

## THE OCCURRENCE, ABUNDANCE, AND ACTIVITY OF DOMESTIC DOGS (*CANIS LUPUS FAMILIARIS* LINNAEUS, 1758) IN THE MATA OF SANTA GENEVRA CONSERVATION UNIT, CAMPINAS, BRAZIL – POSSIBLE IMPACTS AND MITIGATION PROPOSALS

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**Abstract:** The introduction of exotic species is currently the second largest cause of extinction. In this sense the domestic dog (*Canis lupus familiaris*) stands out, given its wide distribution and adaptive plasticity. Understanding the dynamics of dog occurrence in natural areas is of major importance in order to understand the impacts on native fauna. In this work, we aimed to carry out an updated survey of the presence of dogs in the Area of Relevant Ecological Interest Mata of Santa Genevra, focusing on the number of individuals, their periods and areas of greatest activity. Sampling was carried out using camera-traps on nine different trails in the area, with a sampling effort of 2754 camera-days. A total of 316 mammal records were obtained of which 28% documented the presence of dogs. The results point to greater activity of dogs in areas of extensive trails, clearings and forest edge, in addition to the preference for night periods and rainy season. The results were compared with the periods of activity of native non-flying mammals of the area, obtaining a similar occupation of places and periods, both of domestic dogs and native fauna. Finally, proposals were presented to mitigate this problem in the area.

**Keywords:** Alien species; anthropization; camera-trap; mammals; urban forest

### A OCORRÊNCIA, ABUNDÂNCIA E ATIVIDADE DE CÃES DOMÉSTICOS (*CANIS LUPUS FAMILIARIS* LINNAEUS, 1958) NA UNIDADE DE CONSERVAÇÃO MATA DE SANTA GENEVRA, CAMPINAS, BRASIL - POSSÍVEIS IMPACTOS E PROPOSTAS DE MITIGAÇÃO

**Resumo:** A introdução de espécies exóticas é, hoje, a segunda maior causa de extinção de espécies. Neste sentido, o cão doméstico (*Canis lupus familiaris*) se destaca, visto sua ampla distribuição e plasticidade adaptativa. Entender a dinâmica de ocorrência de cães em áreas naturais é de suma importância, a fim de compreender os impactos para a fauna nativa. Neste trabalho, visou-se realizar

um levantamento atualizado da presença de cães na Área de Relevante Interesse Ecológico Mata de Santa Genebra, com enfoque no número de indivíduos, seus períodos e áreas de maior atividade. A amostragem foi realizada com uso de armadilhas fotográficas em nove trilhas distintas da área, com esforço amostral de 2754 câmeras-dia. Foram obtidos 316 registros de mamíferos, dos quais 28% documentaram a presença de cães. Os resultados apontam para maior atividade dos cães em áreas de trilhas extensas, clareiras e borda da mata, além da preferência por períodos noturnos e estação chuvosa. Os resultados foram comparados com os períodos de atividade dos mamíferos não voadores nativos da área, obtendo-se uma ocupação semelhante de locais e períodos, tanto dos cães domésticos quanto da fauna nativa. Por fim, foram apresentadas propostas para mitigação desta problemática na área.

## INTRODUCTION

**S**pecies extinction and reduction in their abundance are occurring at increasingly alarming rates as a result of human action and at a speed comparable to, or even greater than, major geological extinction events (Barnosky et al., 2011). Among the different human activities that accelerate extinctions, the introduction of exotic species stands out (Leão et al., 2011; Sampaio & Schmidt, 2013; Bellard et al., 2016; MMA, 2016). This currently represents the second largest cause of global biodiversity loss, accounting for 40% of extinctions recorded since the 17th century (PRIMACK, 1998; MMA, 2006; CBD, 2006; Brandão et al., 2019).

Despite the prohibition by law of the introduction of exotic species in Conservation Units (CUs) (Federal Law 9.985/00), such species have confirmed records in many of the protected areas in the Brazilian territory, mainly dogs and cats (Chiarello, 2000; Vilela & Lamim-Guedes, 2014). However, the impact and consequences of the presence of these exotic species in natural areas and CUs in Brazil are still poorly understood, although the consequences of their introduction are already well-studied globally (Zalba & Ziller, 2007).

In this context, the presence of the exotic species *Canis lupus familiaris* Linnaeus 1758, Canidae, the domestic dog, requires our attention. This species has been recorded in 28 of the 71 National Parks in Brazil, and at least 69 CUs, but these numbers are still underreported (Lessa et al., 2016; Ribeiro et al., 2018; Instituto Hórus de Desenvolvimento e Conservação Ambiental, 2022).

Dogs are the most abundant domestic carnivores on the planet, with a cosmopolitan distribution. Their wide distribution, associated with the humans', enables their interaction with different species and in the most distinct ecosystems (Hughes & MacDonald, 2013; Vilela & Lamim-Guedes, 2014). Dogs are considered generalist-opportunistic organisms. Thus, they can feed on wild animals, carcasses, hit or

weakened animals, cubs, vegetables, fruits, seeds and even garbage (Nesbitt, 1975; Green & Gipson, 1994). They may exhibit solitary behavior but usually form collaborative groups with several individuals (Galetti & Sazima, 2006; Ziller & Zalba, 2007, Gompper, 2014). Thus, dogs can efficiently prey on small and medium-sized animals, up to large animals, when organized in packs (Scott & Causay, 1973; Galetti & Sazima, 2006).

In this context, domestic dogs represent a global threat to wild species, being responsible for the death of approximately 33,000 wild animals annually in Poland (Wierzbowska et al., 2016) and around 80 attacks on native animals in a year and a half of monitoring in India (Home et al., 2016). There are studies on the impact of domestic dogs in many other countries, such as the United States (Scott & Causey, 1973), Iran (Nayeri et al., 2021), Kenya (Kitala et al., 2001) and Zimbabwe (Butler & Du Toit, 2002).

Added to this cosmopolitan distribution, it is estimated that a large proportion of the world's dog population (between 600 and 700 million) are free-ranging dogs (Gompper, 2014). These are dogs with no owner, or those that do not have their whereabouts strictly controlled by their owners but still resort to humans as an alternative to obtain resources such as food and shelter (Gompper, 2014; Vilela & Lamim-Guedes, 2014).

Free-ranging are responsible for the main documented impacts of dogs on native animals (Young et al., 2011). This is because they are constantly in natural areas, given the lack of space restrictions, and can impact the native fauna in different ways. For instance, by changing predator-prey interactions, preying on native animals, competing for resources (territory, food, water) and introducing diseases and disturbance (Nesbitt, 1975; Green & Gipson, 1994; Butler & du Toit, 2002; Lacerda et al., 2009; Silva-Rodriguez & Sieving, 2011; Young et al., 2011; Hughes & MacDonald, 2013; Gompper, 2014; Curi et al., 2016; Silva et al., 2018; Allemand et al., 2019; Bianchi et al.,

2020).

In addition, dogs tend to exhibit a distinct invasion process compared to wild species, not establishing populations in natural areas and hardly becoming totally independent from humans (Ribeiro et al., 2018). The opportunity to turn to humans for food and protection means that dogs can overcome unfavorable conditions in the wild and their populations do not respond numerically to prey predation as native predators do. In other words, the reduction in prey populations does not lead to a reduction in feral dog numbers due to a lack of resources, so they can deplete wild populations to the point of local extinction (Galetti & Sazima, 2006; Young et al., 2011; Hughes & MacDonald, 2013; Gompper, 2014; Allemand et al., 2019).

