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YOU SAY GOODBYE, AND I SAY HELLO: THE GIANT ANTEATER (*Myrmecophaga tridactyla*) ACTIVITY PATTERN IN RESPONSE TO TEMPERATURE AND HUMAN PRESENCE

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ABSTRACT. Mammals modulate patterns of activity and habitat use in response to local biotic and abiotic factors. The giant anteater (*Myrmecophaga tridactyla*) presents cathemeral activity. That is, it adjusts to the daily temperature conditions in a protected area in Central Brazil. We tested the hypothesis that giant anteater may be avoiding the extreme temperatures of the Brazilian Cerrado displaying more significant twilight activity (milder hours), avoiding being exposed during unfavorable hours of the day, and losing or overheating. We also tested whether the anteaters avoid being active during the day, reducing encounters with humans. The protected area is inserted in a highly disturbed landscape, experiencing anthropic pressure within and around it. The description of the giant anteater's activity pattern in the protection area was carried out by analyzing photos obtained by camera traps from March to June 2018. The average temperature was 19.3 °C during the study period, ranging from 6.7 °C to 31.5 °C. The giant anteater showed a pattern of nocturnal and twilight activity, while humans showed exclusively daytime activity. The dissimilarity observed between the giant anteater's activity pattern and human activity supports the hypothesis that there is an influence of the risk of predation on the temporal activity of this species. We recorded several invasions of humans and dogs in restricted areas during the day. These results show the influence of anthropogenic factors on the anteater's behavior in the study area. However, this pattern can be favorable to the conservation of the population by reducing the likelihood of agonistic encounters with humans and dogs. We recommend long-term studies and evaluation of temporal overlap with dogs to better understand the patterns observed.

RESUMO. VOCÊ DIZ ADEUS, E EU DIGO OLÁ: PADRÃO DE ATIVIDADE DO TAMANDUÁ-BANDEIRA (*MYRMECOPHAGA TRIDACTYLA*) EM UMA ÁREA COM PERTURBAÇÃO HUMANA. Os mamíferos modulam os padrões de atividade e uso de habitat em resposta aos fatores bióticos e abióticos locais. O tamanduá-bandeira (*Myrmecophaga tridactyla*), é uma espécie de atividade catemeral, ou seja, se ajusta às condições de temperatura diária em área protegida no Brasil Central. Testamos a hipótese do tamanduá-bandeira evitando as temperaturas extremas do Cerrado brasileiro com maior atividade crepuscular (horas mais amenas). Testamos também se o tamanduá evita estar ativo durante o dia, reduzindo encontros com humanos. A área protegida está inserida em uma paisagem altamente perturbada, sofrendo pressões antrópicas dentro e em seu entorno. A descrição do padrão de atividade do tamanduá-bandeira na área de proteção foi realizada por meio da análise de fotos obtidas por armadilhas fotográficas, no período de março a junho de 2018. Durante o período de estudo, a temperatura média foi de 19.3 °C, variando de 6.7 °C a 31.5 °C. O tamanduá-bandeira mostrou padrão de atividade noturna e crepuscular, enquanto humanos mostraram atividade exclusivamente diurna. A dissimilaridade observada entre o padrão de atividade do

tamanduá-bandeira com a atividade humana apoia a hipótese da existência de influência do risco de predação na atividade temporal dessa espécie. Registramos diversas invasões de humanos e cães em áreas restritas durante o dia. Esses resultados mostram a influência de fatores antrópicos no comportamento do tamanduá na área de estudo. Esse padrão pode, no entanto, ser favorável à conservação da população ao reduzir a probabilidade de encontros agonísticos com humanos e cães. Recomendamos estudos de longo prazo e avaliação da sobreposição temporal com cães para melhor compreensão dos padrões observados.

Key words: Anthropogenic impact, behavioral ecology, camera-trap, protected area.

Palavras-chaves: Área de proteção, armadilha fotográfica, ecologia comportamental, impacto antrópico.

