ordens, sendo que 40% dos espécies de mamíferos registrados estão ameaçados de extinção em nível estadual, nacional ou internacional. Também encontramos duas espécies exóticas e uma doméstica nas áreas protegidas. Nossos resultados melhoram a compreensão da fauna do sul do Brasil, destacando a importância das áreas protegidas EEMR e PMMP como refúgios para mamíferos de médio e grande porte na Mesorregião Centro Ocidental do Estado do Paraná.

Palavras-chave: inventários de biodiversidade, estratégias de conservação, Floresta Ombrófila Mista.

INTRODUCTION

The geographical distribution of most species is not fully understood; therefore, it is often inadequate at all measurement scales (Lomolino, 2004). Among the shortfall affecting large-scale knowledge of biodiversity is the so-called Wallacean shortfall which refers to the lack of knowledge about the geographic distribution of species (Lomolino, 2004). According to Hortal et al. (2015), this shortfall arises from geographical bias in information about species distribution, which makes many of the observed biodiversity maps resemble research effort maps (Hortal et al., 2007). That is, the distribution of species is closely related to the temporal and spatial variation in the sampling effort in a given region (Hortal et al., 2015). Biodiversity inventories contain important information about the species richness, structure, and composition of the community, in addition to critical information on the ecology of natural ecosystems, and usually are the first step in the development of conservation and mitigation strategies on local to regional scales (Bogoni et al., 2021).

Although mammals are the most well-known zoological group in Brazil, few regions have been properly monitored, thus generating incomplete lists of species and numerous gaps in information on biological aspects and uncertainties regarding the geographical and taxonomic distribution of many species (Souza et al., 2019). Mammals play an important role in the maintenance and balance of forest ecosystems, performing broad ecological services (Lacher et al., 2019). These include population control of prey, plant pollination, and seed dispersal, all of which contribute to forest regeneration (Lacher et al., 2019). However, due to forest fragmentation, changes in habitat, introduction of exotic species, and other factors correlated with anthropogenic disturbance in the natural environment, several species of medium and large sized mammals are severely threatened by population declines (Bogoni et al., 2018; Dirzo et al., 2014). Thus, they are threatened by extinction in many biomes, ecoregions, and vegetation types (domains) corresponding to various Brazilian states (ICMBIO, 2018).

Based on research conducted at numerous sites throughout the Atlantic Forest biome Lima et al. (2017) and Souza et al. (2019) compiled and organized a dataset containing the distribution and wealth of medium and large mammal species. Despite the praiseful collective effort to create the datasets mentioned above, there are still large gaps in information regarding the diversity of medium-sized and large-scale mammal species in regions heavily altered by anthropological processes, such as the Central Western Mesoregion of Paraná State, Brazil (*i.e.*, the focus region of the present study). Thus, we aimed to characterize the community of medium-sized and large mammals that occur in two protected areas of the Atlantic Forest located in the municipality of Roncador-PR.

MATERIAL AND METHODS

Study site

The samplings were performed in the Estação Ecológica Municipal de Roncador (EEMR), (24°33'44,25''S; 52°29'6,64''O; Datum WGS84, 491 m) featuring an area 21.33 ha, and at the Parque Municipal Miguel Pereira (PMMP) (24°35'42,87''S, 52°17'17,93''O, Datum W GS84, 523 m), featuring an area of 6 ha; both sites are Protected Areas (PAs) located in the Central Western Mesoregion of Paraná State, municipality of Roncador (Fig. 1). The predominant vegetation in the region is the Mixed Ombrophilous Forest (FOM; Araucaria Forest), a type of Atlantic Forest that occurs mainly in south Brazil (Maack, 2017). FOM has been systematically reduced by anthropic action such as firewood for domestic purposes, timber industry, agribusiness, and urbanization (Passos et al., 2021), nowadays, it is considered one of the most threatened ecosystems on the planet, in addition to being one of the phytophysiognomies with the lowest number of protected areas in the Atlantic Forest (SOS Mata Atlântica & INPA, 2018).