The presence of alien species in natural fragments and protected areas is facilitated by human factors, such as anthropization, urban sprawl and increased human population density in nearby areas (Pysek et al., 2008; Sampaio & Schmidt, 2013). In this context, regions with older histories of human occupation, such as the coastal region and the Atlantic Forest, in Brazil, suffer more intensely from anthropogenic actions and exotic species when compared to areas of more recent occupation, such as the Amazon region (Tabarelli et al., 2005; Galetti & Sazima, 2006; Sampaio & Schmidt, 2013).

The proximity of anthropized areas to natural fragments also facilitates the inappropriate release and abandonment of pets (dogs and cats) by humans in natural areas (Pontes & Mello, 2013; Pysek et al., 2008). In the case of the presence of domestic dogs in natural fragments, their presence is more related to characteristics of human occupation around the area than to physical characteristics such as landscape and vegetation (Lacerda et al., 2009).

Another important factor influencing the entry, presence and settlement of alien species in natural fragments is the edge effect (Metzger, 1999; Primack & Rodrigues, 2001; Mello & Costa, 2012). The presence of dogs inside protected areas tends to be lower in the central areas of the fragments and higher in the peripheries, where the edge effect is higher, mainly in view of the more open forest formations and the ease of circulation in the fragments (Lacerda et al., 2009; Gompper, 2014; Silva et al., 2018). Butler & du Toit (2002) demonstrated the influence of the edge effect on dog presence in a study conducted in rural and protected areas of Zimbabwe. From the use of experimental carcasses, it was observed that free-ranging and feral dogs of the region located and consumed the carcasses present in the surrounding and edge areas of the reserve. However, there was no record of

interaction of dogs with the carcasses left in the more secluded areas of the reserves.

Finally, another factor that influences the presence of exotic species in natural areas is the presence of trails. Currently, trails are commonly found in natural areas and CUs as a way to enable human contact with nature (Ikemoto et al., 2009; Eisenlohr et al., 2013; Pontes & Mello, 2013). Trails can also act as entry and exit points to natural areas for dogs, as well as easy dispersal corridors to different sites or resources in natural areas (Baret & Strasberg, 2005; Nemec et al., 2011; Eisenlohr et al., 2013).

A CU that is in a context encompassing these various factors is the Area of Relevant Ecological Interest (ARIE) Mata de Santa Genebra, in Campinas, São Paulo. This area is an urban remnant of semideciduous seasonal forest and, perhaps surprisingly, has records of several species, among them some that are threatened in the State of São Paulo, such as the howler monkey (*Alouatta guariba clamitans* Cabrera, 1940, Atelidae), the cougar (*Puma concolor* Linnaeus, 1771, Felidae) and the ocelot (*Leopardus pardalis* Linnaeus, 1758, Felidae) (Magioli et al., 2014). Due to its surrounding context with intense human presence (with both rural and urban areas), the area has suffered historically with the presence of exotic fauna in its interior, especially dogs and cats (*Felis catus* Linnaeus, 1758, Felidae) that compete and prey on native fauna, are host of parasites, spreading diseases and therefore impact the ecosystem (Galetti & Sazima, 2006; Magioli et al., 2014; ICMBIO-MMA, 2021). The presence of dogs in the interior of this CU is widely documented and may be related to the local extinction of two species: Gray Brocket (*Subulo gouazoubira* Fischer, 1814, Cervidae) and Agouti (*Cuniculus paca* Linnaeus, 1766, Cuniculidae) (Galetti & Sazima, 2006).

This work sought to survey the updated frequency of occurrence of domestic dogs on the trails of Mata de Santa Genebra considering the influence of aspects such as human presence in the surroundings, the edge effect, the use of trails by dogs and the peak of dogs' activity in terms of hours of the day and months. From this, we aimed to assess possible impacts on the native fauna, as well as proposals for the mitigation or reduction of the problem involving domestic dogs in this area.

## MATERIAL AND METHODS

### STUDY AREA

Mata de Santa Genebra is located in the district of Barão Geraldo, in Campinas, in the Brazilian state of São Paulo, under the geographical coordinates 22°44'45" S,

47°06'33" W. This CU has 251.7 ha, being the largest remnant of Semideciduous Seasonal Forest in the Municipality of Campinas (ICMBIO-MMA, 2021).

#### CHARACTERISTICS OF THE SURROUNDING AREA

The surroundings of Mata de Santa Genebra are characterized by a mix of urban and rural landscapes. The urban area corresponds to one-third of the perimeter of the CU's surroundings (Fig. 1). The nearby rural areas are mainly composed of monocultures of sugarcane and family farms (ICMBIO-MMA, 2021).

The biological characteristics of the surroundings include three types of forest formations: the Semideciduous Seasonal Forest, characterized by a seasonal partial loss of leaves; the Paludosa Forest, characteristic of swampy and waterlogged areas; and the Cerrado, characterized in the region by a non-dense formation, composed mainly of shrubs and spaced trees (Lecoq-Muller, 1947; Leitão Filho, 1982; Torres et al., 1994).

The fauna that is present in the surroundings of Mata de Santa Genebra stands out for its great diversity of species, mainly birds and mammals, with records of small, medium and even large animals, such as the cougar (*Puma concolor*) and the maned wolf (*Chrysocyon brachyurus* Illiger, 1815, Canidae) (Gaspar, 2005; Passos, 2009; Magioli et al.,

2014; ICMBIO-MMA, 2021).