INTRODUCTION

There is consensus that species' characteristic patterns of activity represent an imperative aspect of the natural history of mammals. Mammals may show a diurnal, crepuscular, nocturnal, or cathemeral (evenly distributed throughout the 24 h of the daily cycle) activity pattern (Tattersall 2006; Bennie et al. 2014; Yan et al. 2020). Abiotic and biotic factors, such as environmental temperature, precipitation, availability of resources, species interactions, and luminosity, can have strong influences on the activity patterns of mammals and the stability of those patterns (Gaston et al. 2017; Guiden & Orrock 2020; Van Der Vinne et al. 2019). Typically, animals distribute their time between periods of rest and activity, modulating their behavior according to conditions in their environments (Ashby 1972; Beier & McCullough 1990; Beltran & Delibes 1994). Species often exhibit strategies to avoid unfavorable factors as conditions shift (Shaw et al. 1987; Van Schaik & Griffiths 1996). For example, a species may show an active period shift to diminish potential contact with predators and competitors or maintain temporal overlap with prey activity (Ramesh et al. 2012; Frey et al. 2017).

Human activities influence fauna behavior, including space, foraging activities, and social and reproductive activities (Andrén 1994; Parks & Harcourt 2002; Treves & Karanth 2003; Ohashi et al. 2013; Paolino et al. 2016; Zapata-Ríos & Branch 2016; Paschoal et al. 2018). Species in humans proximity may exhibit behavioral modifications that enable them to avoid inter-species conflicts, including temporal activity shifting. Human disturbance can cause fear in wildlife, promoting nocturnality (Sibbald et al. 2011; Gaynor et al. 2018). According to Frid & Dill (2002); the stimulus of disturbance caused by human presence is analogous to a predation risk. The consequences of human avoidance can indirectly affect the fitness and dynamics of the population through the energy expenditures and the loss of opportunities of animals. Species responses to potentially threatening

stimuli, such as loud noises and rapidly approaching objects, may affect foraging, growth, parental care, and mating (Frid & Dill 2002; Cresswell 2008). Some mammalian species have shifted toward nocturnal habits in response to human presence, seeking to minimize contact (Bennie et al. 2014).

Compared to rest periods, activity periods are more energy-intensive because of the energy expenditure for locomotion, feeding, thermal stress responses, and predator avoidance (Lagos et al. 1995; Fernandez-Duque 2003; Mourão & Medri 2007; Vieira et al. 2010; Mendonça et al. 2015; Rota et al. 2016). Optimization of activity periods can involve activity trade-offs (McNab 1963, 1984; Lucherini et al. 2009; Caravaggi et al. 2018), especially in the species of the Superorder Xenarthra, which have a low body temperature and a low metabolism regarding its body size (Messias-Costa et al. 2001; Miranda et al. 2014; Maccarini et al. 2015; Attias et al. 2018). Changes in activity may also enable animals to avoid unfavorable temperature schedules that could affect the permanence of species in the environment.

The giant anteater (*Myrmecophaga tridactyla* Linnaeus, 1758) is threatened (vulnerable status) globally (IUCN 2014) and within Brazil (Machado et al. 2008), but considered already extinct in Belize, Nicaragua, Guatemala, and Uruguay (Fallabrino & Castiñeira 2006), as well as in the Brazilian states of Espírito Santo (Passamani & Mendes 2007) and Santa Catarina (FATMA 2011). The giant anteater's major threats are anthropogenic activities that cause habitat loss as well as fires events, feral dog presence in their habitat range, illegal hunting, and road-kills (Miranda et al. 2015). Giant anteaters occupy several habitats, ranging from open fields, dry forests, and savannas to tropical forests (Miranda et al. 2014; Di Blanco et al. 2015; Quiroga et al. 2016). They can be active during the day and at night, depending on abiotic factors such as temperature and rainfall (Camilo-Alves & Mourão 2006; Di Blanco et al. 2016). In general, anteaters are active during warm hours

(17–27 °C) when seen in open areas, such as campo limpo, one of the phytophysiognomies of biome Cerrado (Medri & Mourão 2005; Camilo-Alves & Mourão 2006; Mourão & Medri 2007). In Pantanal, during periods of the day with extreme temperatures (< 17 °C and > 28 °C), they favor protective locations closed in by vegetation (Camilo-Alves & Mourão 2006). This behavioral pattern changes across seasons and in response to other local conditions; thus, giant anteaters exhibit different activity start, peak, and end times between biomes. Accordingly, this species is cathemeral, adjusting according to conditions (Di Blanco et al. 2016).