Sampling methodology

Sampling occurred between September 2021 and September 2022, totaling over 180 h of active search along approximately 125 km of trails and roads, with an average of eight monthly hours of active search in each area. To enable a broad record of different species of medium- and large-sized mammals, we used direct active search method (visual sightings and acoustic signals) and indirect methods (analysis of footprints, carcasses, signs, and burrows), in addition to camera traps. To confirm the species, specific field guides for the group were used (Azevedo et al., 2021; Becker & Dalponte, 2013; Reis et al., 2009, 2014).

Nine camera traps (Bushnell, model Trail Cam HD) were used: five in the EEMR and four in the PMMP, distributed throughout the forest remnants studied, and preferably installed in locations favorable to animal concentration, such as natural trails and near water sources. Cameras were kept at a distance of at least 500 m and placed 50 cm above the ground on trees. The position and location of the camera traps were changed every two months, whenever possible, to expand the search radius using the equipment (Fig. 1). Camera traps were active for 10 months, totaling a sampling effort of 64,800 camera trap hours. An event (a capture
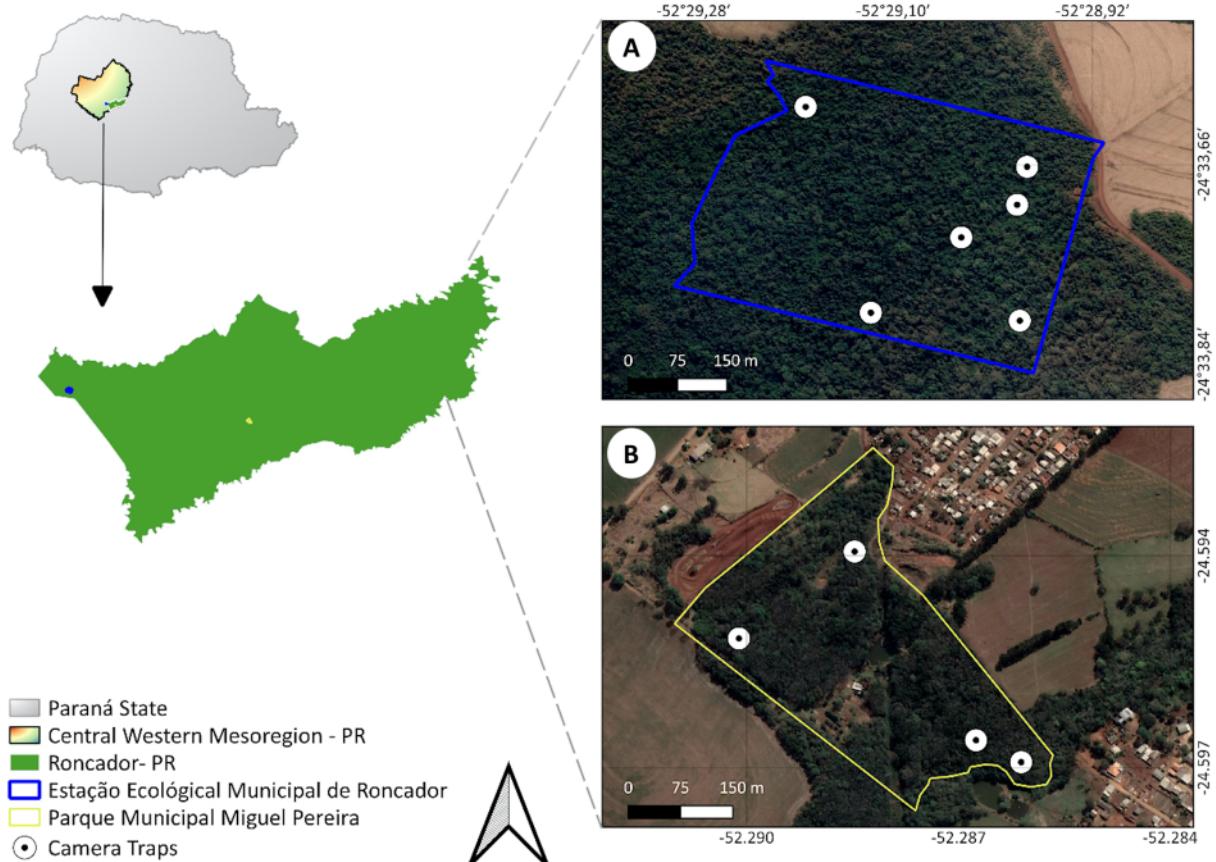
Fig. 1. Location of sampling sites (protected areas) Estação Ecológica Municipal de Roncador (EEMR) and Parque Municipal Miguel Pereira (PMMP) in relation to Paraná State in southern Brazil.