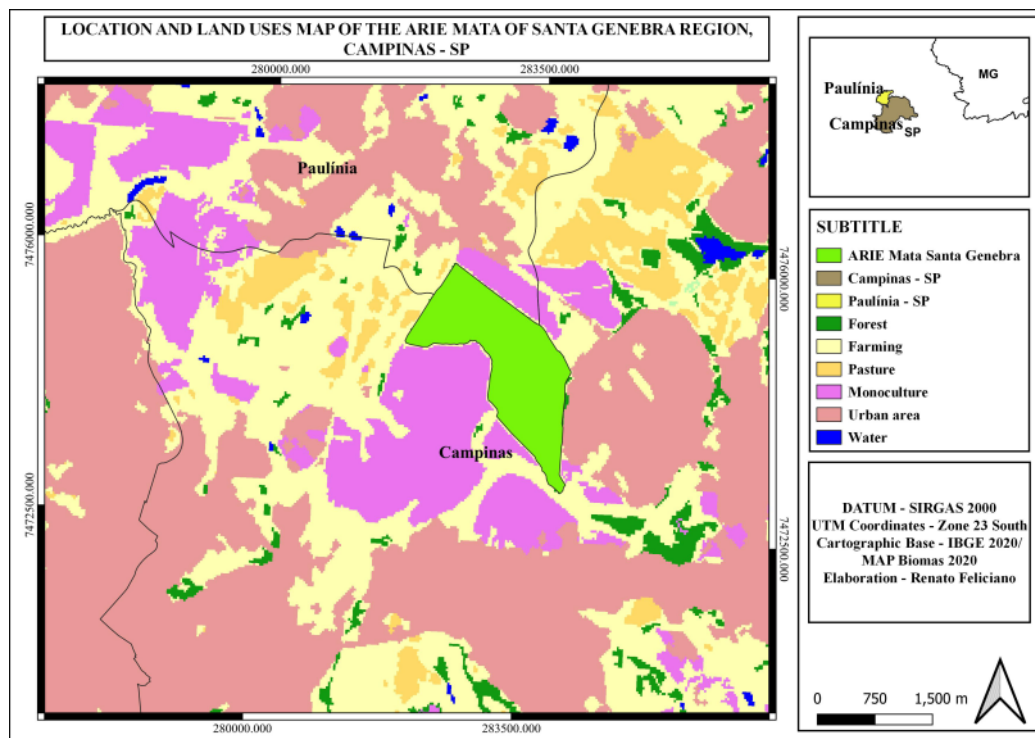
#### PHYSICAL AND BIOLOGICAL CHARACTERISTICS OF ARIE MATA OF SANTA GENEBRA

According to the Koeppen classification, our study area has a subtropical dry winter climate (Cwa). During the winter, its temperatures drop below 18°C and, in the summer, they are above 22°C, with an increased rainfall (rainy season) (Rolim et al., 2007; Blain, 2011). Inside the CU, the vegetation is mainly composed of the Semideciduous Seasonal Forest (85% of the total composition of CU) and the Paludosa Forest (15% of its total composition) (ICMBIO-MMA, 2021).

Its fauna is characterized by a great diversity of vertebrates and arthropods, even considering the urban context of the surroundings. The species found are representative of the different biomes and domains of the region, with taxa typical of the Semideciduous Seasonal Forest, the Paludosa Forest and the Cerrado. More than 150 species of birds and about 50 species of mammals have been recorded in the area (Brown & Freitas, 2003; ICMBIO-MMA, 2021).

#### CAMERA-TRAPS

We used 09 Bushnell TrophyCam traps, model 119436C (Bushnell Outdoor Products,



**Fig. 1.** Location map of ARIE Mata de Santa Genebra. Campinas, São Paulo, Brazil.

Kansas, USA). These traps were distributed near the existing trails (n = 9, P2, P3, P4, P5, P6, P7, P8, P9 and P10) (Fig. 2). We included P1 on the map of collection points because the presence of dogs in it was recorded by personal observation; no cameras were installed at it. During the filming, we chose non-selective sampling without the use of baits.

The images were collected in the period between July 15, 2021 and May 15, 2022, both in the rainy months and dry periods, as proposed by Srbek-Araujo & Chiarello (2007) and Ribeiro-Silva, et al. (2018). We installed the cameras at selected points along the trails, considering aspects of vegetation, proximity to water bodies and the presence of mastofauna traces. The sampling effort was calculated by multiplying the number of cameras (9) by the number of days the cameras were active (306), resulting in the trap-day effort proposed by Srbek-Araujo & Chiarello (2007).

We configured the cameras to be active 24 hours a day, collecting 40-second videos, with low LED exposure, high sensor sensitivity, and 3-second intervals between the shots. They were fixed on trees with at least 15 cm in diameter and at 45 cm from the ground and secured with straps to ensure fixation in the desired position and good quality frames.

#### ACTIVE SEARCH

We searched for traces of dogs in the sampled trails, as proposed by Galetti & Sazima (2006). The active searches were carried out once a month, from July 20, 2021 to April 20,

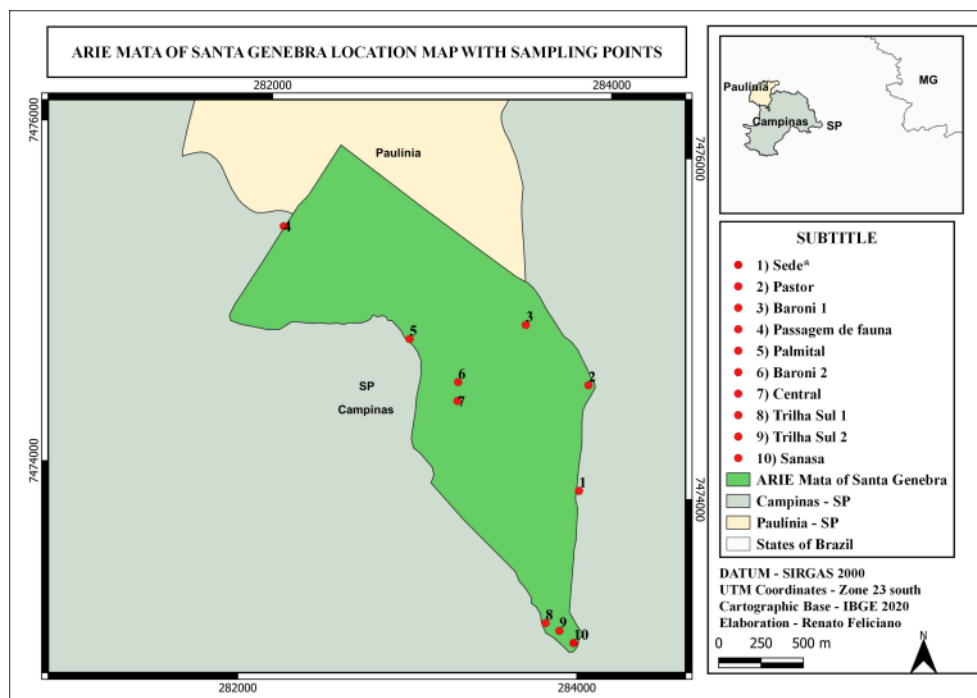
2022, on the transects where P7 is located (1,059 meters long) and the transect between P1 and P2(723 meters long). Sampling time on each trail varied between 30 and 60 minutes. We sampled these two transects on five different dates each, totaling 10 events, five hours of active searching on each trail, with four days of sampling taking place from 9:00 a.m. to 11:00 a.m. and six days from 1:00 p.m. to 3:00 p.m.

#### DATA ANALYSIS

From the data collected, we prepared Kernell density maps using the QGIS (QGIS Geographic Information System) software, obtaining the places of greatest activity and distribution of dogs in the CU graphically. We also made graphs referring to the photoperiod and seasons with greater activity of the dogs.

The images were used to characterize the packs, assessing the number and size of individuals, classifying them as small (40 cm shoulder height), medium (60 cm shoulder height) or large (greater than 60 cm shoulder height) and differentiating sex. Records of the same individual, in the same location, made up to five minutes apart, were considered the same record.

We used the exact date and time of the records to register the period of activity and season. Records made between 6:01 a.m. and 6:00 p.m. were classified as daytime and those between 6:01 p.m. and 6:00 a.m. as nighttime (12 hours per period). Regarding the seasons, the period from April to September was



**Fig. 2.** Location map ARIE Mata de Santa Genebra, Campinas, São Paulo, Brazil. with highlighted camera trap collection points. Legend: \* - P1 did not have cameras, but dogs were recorded from personal observation.

considered dry and from October to March, it was considered rainy (six months per season).

To understand the differences between the presence of domestic dogs in the CU between the day/night periods and the dry/rainy seasons, we used General linear model ("GLM") functions, with Poisson family distribution, since they are count data. These analyses were carried out using the RStudio application (version 4.3.2) (RStudio Team, 2020). We investigated the assumptions of the fitted models by checking for normal distribution of the residuals using histograms and normal Q-Q plots, and homoscedasticity by visualizing the fitted model values vs. standardized residuals. In the first analyses, we used Periods (day x night) as the predictor variable and the number of domestic dog records obtained as the outcome variable (number of records in each hour of each period). In the second analysis, we used Seasons (dry x rainy) as predictor variable and

the number of domestic dog records obtained as the outcome variable (number of records in each month of each season).