Anthropogenic influences on fauna within the reserve area where our study was conducted have not been elucidated. Moreover, there is little data available regarding the influence of human presence on protected areas occupied by anteaters and the role of this mutual coexistence on the anteater's ecology. Understanding the factors that influence the pattern of activity of the giant anteater and its plasticity in the face of human disturbances is essential to understand the threats to the species. This study aimed to characterize the giant anteater's activity pattern in a protected area of the Cerrado in the Brazilian Central Plateau. We estimated the overlap of *M. tridactyla* activity with that of humans captured in our photographs. We expected that anteaters would be most active at twilight when temperatures are mild and would enable them to avoid exposition during the hottest hours of the day in the dry season (Camilo-Alves & Mourão 2006; Di Blanco et al. 2016).

Additionally, we tested the hypothesis that giant anteaters would be less active during the hours that humans are most active. Given the intense diurnal anthropogenic activity within and around the study area, nocturnal activity would reduce potential encounters with humans, permitting anteaters to avoid possible threats. The giant anteater's natural predators are big cats, as well as, potentially, humans (Taber et al. 1997; Wolff 2001; Azevedo et al. 2018).

MATERIALS AND METHODS

Study area

The study was conducted in the Environmental Protection Area Gama e Cabeça de Veado – EPAGCV (15°54'44.7"S, 47°52'10.9"W), which is a protected area of the Cerrado Biosphere Reserve (Law No. 742 1994) that encompasses about 25 000 hectares in the Federal District of Brazil (Fig. 1). The prevailing climate in the region is tropical savanna (Köppen classification) with annual precipitation ranging from 1 200 mm to 1 700 mm. The dry season runs from April to September and the rainy season from October to March. The average annual temperature varies

from 18 °C to 22 °C. The EPAGCV has high environmental heterogeneity, encompassing several phytophysiognomies of the Cerrado biome (Unesco 2003).

The EPAGCV (hereafter EPA) was founded with the primary objective of protecting the headwaters of the Gama and Cabeça de Veado streams. To protect the integrity of these drainage waterways from increasing anthropogenic pressures, the EPA has been classified as a high-value conservation area of the Cerrado in the Federal District (Unesco 2003). It is classified as a reserve for sustainable use; the unit has environmental preservation and education, allowing access for tourist activities, and scientific experiments in minor and determined locations upon proper authorization (Unesco 2003). The reserve area includes, in addition to protected areas, rural housing, urban centers, and the Brasília International Airport (Felfili & Santos 2004). There are sites for recreational use and sites exclusively for research. However, the protected area faces problems with its surroundings with the disorderly increase of individual houses and condominiums, influencing the landscape and causing direct impacts on biodiversity. The invasion of exotic species, e.g., dogs, and illegal tourism and hunting, are also recurrent problems reported by managers (Pers. Comm.). This study was carried out in the IBGE Reserve, Jardim Botânico de Brasília Reserve, and Água Limpa/UnB Farm - (hereafter FAL) within the EPA (Felfili & Santos 2004; Ribeiro 2011). Together with the FAL experimental and agricultural activities, the Jardim Botânico de Brasília Reserve presents several hiking trails. All three sites allow researches.

Sampling design

We installed one camera trap (Bushnell Trophy Cam HD) in each of the 58 study sites, sampled in rotation, to investigate the daily activity patterns of the giant anteater from March to June of 2018. We installed camera traps in tree trunks, approximately 45 cm from the ground and 1000 m between sites. Each camera remained active 24 hours/day for 15 consecutive days and programmed to take pictures at one-minute intervals. During the sampled period, meteorological data were obtained from the local AgroClima Bulletin (www.fal.unb.br). On the Água Limpa/UnB Farm, the study area has a weather station for use in teaching and research.