record) was considered independent when there were (a) consecutive photographs by the same camera an interval of at least 60 minutes, and (b) non-consecutive photographs by the same camera (Srbek-Araujo & Chiarello 2013). All those species with an adult body mass ≥1 kg were considered medium-sized and large mammals (Chiarello, 2000). In addition, for the purpose of complementing our final species list, we took into account occasional camera trap records of smaller mammals (*i.e.*, <1 kg), such as marsupials and native squirrels, highlighted in Tab. 1 as representatives of this category. The taxonomic ordering and nomenclature of the species followed Abreu et al. (2022) and Acosta et al. (2020) for peccaries. Conservation status was obtained for each species within state, country and international context (ICMBIO, 2018; IUCN, 2023; PARANÁ, 2010).

Data analysis

We calculated the occurrence frequency (FO%) in relation to the studied fragments, using the formula: %fo = (Ni/N) × 100; where %fo = occurrence frequency of the species category; Ni = number of records; N = total number of records per site. We employed rarefaction curves based on the interpolation and extrapolation of species richness, taking into account double the number of samples for the extrapolation curve based on sample size, as suggested by Colwell et al. (2012). We performed these analyses in R version 4.2.1 (R Core Team, 2022), based on the package "iNEXT" (iNterpolation/EXTrapolation) (Hsieh et al., 2020).

Results

A total of 24 medium and large-sized mammal species were recorded in the study region, including two exotic and one domestic species, plus three small-sized native species (*Caluromys lanatus* Olfers, 1818; *Chironectes minimus* Zimmermann, 1780 and Guerlinguetus brasiliensis Gmelin, 1788), Thus, our list includes 27 mammal species distributed in seven orders and 15 families (Tab. 1).

For EEMR, 26 species were recorded with an estimated richness of 29.40 ± 7.77. For PMMP, 11 mammals were recorded and, the estimated richness stabilized at 11 ± 1.88 species.

Tab. 1. List of land medium-sized and large mammal species at the Estação Ecológica Municipal de Roncador (EEMR) and Parque Municipal Miguel Pereira (PMMP) located in the Central Western Mesoregion of Paraná State. Record type (R.T); Footprint (F), Visualization (VI), Camera traps (CT), Photo (PT). Conservation status by (IUCN), Brazilian List of Threatened Species (BR), Paraná state List of Threatened Species (PR). Data Deficient (DD), Endangered (EN), Least Concern (LC), Not evaluated (NE), Near Threatened (NT), Vulnerable (VU) and Critically Endangered (CR). Exotic species (*). Small species (**).

Taxon	Common name	Number of records EEMR		Number of records PMMP		R.T	Conservation status		
		N	Fo%	N	Fo%		IUCN	BR	PR
Didelphimorphia									
Didelphidae									
Caluromys lanatus Olfers, 1818**	Brown-eared woolly opossum	1	0.16			VI-PT	LC	NE	LC
Chironectes minimus Zimmermann, 1780**	Water opossum			1	0.98	VI	LC	NE	LC
Didelphis albiventris Lund, 1840	White-eared opossum	18	2.81	25	24.5	CT	LC	LC	LC
Cingulata									
Dasypodidae									
Dasypus (Dasypus) novemcinctus Linnaeus, 1758	Nine-banded armadillo	29	4.52	14	13.7	CT-F	LC	NE	LC
Cabassous tatouay Desmarest, 1804	Greater naked-tailed armadillo	4	0.62			CT	LC	DD	LC
Primates									
Cebidae									
Sapajus nigritus Goldfuss, 1809	Black-horned tufted capuchin	15	2.34	5	4.9	CT –VI	NT	NE	NE
Lagomorpha									
Leporidae									
Sylvilagus brasiliensis Linnaeus, 1758	Tapeti	3	0.47			VI- CT	LC	-	VU
Lepus europaeus Pallas, 1778*	Brown hare	13	2.03			VI-PT-F	-	-	-
Rodentia									
Cuniculidae									
Cuniculus paca Linnaeus, 1766	Spotted paca	3	0.47			CT	LC	NE	EN
Dasyproctidae									
Dasyprocta azarae Lichtenstein, 1823	Azara's agouti	40	6.24	21	20.5	CT	DD	NE	LC
Erethizontidae									
Coendou (Sphiggurus) spinosus Cuvier, 1823	Guiara	1	0.16	2	1.96	CT –VI	DD	NE	LC
Sciuridae									
Guerlinguetus brasiliensis Gmelin, 1788)**	Brazilian squirrel	3	0.47			CT	NE	NE	NE