All the data in this work has been deposited in the repository of the Federal University of São Carlos (UFSCar).

## RESULTS

With a total sampling effort of 66,146 hours (66,096 hours of filming: 2,754 camera-days x 24 hours + 50 hours of transect sampling), we obtained 316 mammal records, 88 of which were domestic dogs (27.8% of total records), and 228 were native mammals. Eleven mammal species were identified, 10 of which are native and one, the domestic dog, is exotic. Among the identified species, we recorded six orders, of which Carnivora stood out, with a greater diversity and number of records (Tab 1). Twenty-four dog individuals were also identified, nine of which were males,

**Tab. 1.** Mammal species recorded in camera traps during the 2021/2022 period at ARIE Mata de Santa Genebra, Campinas, São Paulo, Brazil.

Order	Family	Species	N	Ni	% tot. records
Didelphimorphia	Didelphidae	<i>Didelphis albiventris</i>	19	n.a.	6,01
		<i>Didelphis aurita</i>	5	n.a.	1,58
Primata	Cebidae	<i>Sapajus nigritus</i>	1	1	0,32
Xenarthra	Dasypodidae	<i>Dasypus novemcinctus</i>	30	n.a.	9,49
Carnivora	Canidae	<i>Cerdocyon thous</i>	26	3	8,23
		<i>Canis lupus familiaris*</i>	88	24	27,85
	Procyonidae	<i>Procyon cancrivorus</i>	1	1	0,32
	Felidae	<i>Puma concolor</i>	115	5	36,39
		<i>Leopardus pardalis</i>	3	1	0,95
Lagomorpha	Leporidae	<i>Sylvilagus minensis</i>	5	n.a.	1,58
Rodentia	Caviidae	<i>Hydrochoerus hydrochaeris</i>	23	n.a.	7,28

two females and the others of unidentified sex.

**PHOTOPERIOD AND SEASON**

The results showed a significant accumulation of domestic dog activity records on the trails of Mata de Santa Genebra during the night ( $P < 0.0001$ ;  $z = 4.46$ ), with peaks of records between 21:01 p.m. and 01:00 p.m. (Fig. 3A). Moreover, the results showed a significant accumulation of domestic dog activity records on the trails of Mata de Santa Genebra in the rainy season ( $p < 0.0001$ ,  $z = 5.44$ ), with November having the highest number of records (Fig. 3B).

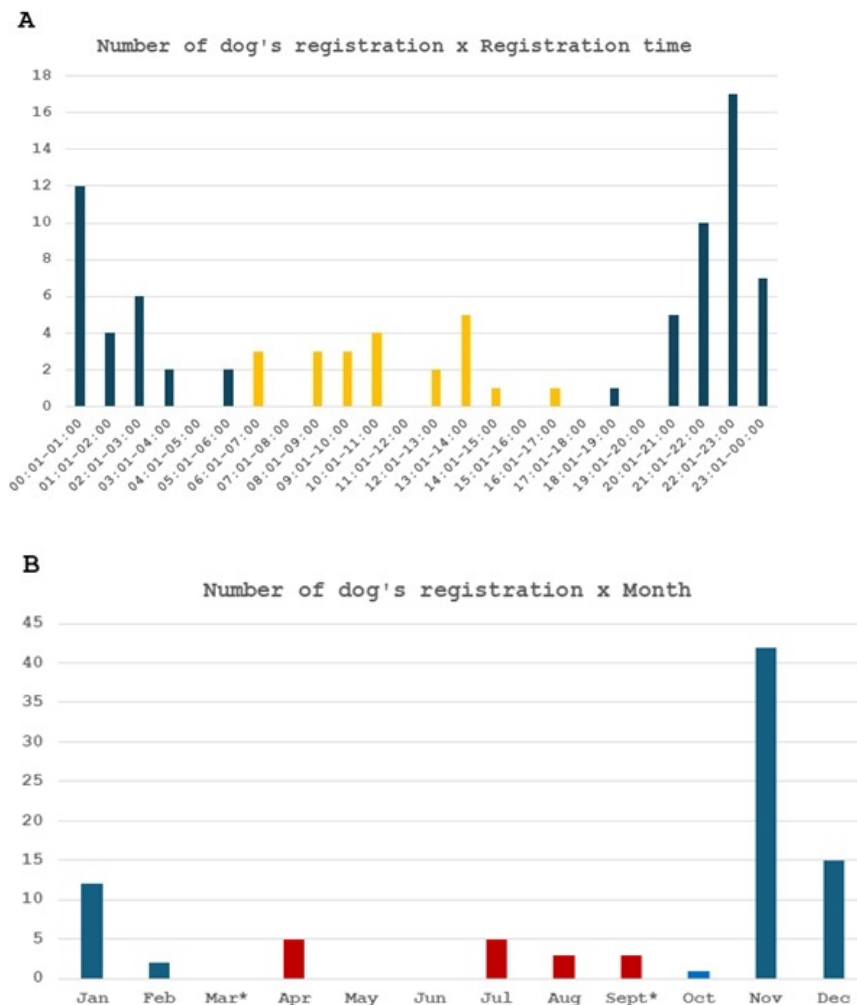
**OCCURRENCE OF DOMESTIC DOGS AND NATIVE MAMMALS ON TRAILS**

Records of domestic dogs showed a

higher concentration of capture on the trails of P7, with 46 records (52.2% of total dog records), and P3, with 26 records (29.5% of total dog records) (Figs. 4-, 5).

We assessed the use of the CU's trails by native mammals by segregating them into two main groups, taking into account their ecological niches and potential to act as prey or predators of dogs. Because the cougar is the only species present capable of preying on domestic dogs, we differentiated the groups between them and other mammals (considered medium and small mammals).

Cougars were the species with the highest number of records, being recorded in almost all the trails sampled. According to the results, the trails with the highest number of activity records of this species were P7, with 47



**Fig. 3.** A. Number of records of domestic dog activity at ARIE Mata de Santa Genebra, Campinas, São Paulo, in relation to photoperiod. Legend: Dark blue - times considered night photoperiod; Yellow - times considered day photoperiod; B. Number of records of domestic dog activity in ARIE Mata de Santa Genebra, Campinas, São Paulo, in relation to the dry and rainy seasons. Legend: Blue - Months that include the rainy season; Red - Months that include the dry season; \* - Months in which the transition between seasons occurs.