Statistical analysis

We organized the photos according to the species photographed, noting the time and site of the record. We used photographs of the same species taken with the same camera only when they were taken with a ≥ 1 -hour difference to ensure record independence. Uniformity of activity distribution throughout the 24-hour circadian cycle was assessed with the Rayleigh test in Oriana software v.4 (Kovach Consulting Services, Wales, UK). We calculated the overlap between the activities of anteaters and humans using the package Overlap (Meredith & Ridout 2016) in R software, with an estimator of 1 (ideal for small samples, <75). The overlap coefficient can vary from 0 (no overlap) to 1 (total temporal overlap in activities) (Linkie & Ridout 2011).

RESULTS

We obtained 45 records of anteaters (*M. tridactyla*) and 60 of humans. These species presented distinct

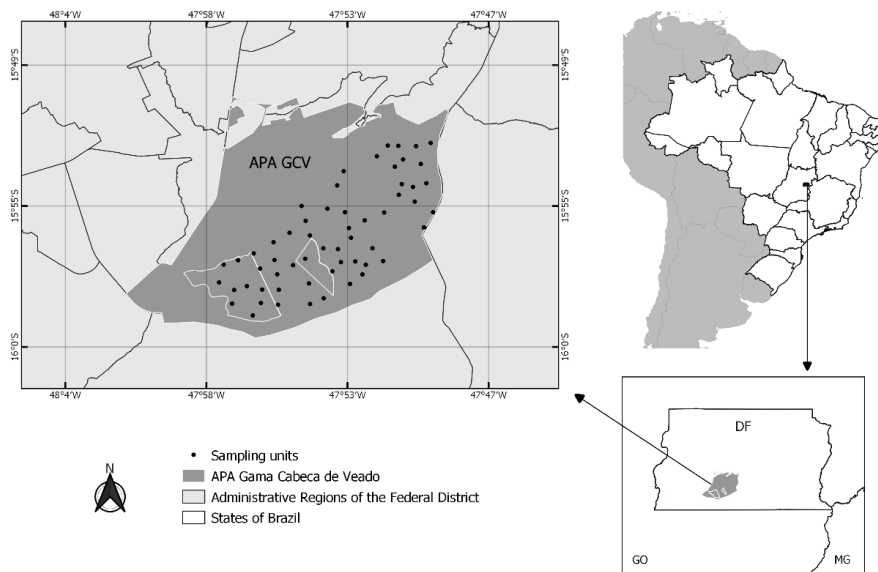


Fig. 1. Location of the Environmental Protected Area Gama e Cabeça de veado (EPAGCV) within the Federal District of Brazil (DF). Black dots are camera-trap sampling units.

patterns of activity. The giant anteater showed a nocturnal and crepuscular activity pattern, while humans showed a diurnal pattern (Fig. 2). The average temperature recorded by the EPA meteorological station during the study period was 19.3 °C. The maximal temperature mean was 27 °C (22.1 °C - 31.5 °C), and the minimal was 13.1 °C (6.7 °C - 19.3 °C) (Fig. 3). The Rayleigh test did not show a uniform circadian activity pattern for anteaters ($Z = 22.1$; $p < 0.001$) or humans ($Z = 40.1$; $p < 0.001$).

Anteaters were found to have low activity overlap coefficients (Fig. 4) with humans ($\hat{\Delta}_1 = 0.147$) (Table 1). Anteaters showed their lowest activity density during the hours when pumas were active. As shown in Figure 2 and 4, the nadir of anteater activity density occurred in the early morning hours (6:00~9:00 h) with an average temperature of 16.9 °C. Their activity level remained low until late afternoon, when they showed a rapid increase in activity density, leading to an extended high activity density period from twilight through the middle of the night. Then, they presented a sustained very high activity density (>0.08) from ~18:00 h to ~24:00 h (maximum at ~22:00 h), with a mean temperature of 22.3 °C, followed by a rapid decline from 02:00~06:00 h (mean 18 °C). In contrast, humans showed a diurnal

pattern with a minor activity density peak in the morning and a major activity density peak in the mid to late afternoon. These anthropogenic records are mostly from visitors, except for the record of two guards and a researcher (Fig. 5). We recorded several human invasions of equestrians and hikers, although the presence of these people is partially allowed. In the points of restricted access, it was possible to observe an intense illegal use of the area by cyclists, in some cases groups of 10 people. None of those registers indicated the presence of illegal hunters.