Carnivora									
Canidae									
Canis lupus familiaris Linnaeus, 1758*	Domestic dog	70	10.9	18	17.6	CT-F-VI	-	-	-
Cerdocyon thous Linnaeus, 1766	Crab-eating fox	21	3.28	4	3.92		LC	NE	NE
Chrysocyon brachyurus Illiger, 1815	Maned wolf	1	0.16			VI-PT	VU	VU	VU
Mustelidae									
Eira barbara Linnaeus, 1758	Tayra	4	0.62			CT –F	LC	NE	NE
Procyonidae									
Nasua nasua Linnaeus, 1766	South American coati	36	5.62	8	7.84	CT –VI	LC	NE	LC
Procyon cancrivorus Cuvier, 1798	Crab-eating raccoon	17	2.65			CT –F	LC	NE	LC
Felidae									
Herpailurus yagouaroundi É. Geoffroy Saint-Hilaire, 1803	Jaguarundi	3	0.47			CT	LC	VU	DD
Leopardus guttulus Hensel, 1872	Southern tiger cat	4	0.62	2	1.96	CT	VU	VU	VU
Leopardus pardalis Linnaeus, 1758	Ocelot	1	0.16			F	LC	-	VU
Leopardus wiedii Schinz, 1821	Margay	2	0.31	2	0.96	CT	NT	VU	VU
Puma concolor Linnaeus, 1771	Puma	2	0.31			CT –F	LC	VU	VU
Cetartiodactyla									
Cervidae									
Mazama americana Erxleben, 1777	South American Red Brocket	12	1.87			CT	DD	NE	VU
Mazama gouazoubira Fischer, 1814	South American Brow Brocket	12	1.87			CT –VI	LC	-	-
Tayassuidae									
Dicotyles tajacu Linnaeus, 1758	Collared Peccary	243	37.7			CT -VI-F	LC	NE	VU
Suidae									
Sus scrofa Linnaeus, 1758*	Wild boar	84	13.1			CT -VI-F	-	-	-

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(Fig. 2). Among the species recorded, 41% of the species belong to the order Carnivora, followed by Cetartiodactyla and Rodentia (15% each), Didelphimorphia (11%), Cingulata and Lagomorpha (7% each), and Primates (4%) (Tab. 1). Among the 27 species recorded in the current study, 11 (40.74%) are included in some degree of threat at the state, national, or international level according to the criteria established by the IUCN (Tab. 1; Fig. 3).
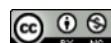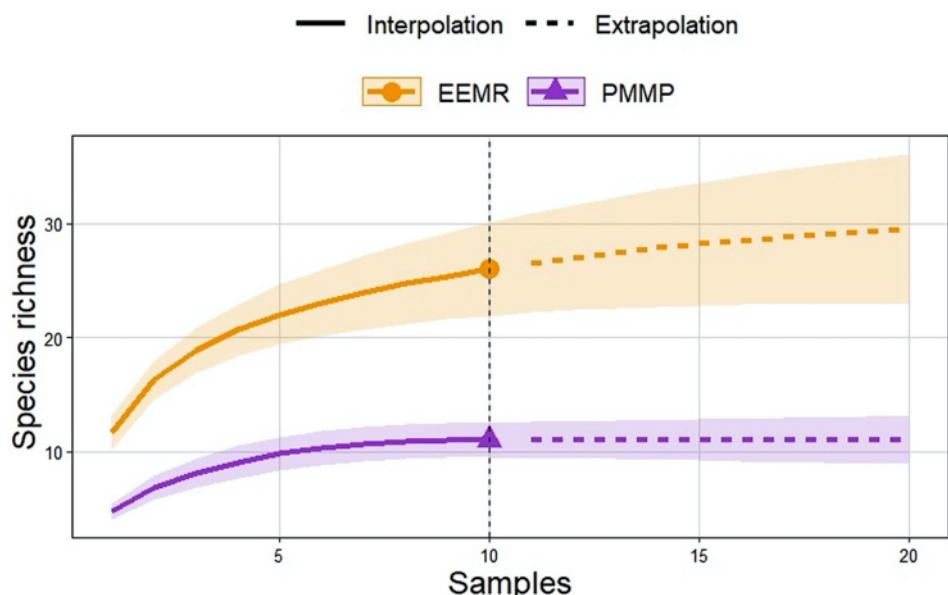
Fig. 2. Rarefaction curves with a 95% confidence interval for extrapolation of the richness of medium and large-sized mammals recorded at Estação Ecológica Municipal de Roncador (EEMR) and Parque Municipal Miguel Pereira (PMMP).