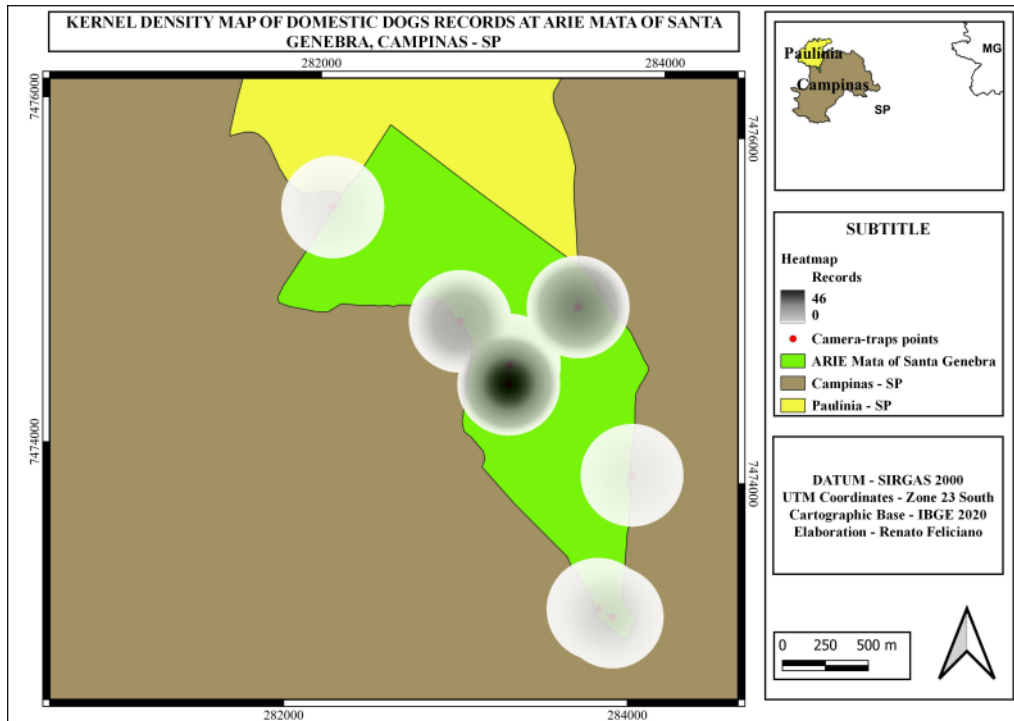


records (40.8% of the total cougars records); P4, with 28 records (24.3% of the total cougars records); P2, with 17 records (14.7% of the total cougars records); and P6, with 15 records (13% of the total cougar records) (Fig. 6).

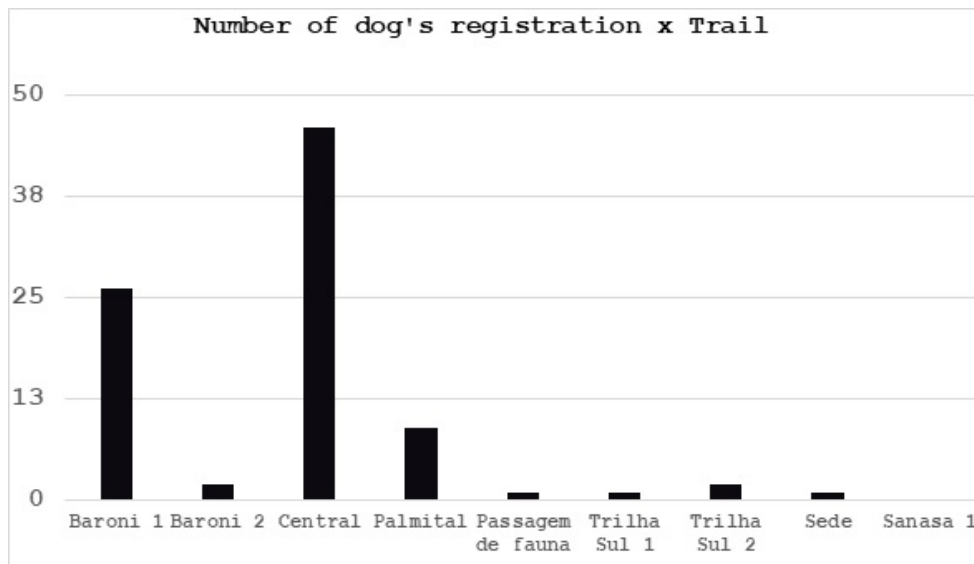
It is worth mentioning that the study period included the reproductive season. Thus, the area that would normally have only one resident cougar presented a population of five

(the resident female, the male present during the mating period and three cubs).

Regarding the other native mammals identified, the results showed an intense use of two trails, as follows: P6 with 56 records (51% of the total records of medium and small mammals); and P7 with 23 records (21.2% of the total records of medium and small mammals) (Fig. 7).