DISCUSSION

Central Brazil has developed very rapidly since Brasília's creation, the country's capital (Lucarelli et al. 1989), changing the regional landscape. This fast growth of the urban environment of the Brazilian Federal District could be a threat for populations that persist. In addition to its small size, the EPA is limited by an urban matrix of human settlement, urban constructions, and highways. This research was the first study carried out in a highly urbanized matrix seeking to understand the relationships between temporal overlaps in the Central Cerrado.

Tabela 1

Overlap coefficient ($\hat{\Delta}_1$) for daily activity pattern between giant anteaters (*M. tridactyla*) and humans, in the EPAGCV, DF, Brazil, during the dry season, in 2018.

Species	Overlap	95%CI
	Coefficient	
<i>M. tridactyla</i> - Human	0.147	0.087–0.238

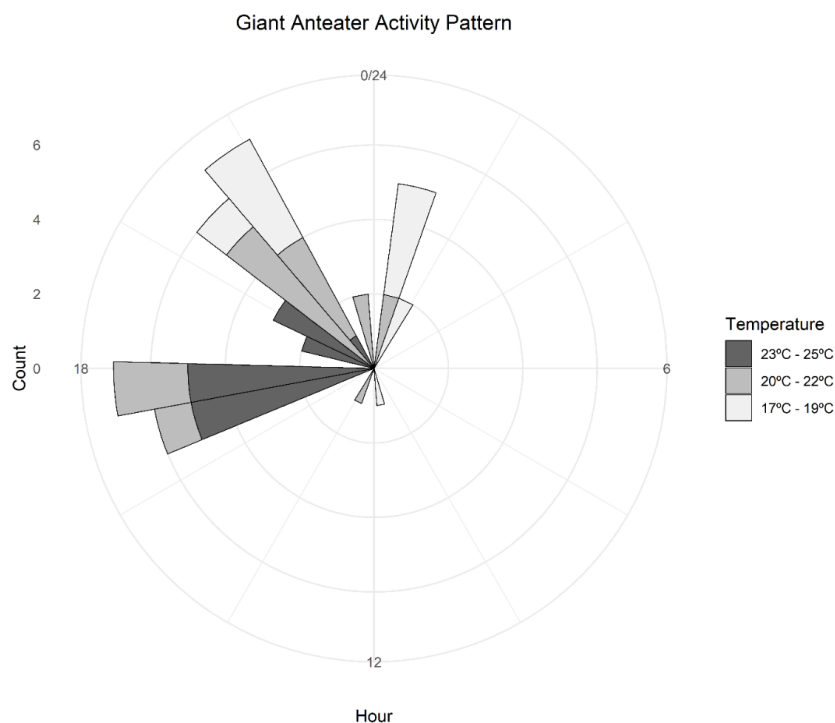


Fig. 2. Patterns of activity of giant anteaters (*M. tridactyla*) with ambient temperature at the registration time in the EPAGCV, Federal District, Brazil. Radial bar size represents the activity density within each period, and colored in grayscales for each temperature range. The chart is divided into 24 hour-long periods.

The pattern of crepuscular and nocturnal activity observed for the giant anteater in this study was consistent with our hypothesis and corroborated results found in studies conducted in other biomes (Montgomery & Lubin 1977; Shaw et al. 1987; Miranda 2004; Camilo-Alves & Mourão 2006). However, these studies were conducted in large conservation areas, or natural areas, with a less

disturbed landscape. The pattern of activity observed for the giant anteater, a low-metabolism species due to its body size compared to other mammals, is likely influenced by environmental temperature (McNab 1984). A nocturnal pattern enables animals to rest in areas protected from direct sunlight by vegetation during the warmest hours of the day and to be active during relatively cool, mild-temperature hours