DISCUSSION

This study provides a list composed of 27 species, which is the first inventory of medium and large-sized mammal species for the municipality of Roncador - PR. Species richness was higher in the EEMR protected area (S = 26) when compared to PMMP (S = 10), and 16 species were exclusive to the first area: *C. lanatus*, *C. tatouay*, *M. gouazoubira*, *M. americana*, *D. tajacu*, *S. scrofa*, *C. brachyurus*, *H. yagouaroundi*, *L. pardalis*, *P. concolor*, *E. barbara*, *P. cancrivorus*, *S. brasiliensis*, *L. europaeus*, *C. paca* and *G. brasiliensis.*

The rarefaction curves indicated that, with an increase in sampling effort for EEMR, it would be possible to increase the number of species by up to five; however, for PMMP, even with an increase in effort, the estimate remained the same as the number found. This result may be related to the size of the remaining forest, connectivity with adjacent fragments, and the surrounding matrix. However, we emphasize the exclusive record for the PMMP of the Water Opossum (*C. minimus*). This small marsupial exhibits nocturnal habits and inhabits forested areas, always in close proximity to water, typically isolated streams (Reis et al., 2011), characteristics found only in the PMMP. Despite its small size, it retains natural landscape features such as bodies of water absent in the EMRR interior. Nevertheless, habitat size and quality are significant variables that affect the richness and diversity patterns of mammal populations in Neotropical ecosystems (Canale et al., 2012), especially in the Brazilian Atlantic Forest (Bogoni et al., 2018; Pereira et al., 2021).

There are few published studies providing information on the diversity of medium and large-sized mammals in the Central Eastern Western Mesoregion of the state of Paraná (see Lima et al., 2017; Souza et al., 2019). The presence of gaps in diversity studies can limit regional knowledge of medium to large-bodied species and mammals, making it difficult to make effective decisions for the conservation of these species (Bogoni et al., 2021). Among the few studies conducted in the Central Eastern Western Mesoregion of the state of Paraná, Rocha-Mendes et al. (2005) recorded 39 mammal species based on interviews with local residents in the municipality of Fenix - PR, leaving some records that need to be confirmed using other methods, according to the authors themselves. In this study, we provide confirmed evidence for the occurrence of *M. gouazoubira*, *M. americana*, *C. brachyurus* and exotic species such as *S. scrofa* and *L. europaeus* in the Central Eastern Western Mesoregion of the state of Paraná. Our results are similar to those of other studies conducted in the Paraná Mixed Ombrophilous Forest, which used similar methods to our study, such as Pereira & Bazilio (2014) in the Floresta Naciona de Irati (S=24), Bender et al. (2018) in the Reserva Biológica das Araucárias (S=30), and Pereira et al. (2018) in fragments of FOM in the Central Eastern Eastern region of Paraná State (S=30).