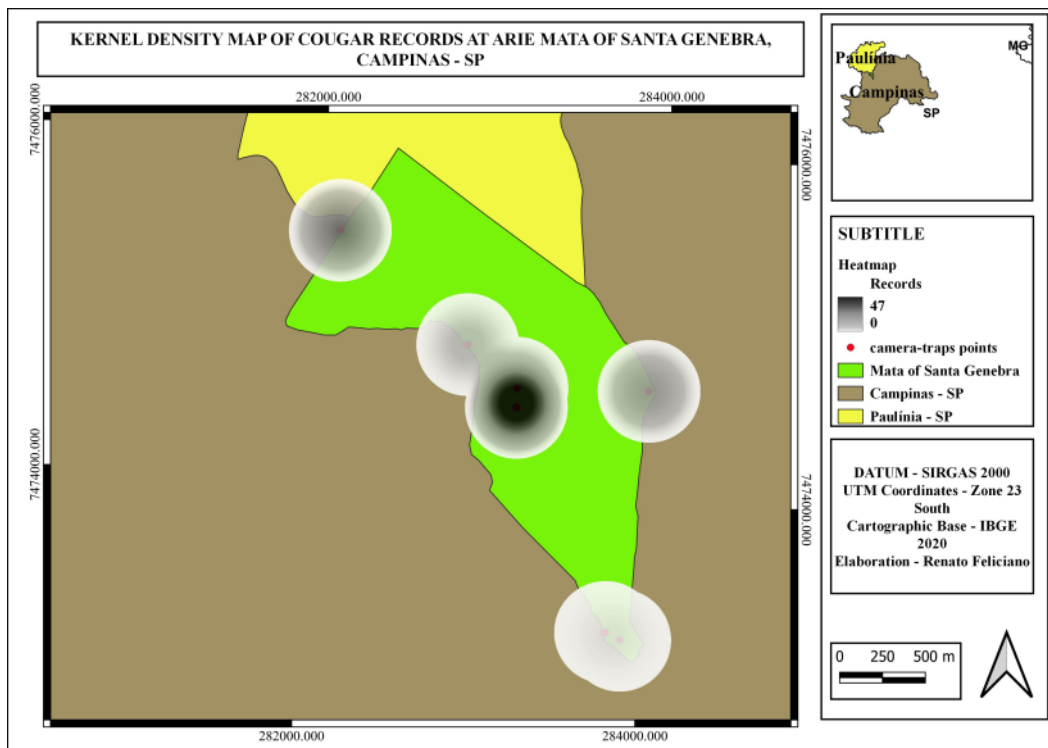


**Fig. 4.** Kernell density map of domestic dog records in ARIE Mata de Santa Genebra, Campinas, São Paulo, Brazil.



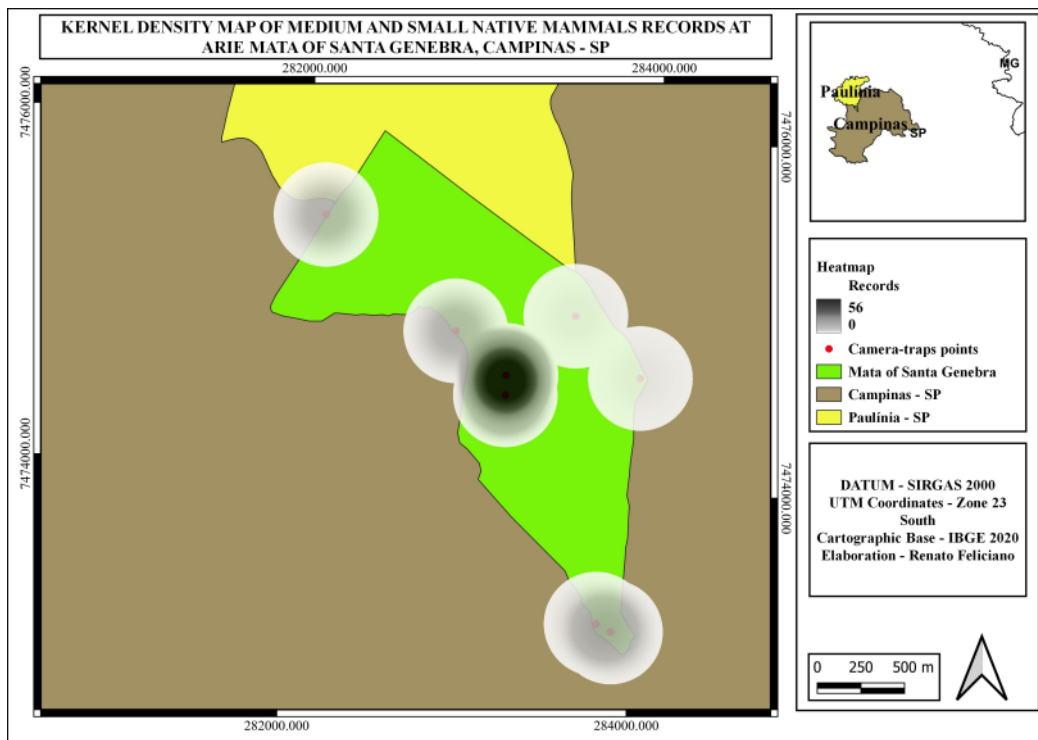
**Fig 5** Number of records of domestic dogs per trail at ARIE Mata de Santa Genebra, Campinas, São Paulo. Brazil.





**Fig 6-** Kernell density map of cougars (*Puma concolor*) records in ARIE Mata de Santa Genebra, Campinas, São Paulo, Brazil.

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**Fig 7 .** Kernell density map of medium and small native mammal records in ARIE Mata de Santa Genebra, Campinas, São Paulo, Brazil

## CHARACTERIZATION OF THE DOGS

From the analysis of the images, we could characterize the dogs individually regarding their size, coloration, fur pattern and shape. Of the 24 dogs identified, we classified 20.83% as large; 54.17% as medium-sized; and 25% as small. In addition, of these 24 dogs, we could identify the sex of 11: nine were male and two were female.

Regarding the organization into packs the shots recorded two groups of well-organized domestic dogs in pack formation. The first pack was composed of three males and one female (medium-sized). This group was recorded 21 times, between the months of November 2021 and January 2022 (about 23% of the total dog records).

The other group contained four individuals: two males and two of unidentified sex. The second group was recorded 6 times, between the months of August 2021 and January 2022 (approximately 6.8% of total dog records). The other records were of solitary dogs or dogs that were not recorded together more than once, so they could not be characterized as permanent packs.

## DISCUSSION

### THREAT TO NATIVE FAUNA

Mata de Santa Genebra is home to three threatened species of non-flying mammals: the cougar, ocelots and howler monkeys, all of which present some degree of threat either in the state of São Paulo, in the country or both. Howler monkeys are preyed by domestic dogs, which is one of the main current threat factors to their populations (Bicca-Marques, et al. 2015). Predation of this species by dogs has been previously documented in the area (Galetti & Sazima, 2006). Thus, the continuous presence of dogs in this CU represents an impact on the remaining populations of this species (Galetti & Sazima, 2006; Pereira et al., 2019). Domestic dogs do not represent a predation threat to cougars and ocelots. However, the presence of these dogs is related to disturbances, disputes over territory and competition for resources with these felines (Vilela & Lamim-Guedes, 2014; Azevedo et al., 2018). In addition, there are records of individuals of both native species infected with canine distemper virus (canine morbillivirus) in Brazil, demonstrating that infection from contact with sick domestic dogs can occur (Jorge et al., 2010; Lima et al., 2020). Other diseases recorded in these species from contact with domestic animals were rabies (Lyssavirus sp.), *Leptospira* spp., *Leishmania* spp. and ectoparasites (Jorge et al., 2010).

As these are endangered species with declining populations in the State of São Paulo and with few individuals in the study area. It is important to implement actions that prevent their contact with domestic dogs to avoid population downsizing in the area and, in more critical cases, local extinction.

The threats concerning the crab-eating fox are mainly competition for resources and territory, disturbance and disease transmission (distemper, rabies, mange and other parasites) (Jorge et al., 2010; Teodoro et al., 2018). Similarly, another species that can be affected by diseases is the crab-eating raccoon (*Procyon cancrivorus* Cuvier, 1798, Procyonidae) (Jorge et al., 2010). Also, there are some records of this species being preyed upon by domestic dogs in literature (Rangel & Neiva, 2013).

Considering both recorded opossum species (*Didelphis albiventris* Lund, 1840, Didelphidae and *Didelphis aurita* Wied-Neuwied, 1826, Didelphidae) plus the nine-banded armadillo (*Dasypus novemcinctus* Linnaeus, 1758, Dasypodidae), the threat dogs represent to them is mainly predation, with several records already reported (Galetti & Sazima, 2006; Campos et al., 2007; Rangel & Neiva, 2013; Pereira et al., 2019).

In the case of capybaras (*Hydrochoerus hydrochaeris* Linnaeus, 1766, Caviidae) the scenario is different. The occurrence of capybara predation by domestic dogs is poorly documented and probably not very recurrent. Nevertheless, predation of this species by dogs has already been recorded (Brito et al., 2004; Campos et al., 2007). The low predation of capybaras by dogs is presumably due to two main factors: the large size of the species (1.3 meters long and 50kg on average) and its social and territorial behavior (Ferraz & Verdade, 2001).

Capuchin monkeys (*Sapajus nigritus* Goldfuss, 1809, Cebidae), although little recorded in the camera traps, are abundant in our study area, with well-demarcated and numerous family groups. This species has been recorded in several studies as being preyed by dogs, being more vulnerable during moments of foraging on the ground and feeding (Galetti & Sazima, 2006; Oliveira et al., 2008; Pereira et al., 2019). Another species that is subject to a great threat of predation by dogs in the area is the cottontail (*Sylvilagus minensis* Thomas, 1901, Leporidae). This species showed the highest number of records of carcasses preyed by dogs in Mata de Santa Genebra in a study by Galetti & Sazima (2006), and such predation is facilitated by the fact that they inhabit forest edge regions and clearings.

Thus, the species that are the most vulnerable to predation by dogs are those of smaller size, unable to climb, that display

curiosity in their behavior and inhabit edge areas or clearings (Galetti & Sazima, 2006). In addition, the threat of new pathogens introduction is a reality. Among the dogs recorded inside the CU, four puppies stood out, left in the P1 area and collected by José Pedro de Oliveira Foundation employees (FJPO - the organization responsible for managing Mata de Santa Genebra).