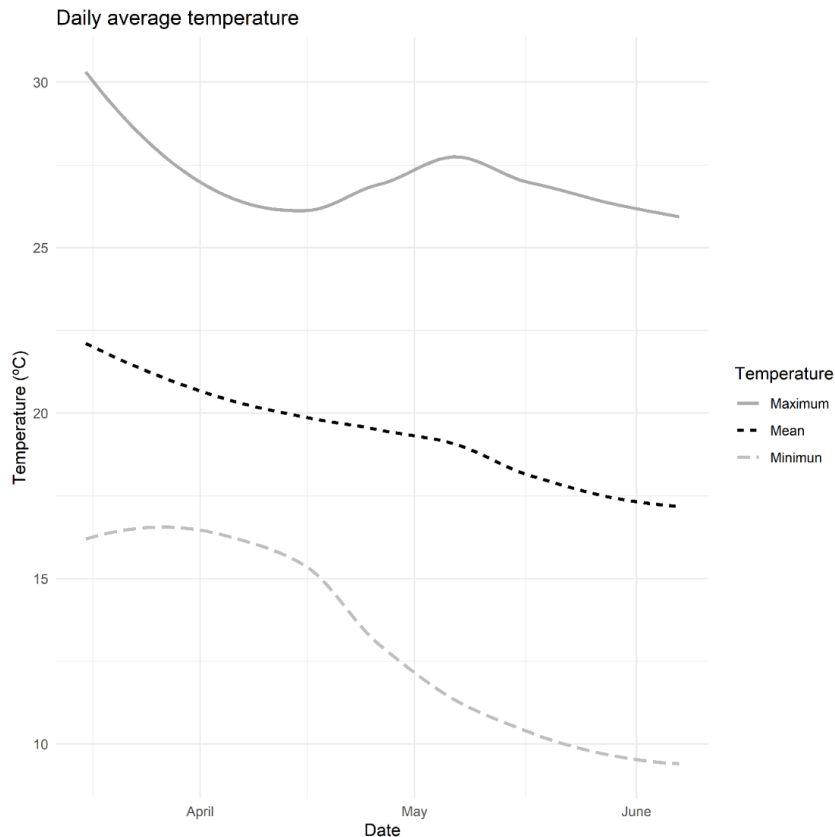


Fig. 3. Maximum, mean and minimum temperature recorded during the sampling period. Data obtained from the Água Limpa / UnB Farm weather station within the EPAGCV.

(Camilo-Alves & Mourão 2006; Mourão & Medri 2007; Di Blanco et al. 2016). According to the EPA weather database, peak daytime temperatures during the study reached up to 31.5 °C in the afternoon.

Camilo-Alves & Mourão (2006) reported that giant anteaters in the Pantanal exhibit a more nocturnal activity pattern with greater utilization of forested habitats, allowing them to rest on hot days (28–30 °C). Anteaters were active between sunset and night in 25 °C of daily average ambient temperature. Some studies noted that the giant anteater might have some flexibility in its daily activity pattern, sometimes being active during the afternoon (Blake et al. 2012; Di Blanco et al. 2016). However, we did not observe that flexibility in the present study. The propensity of animals to show such plasticity in their periods of activity may differ according to climate conditions and local daily temperatures. Our result may reflect the study's seasonality. The present study was conducted in a transition period, the end of the

rainy season (March) and the first half of the dry season (April–June), when the mean temperatures were hot (range 22.1 °C – 31.5 °C) from the morning through the early afternoon. We expect the same pattern of anteater behavior in the dry season peak, when there is an increase in the mean temperature, intense insolation, low humidity in the air, and reduced rainfall. In a study conducted in Venezuela during the dry season, giant anteaters exhibited exclusively nocturnal behavior (Montgomery & Lubin 1977).