The order Carnivora, with 11 species, was the most representative in our study. Owing to differences in diet, carnivores are incredibly diverse in terms of size, shape, and lifestyle habits (Macdonald, 2009). Carnivores occupy a
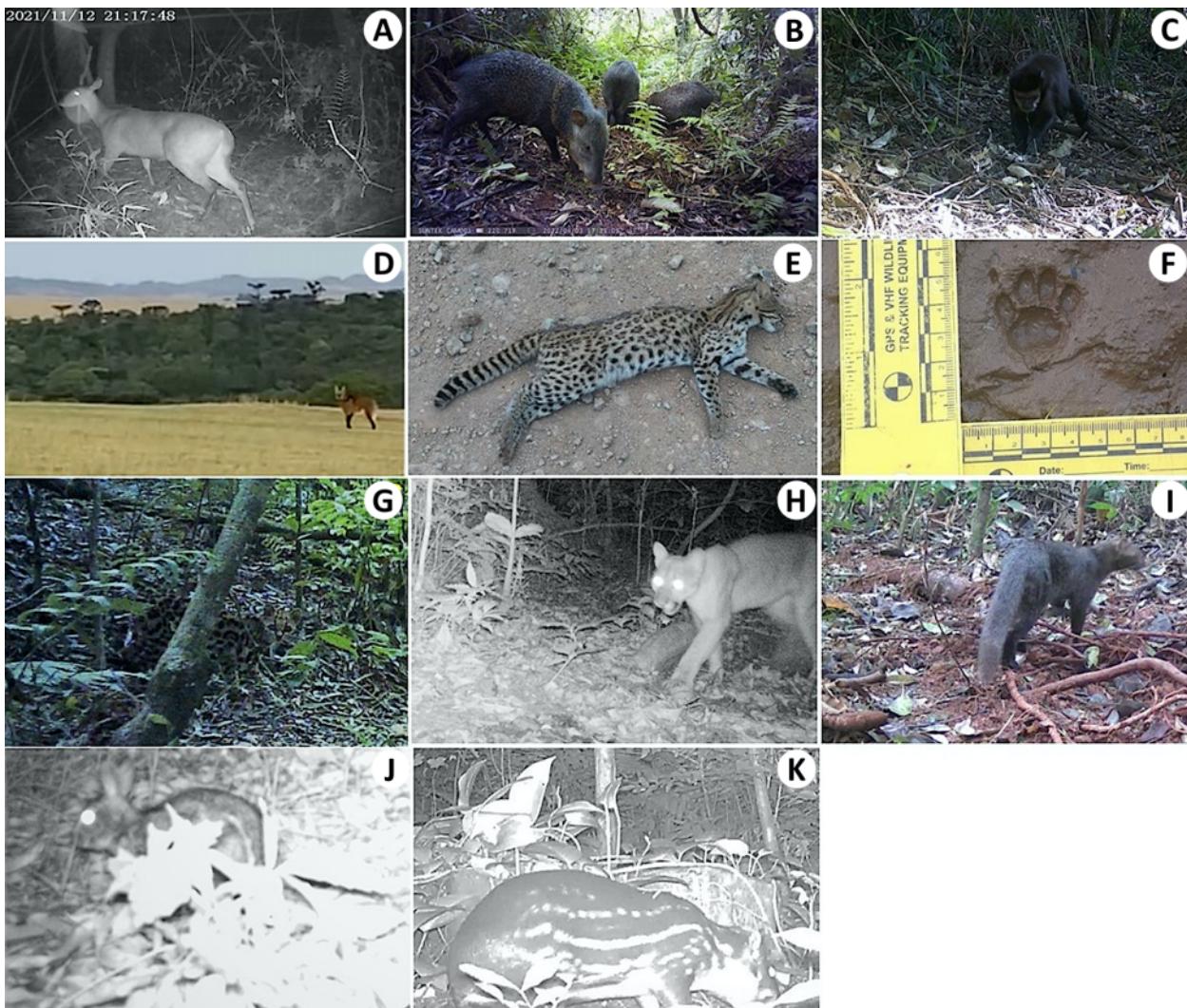
Fig. 3. Representatives of threatened species at the global, national, or state level in Paraná recorded in the present study. *Mazama gouazoubira* (A); *Dycotyles tajacu* (B); *Sapajus nigritus* (C); *Chrysocyon brachyurus* (D); *Leopardus guttulus* (E); Footprint of *Leopardus pardalis* (F); *Leopardus wiedii* (G); *Puma concolor* (H); *Herpailurus yagouaroundi* (I); *Sylvilagus brasiliensis* (J) e *Cuniculus paca* (K).