These puppies were duly referred to responsible organs and, later, according to information from FJPO employees, it was found out that they were infected with the canine distemper virus. With this, it is possible to assume that dogs found in the region surrounding Mata de Santa Genebra and, possibly, some of the individuals found within the CU may be contaminated by pathogens, facilitating the infection of individuals of the native species found in the region.

Finally, it is important to emphasize the impact that the interaction of domestic dogs with the native fauna can have on dogs and even humans. During interaction with wild animals, dogs can become infected with certain pathogens, some of which have zoonotic potential. This can occur through processes known as "spill-over" and "spill-back", forming a network of infection between the native fauna, dogs and humans, with the possibility of transmission in different directions (Alho, 2012; Ferreira, 2018).

In the CU, the interaction of dogs with capybaras or areas used by them can result in the infestation of these dogs by ticks and, consequently, there is a potential for contamination by the bacterium *Rickettsia rickettsii* Wolbach, 1919, Rickettsiaceae, responsible for the Brazilian spotted fever (Ghasemzadeh & Namazi, 2015; Luz et al., 2019). Another disease that can affect dogs through contact with infected animals is rabies. Both infections are highly lethal to humans and are considered zoonotic diseases. Thus, the presence of domestic dogs in natural areas also represents a public health problem, due to the potential to facilitate the transmission of pathogens between wildlife and humans (Aggarwal & Ramachandran, 2020).

#### PHOTOPERIOD AND SEASON

Our results indicate that dogs are more active at night in the study area. Previous studies have shown that the period and intensity of activity of dogs can vary according to their age, diet and environment. Thus, young dogs that feed infrequently during the day tend to be more active at night, while older dogs that feed more often during the day tend to be more active during the day and rest at night (Zanghi et al., 2013). In addition, another factor that can influence dogs' activity in different periods

is the lifestyle and environment where they live (Adams & Johnson, 1993). Banerjee & Bhadra (2021) conducted a study in which the activity period of free-ranging dogs in various locations in India was assessed. They observed that the moments of activity are greater than those of rest, both in day and night periods, having a configuration similar to peaks of activity interspersed with periods of rest. Still, comparing day and night, dogs were more active during the day.

The difference between activity periods of dogs in the CU may be related to foraging. The times of greatest activity of native species were much higher during the night. Among the species considered as potential prey for domestic dogs, 95.2% of the activity records were nocturnal. Thus, greater activity at times similar to those of native species would allow greater ease of predation and food obtainment for dogs (Galetti & Sazima, 2006).

Their more intense activity at night may also be associated with free-roaming dogs that live near the area or free-ranging dogs on farms surrounding the CU. Part of the rural population has the habit of releasing dogs to "protect" their properties at night, without controlling their whereabouts. Thus, given the proximity of these properties to the CU, many dogs end up entering the fragments, either to search for food or simply sporadically (Campos et al., 2007; Hughes & MacDonald, 2013; Majumder et al., 2014).

The dogs present in the CU already showed hunting behavior predominantly at night, as shown by Galetti & Sazima (2006). Thus, the present results reinforce the previously observed behavior and the tendency of domestic dogs in this area to prioritize the night for hunting and foraging.

Regarding the seasons, the presence of domestic dogs in Mata de Santa Genebra was more intense during the rainy season. This variation can be considered normal and recurrent, being influenced by the location and the individuals' preferences (Campos et al., 2007; Santos, 2011). In this case, the preference for the rainy season, may be related to the greater availability of resources during this season. As it is an area classified as Semideciduous Seasonal Forest, the availability of resources such as water, fruits and animals that consume fruits, tends to be greater during the rainy season (Regolin, 2017; Piotto et al., 2019; Watine et al., 2022).

Canids in general, especially domestic dogs, show broad ecological plasticity. Thus, they are able to withstand long periods of drought, rain and some days without feeding. In addition, dogs are generalist and opportunistic mesopredators, not restricting their diet to just one resource. So they can easily overcome the

absence of a specific resource by exploring other potential food (Nesbitt, 1975; Sillero-Zubiri, 2004; Vilela & Lamim-Guedes, 2014).

Thus, it can be considered normal that the presence of domestic dogs in the area occurs in both the dry and rainy seasons, even if with some distinctions between them.

#### **OCCURRENCE OF DOMESTIC DOGS AND NATIVE MAMMALS ON TRAILS**

The results point to the intense use of the region P7 by dogs. In addition, the low number of records at points close to the CU's boundaries and the large number of records at point P3 stood out. The most likely hypothesis in relation to the low number of records in the boundaries of the CU is the absence of sampling in the places where the dogs are using to enter and exit it (which were not found). Regarding P3, the record of intense dog activity may be related to two distinct factors: the expansion of an irregular human occupation near the edge of the CU, in the buffer zone and the region of the sampling point, in such a way that dogs from these occupations are increasingly close to the forest (Butler & Bingham, 2000; Kitala et al., 2001; Galetti & Sazima, 2006); or the fact that the CU is small in size, making it easier for dogs to move through denser forest areas and farther from the forest boundaries. This is because, at any point, they are always close to clearings, edges, trails or the forest contour, not suffering the pressure of the forest environment as intensely as in large forested areas. This second factor can also be used to explain the presence of dogs at P7, which is in a clearing area (Brokaw, 1998; Primack & Rodrigues, 2001; Ferraz, 2011; Ribeiro et al., 2018).

We also registered the number of records of native mammals per sampling area of the CU. In the case of potential prey of dogs, the highest number of records was made at P6 and P7. Both are close to one another and located in areas with extensive trails that connect the boundaries of the CU, in addition to being close to water bodies and with resources available. This context may represent greater facility of displacement and access to the various areas of the CU, with ease of locomotion, escape and access to different types of resources (Chiarello, 1999; Chiarello, 2000; Araújo et al., 2008; Ribeiro et al., 2018). The highest numbers of records of the cougar (a potential predator) were also at P6 and P7. However, the number of records was higher at P7 than at P6, the opposite of what was observed for the other species. This distribution confirms what was expected, reinforcing the importance of trails that interconnect different points of the CU also for the native fauna, which use it as a route to travel to places of great interest or with great availability of resources (Srbek-Araújo & Chiarello, 2007; Aximoff et al., 2015). In

addition, the concentration of predators at these points may be related to the greater concentration of prey at these same sites, since the predators tend to hunt in the microhabitats and periods when their prey are more probable to be found (Hoogenboom et al., 1984; Greene, 1986).

The constant presence of domestic dogs at P7, with a large number of observations, may also follow the model proposed for native predators. This is because dogs play the role of mesopredators and, therefore, should seek areas with more available resources, such as prey to feed on. They may as well be using this extensive trail as the main form of locomotion within the fragment.