Temporal partitioning of a niche is a phenomenon wherein species exhibit differentiated activity patterns to avoid potential antagonistic encounters, such as predation and competition (Ramesh et al. 2012; Frey et al. 2017). Thus, the niche's temporal partitioning may also explain the present results, which showed that anteaters had shallow activity levels during the hours when potential threats (humans) were most active. More specifically, the giant

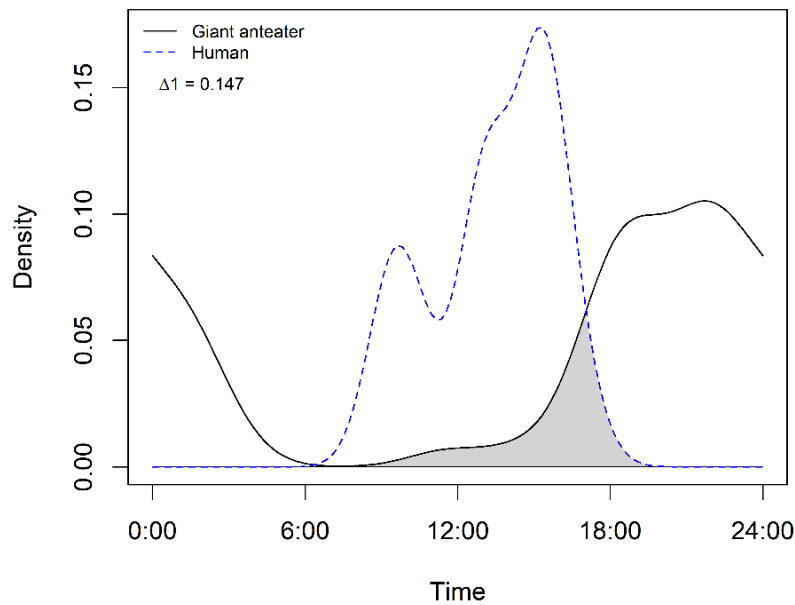


Fig. 4. Número de individuos machos de *Calomys musculus* pertenecientes a la condición de alojamiento solitaria que exhibieron interacciones agonísticas durante los enfrentamientos intrasexuales.

anteater could avoid exposure during the daytime hours when people invasions are most active in this area thus reducing the probability of predator exposure and conflicts.

Furthermore, the observed activity pattern of anteaters may have been influenced by human activities within the species' habitat area, which is limited in size. There are hiking trails, experimental and agricultural activities within the EPAGCV. So resting during the day allows giant anteaters to avoid being active during times of high anthropogenic activity. The presently observed inverse activity patterns between humans and anteaters, with virtually no overlap, is consistent with this possibility. Furthermore, studies conducted in larger protected areas and areas without anthropogenic activity have shown more variable activity pattern ranges of the giant anteater (Shaw et al. 1987; Miranda 2004).

Changes in activity patterns due to human activities have been documented for several mammalian species (Kitchen et al. 2000; Blake et al. 2012; Bennie et al. 2014; Zapata-Ríos & Branch 2016; Massara et al. 2018). Notably, brown bears (*Ursus arctus*) have been reported to adjust their behavior seasonally to avoid encounters with humans during hunting and tourist periods, similar to prey avoiding predators (Ordiz et al. 2011). Recent studies show that human activities

influenced movement (Tucker 2018) and change in mammals' activity patterns (Gaynor et al. 2018; Nickel et al. 2020), i.e., species are showing a more significant activity at night to avoid unfavorable encounters with humans. In the same way, the giant anteater may adopt nocturnal habits to minimize exposure to the activities of people and associated noises (Shaw et al. 1987), however a response to daily temperature is also shaping this patterns.

Human activities carried out in or around, or the insertion of reserves in a non-permissive human management matrix (Tabarelli et al. 2010; Mendonça et al. 2015), could result in an anthropogenic intensification pressure such as invasions by domestic animals (Kupfer et al. 2006; Dechner et al. 2018). The presence of feral animals within conservation units has been increasingly common worldwide (Lessa et al. 2016; Zapata-Ríos & Branch 2016; Paschoal et al. 2018). Because of that, the nocturnal activity of anteaters may also help them avoid domestic dogs, an invasive carnivore in the study area (Lessa et al. 2016; Zapata-Ríos & Branch 2016; Paschoal et al. 2018; Silva et al. 2018). We registered some dogs during the day in the study area, but they were too few to include a species in our analysis. In this study, dog records ($n = 4$) were limited to points closer to the EPA limit and closer to urban areas