wide range of niches and play the role of top predators in the food chain, controlling the size of prey populations and helping maintain the balance of ecosystems (Reis et al., 2011). Although species of Carnivora have great mobility and capacity in exploring man-disturbed environments close to native vegetation, many populations of representatives of this order are rapidly declining throughout the Brazilian Atlantic Forest, and are particularly vulnerable to local extinction due to successive defaunation events (Bogoni et al., 2018; Pereira et al., 2021). Thus, we highlight the presence of five out of the seven species of felines that occur in the state of Paraná (*L. guttulus*, *L. pardalis*, *L. wiedii*, *H. yagouaroundi* and *P. concolor*), all them being threatened species (see ICMBIO, 2018; IUCN, 2023; PARANÁ, 2010). We also highlight the record of the canid *C. brachyurus* (Maned Wolf), which is primarily found in the Campos Gerais region. Some studies indicate that there has been a reduction in *C. brachyurus* population numbers over the past few decades, making records of this species scarce throughout Paraná territory (Pereira et al., 2020; Torres et al., 2013).

The record of species such as *M. gouazoubira*, *M. americana* and *D. tajacu* as representatives of the order Cetartiodactyla, and *C. paca* and *D. azarae* belonging to the Caviomorpha (in the Rodentia order), is important due to the ecological services performed by

these species in the environment. According to Elschot et al. (2015), large herbivores such as *M. gouazoubira* and *M. americana* have an important impact on ecosystem processes by controlling plant biomass and altering vegetation composition over time, thus contributing to ecological succession processes. Similarly, frugivores play important roles in phytodemographic dynamics and forest carbon stocks (Peres et al., 2016) and their presence is a good indicator of the integrity of the forest fragments. *Dicotyles tajacu* Linnaeus, 1758 has a low tolerance for disturbed habitats, which makes it predictive of environmental quality, and therefore its disappearance would indicate a highly disturbed habitat (Mazzolli, 2006).

Although we recorded a significant number of threatened species in the study area, we also obtained records for two exotic species (*L. europaeus* and *S. scrofa*) and another domestic species (*C. l. familiaris*). The European hare, in addition to being a direct competitor of the native Brazilian rabbit (*S. brasiliensis*), can alter the natural predation rates of carnivorous species in the region. (Buenavista & Palomares 2018). Wild boars (*S. scrofa*) are considered one of the top 100 invasive animal species in the world due to their destructive feeding habits and high ecological adaptability (Barrios-Garcia & Ballari, 2012). When domestic dogs enter a natural area, they are considered feral or invasive species, as they can survive without human assistance or intervention (Young et al., 2011). Invasive species pose a threat to native species due to competition for resources, predation, hybridization, and disease transmission, which can result in habitat loss, decreased biodiversity, and even extinction of native species (Young et al., 2011) especially in protected areas in Brazil (Lessa et al., 2016). Therefore, the presence of non-native and domestic species in EEMR and PMMP represents a risk to the other native species recorded, requiring mitigation and control measures in both areas.

Species inventories are a starting point from which biodiversity can be observed over time and provide essential data for long-term conservation planning (Bogoni et al., 2021). Among the species recorded in the municipality of Roncador, *M. gouazoubira, D. tajacu, S. nigritus, C. brachyurus, L. guttulus, L. pardalis, L. wiedii, P. concolor*, *H. yagouaroundi*, *S. brasiliensis* and *C. paca* are threatened on a local, national, or even international scale. Protected areas are a fundamental tool widely recognized for maintaining relatively intact biotas worldwide (Moilanen et al., 2009). In addition, it is an important tool adopted by the Brazilian government to protect threatened species at regional and national levels. Therefore, our study highlights the significance of the protected areas EEMR and PMMP as refuges for medium-sized and large mammals in the Central-Eastern-Western Mesoregion of Paraná state.

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