#### **CHARACTERIZATION OF THE DOGS**

The records allowed the identification of some individuals in terms of their sex and size. The sex ratio among those individuals we could sex showed a tendency towards a greater number of males than females, a pattern also found in the literature (Butler & Bingham, 2000; Kitala et al., 2001; Fiorello et al., 2006). The higher presence of males relative to females in free-ranging dogs cannot be explained by a higher mortality rate of female individuals relative to males, as there are no studies or evidence to support this hypothesis (Daniels & Bekoff, 1989; Fiorello et al., 2006). Thus, what may explain such a conformation is a selection bias on the part of humans, who give preference to male dogs since they are believed to be more efficient for protection, guarding and hunting (Kitala et al., 2001). The higher number of males may also indicate a constant influx of domestic dogs into the CU, with the arrival of new individuals and recurrent recruitment of others by the packs present. This is because groups of feral dogs tend to have a higher proportion of females when already well established (Daniels & Bekoff, 1989). Thus, the inverse proportion observed in this study may indicate that these groups are still in formation, or it may be related to the fact that male dogs move over larger areas and distances when in search of females for mating.

Regarding the size of the dogs, there was a higher proportion of medium and large individuals. This is also probably related to the preference of humans for medium and large animals for activities such as guarding, protection and hunting, especially in rural environments. (Cavalcanti et al., 2015).

The study allowed the identification of 24 individuals, eight of whom were organized in two distinct packs of four dogs each. The organization of dogs into packs is a natural and common process among different canid species (Butler & du Toit, 2002; Galetti & Sazima, 2006). Domestic dogs, in free-ranging or feral

conditions, can form well-organized groups with great cohesion (Lacerda et al., 2009). Pack organization represents greater facility and success of capture and predation of wild animals, in addition to increasing the ability to compete for resources and territory, which increases the chances of survival in the wild (Butler & du Toit, 2002; Galetti & Sazima, 2006; Lacerda et al., 2009; Santos, 2011). At the same time, group aggregation may be a factor that promotes and accentuates the process of domestic dogs towards feralization. Dogs that are unowned or free-ranging may aggregate with other free-ranging or feral dogs and thereby increase their independence from humans (Boitani & Ciucci, 1995; Santos, 2011). Another factor that can directly influence the formation and cohesion of feral dog packs is the degree of genetic relatedness between individuals (Cafazzo et al., 2010; Santos, 2011).

In the present study, individuals did not appear to have a high degree of kinship, given the great morphological diversity among the members. Despite this, the presence of smaller individuals with characteristics of young dogs was recorded (two dogs in the footage appeared to be juveniles), which may indicate that the dogs present in the CU are reproducing and initiating this process of aggregation into family groups.

The results obtained in relation to the presence of organized packs and the number of dogs in Mata de Santa Genebra are in line with the results presented in the study of Galetti & Sazima (2006). This is confirmed since the presence of dogs inside the CU still exists, even in pack formations, as well as the impact of the presence of these dogs on native fauna is sensitive.

The expectation that the number of dogs inside the area had increased in the last 15 years, given the intensification of human occupation in the surroundings, was also confirmed. In comparison to the study by Galetti & Sazima (2006), where only one pack composed of 3 to 6 individuals was recorded in the CU, the current study recorded two packs with four individuals each and 16 other individuals that were recorded wandering independently. This demonstrates an increase in the aggregation of dogs in the area into packs and the increased presence of domestic dogs in the CU.

Regarding the feral or free-ranging status of these dogs, it was not possible to characterize them homogeneously. From the images it was possible to distinguish dogs that are recurrently present inside the CU, exploring the area at different times and with different organizations. However, since feral dogs are defined as those that are completely independent of human resources and there is

still no record of dogs being born inside the area, it is difficult to characterize them as such. The most likely scenario is that these dogs are free-ranging and simultaneously take advantage of resources from humans and resources found inside the CU.

However, it is worth mentioning that the fact that they are not considered feral does not mean they have a lower impact on the CU or its native fauna. Free-ranging dogs can organize themselves into packs, explore natural areas and exhibit territorial behavior. In addition, since they do not depend exclusively on the resources obtained in the CU, these dogs can reach higher population densities than if they were feral groups, managing to resort to human resources to overcome unfavorable conditions such as lack of food, obtainment of safer shelters when weather conditions are unfavorable and to recover from diseases (Young & Ono, 2018; Carvalho et al., 2019; Pereira et al., 2019; Nayeri et al., 2021). Thus, free-ranging dogs can impact natural areas at least as severely as feral dogs (ICMBIO-MMA, 2019; Pereira et al., 2019).

#### **IMPACTS ON NATURAL AREAS AND PROPOSALS FOR MITIGATION**

Understanding the dynamics of Mata de Santa Genebra in relation to the presence of domestic dogs can help us better understand the same phenomenon in other natural areas and CUs. In the context of this study, the influence of some factors on the presence of dogs in the area is evident, such as the edge effect (also considering clearings and trails), the size of the CU, the characterization of the surroundings and the proximity of the human population (Srbek-Araújo & Chiarello, 2007; Eisenlohr et al., 2013; Gompper, 2014; Aximoff et al., 2015; Silva et al., 2018; Ribeiro et al., 2018).

Small CUs with a large influence of the edge effect are very common in Brazil, especially in areas of the Atlantic Forest and Cerrado. In these cases, constant monitoring of the boundaries of the CUs, as well as raising awareness among the surrounding population, can be key aspects in the prevention of the entry of domestic dogs.

As a way to control the presence of domestic dogs in natural areas, two approaches are usually prioritized: the removal of individuals or their eradication (Vilela & Lamim-Guedes, 2014). Concomitant to these, there are also actions focused on the castration of dogs and actions aimed at raising awareness of the surrounding population for responsible animal care (Smith et al., 2019).

For long-term control of free-roaming dog populations, the most suitable approaches are the combination of dog castration programs and

population awareness about responsible guardianship, since they have a positive synergistic effect for population control when applied together. For immediate controls, on the other hand, the best option is the removal of the dogs from inside the CU. However, this is a method that must be applied continuously, since the dog population tends to return quickly to equilibrium when control is ceased (Smith et al., 2019).

Another fundamental aspect is the monitoring of the limits of the CUs and the surrounding regions in order to know the places used by dogs as an entrance and, if possible, locate their owners (Rangel & Neiva, 2013). Finally, actions focused on the vaccination and medication of dogs in the surrounding areas help with problems related to the transmission of diseases between dogs, native fauna and humans (Rangel & Neiva, 2013; Vilela & Lamim-Guedes, 2014).

The results of our study suggest the importance of carrying out a dog population diagnosis in the areas surrounding the CU to understand the problem in the region and identify the most cost-effective strategies. It is also suggested that monitoring and studies be carried out in new areas, both within Mata de Santa Genebra and other CUs. In our study area, it would be interesting to install traps in areas outside the trails, covering both the edge and center of the CU. That would allow us to see if there is variation between these different contexts. In addition, monitoring in other CUs with a similar situation would make it possible to draw parallels, share difficulties and solutions or even promote joint actions between the areas.

## CONCLUSION

This work allowed us to identify the distribution patterns, occupation sites, periods of the day and seasons of greater activity of domestic dogs on the trails of the CU Mata de Santa Genebra. This contributed to our understanding of the dynamics of the presence of domestic dogs in this area and in others that share a similar context.

The data obtained can aid the management of the CU by pointing out possible mitigation measures. It also explores some management policies that may be more suitable in this case. The data also allows us to suggest that native mammals and domestic dogs are occupying the same areas and at similar times within the CU, so it is possible to predict the existence of an encounter between the native species and dogs. It was also possible to observe an increase in the number of dogs and their level of organization in packs compared to previous studies carried out in the area. Finally,

our work updates the already existing data in the literature on the presence of domestic dogs in CUs in Brazil.

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