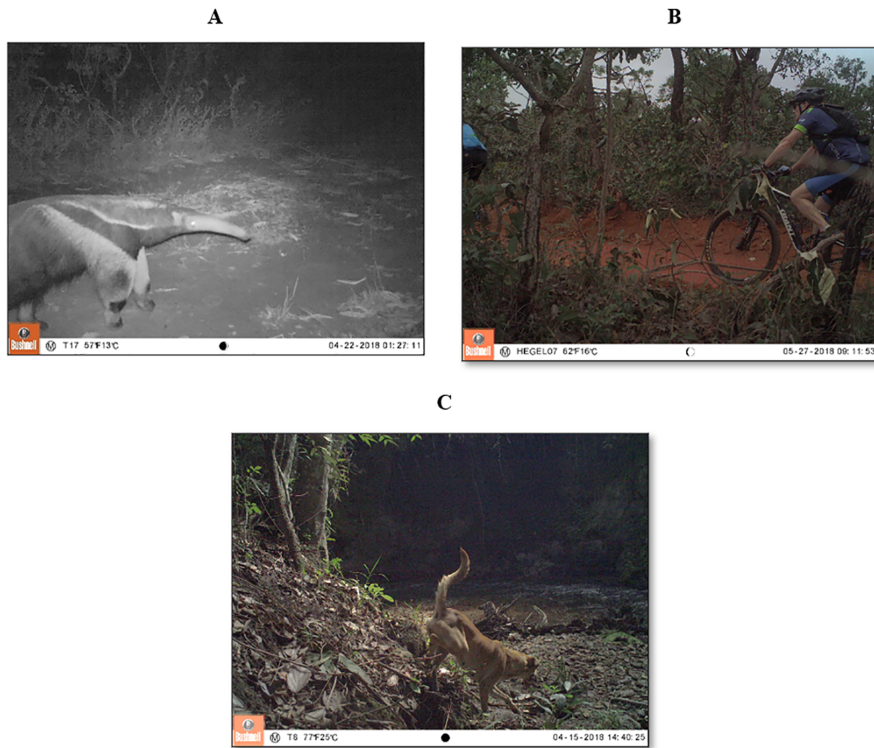


Fig. 5. Records of camera-trap on Gama e Cabeça de Veado Protection Area (EPAGCV). A– Giant anteater; B– Human during the afternoon; C– Domestic dog.

(buildings). The dogs were found alone ($n = 2$) and in pairs ($n = 2$), never more than two individuals and without overlap with humans. Dog records were in the early morning (5:00h-8:00h) and early afternoon (14:20h-14:40h). Although anteaters are not found at the same points as dogs, we obtained them in neighboring areas, which indicates the possibility of encounters. However, long-term studies should be implemented for better understanding.

This study was the first to focus on the anteaters, evaluate temporal behavior and the degree of overlap between the giant anteater and humans, a potential intimidation in the GCV protected area. However, our study was limited by the impossibility of including other predatory species due to the fact that the detection of domestic dogs and pumas is too low to allow the activity pattern to be included in the overlap analysis, and a lack of data collection during the wet season. Despite these limitations, this study provides essential information about the giant anteater and contributes to understanding its behavior in the area and its interaction with possible threats. Studies conducted in natural areas with

anthrophogenic activities in the surroundings are still scarce. It is essential to understand the impact, whether positive or negative, of human disturbances on the anteater's activities. Long-term studies evaluating the landscape, seasonality, and availability of resources are necessary to elucidate the spatial and temporal relationships of giant anteaters with human activities and with their predators. The possible effect of predation risk for the giant anteater because of the presence of domestic dogs in the reserve needs to be assessed and managed.

In conclusion, the present results reveal a principally nocturnal activity pattern of the giant anteater, probably due to the average daily temperature, that largely obviates temporal overlap with humans. This pattern may be favorable to the conservation of the population by reducing agonistic encounters with humans and dogs and avoiding possible persecution or fatalities within the protected area. Temporal data analyses are vital to develop a good understanding of the giant anteater's ecology and behavior. Therefore, other initiatives are encouraged through a broader sampling design at other study sites to

elucidate the different degrees of anthropogenic influence.

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