Mammalogy Notes ISSN 2382-3704
https://doi.org/10.47603/mano.v10n1.359

Activity patterns of domestic dogs and native terrestrial mammals in the Tapacurá Ecological Station, Brazil

Déborah M S Ramos[1,2,4], Lucian V Canto[3], Felipe P da Silva[1,6], Martín A Montes[1,7], João Pedro Souza-Alves[2,4*], Lucas G da Silva[5]

1 Department of Biology, Center of Biosciences, Federal Rural University of Pernambuco, Recife, Brazil. 2 Post-graduate Program in Animal Biology, Center of Biosciences, Department of Zoology, Federal University of Pernambuco, Recife, Brazil. 3 Amazonian Mammals Research Group, National Institute of Amazonian Research, Manaus, Brazil. 4 Laboratório de Ecologia, Comportamento e Conservação (LECC), Centro de Biociências, Departamento de Zoologia, Universidade Federal de Pernambuco, Recife, Brazil. 5 Instituto nacional da Mata Atlântica, Ministério da ciência, tecnologia e inovação, Brasília, Brazil. 6 Post-graduate Program in Ecology and Evolution, Federal University of Goiás, Goiás, Brazil. 7 Post-graduate Program in Biodiversity, Federal Rural University of Pernambuco, Recife, Brazil;

* Correspondencia: souzaalves1982@gmail.com

Resumem

Los perros domésticos son una amenaza para la biodiversidad. Evaluamos los patrones de actividad de los perros domésticos y mamíferos terrestres en un parche de bosque atlántico en el noreste de Brasil. Esperábamos que los mamíferos nativos cambiaran su patrón temporal de actividad en presencia de perros domésticos. Instalamos 16 cámaras trampa en 2019 (enero-marzo) y 16 cámaras en 2021 (febrero-abril), com un esfuerzo de esfuerzo total de 640 días-trampa. Clasificamos la actividad de las especies como diurnos, catemerales, nocturnos y crepusculares. Encontramos 274 registros de 11 especies de mamíferos y solapamiento de actividad entre perros domésticos y mamíferos terrestres. Los coatíes y los agutíes fueron estrictamente diurnos en ambos años, mientras que los perros domésticos presentaron un patrón de actividad catemanal en 2021. Los agutíes y los perros domésticos presentaron un patrón uniforme, pero no así los coatíes. Aunque nuestros hallazgos sugieren una influencia limitada de los perros domésticos sobre los mamíferos terrestres, deben implementarse programas de vacunación o esterilización para evitar un aumento del impacto negativo los perros sobre la fauna nativa.

Palabras clave: especies exóticas, Brasil, área protegida, Mata Atlántica, fauna nativa

Abtract

Domestic dogs are a threat to biodiversity. We evaluated the activity patterns of domestic dogs and terrestrial mammals in a patch of Atlantic forest in northeastern Brazil. We expected native mammals to change their temporal pattern of activity in the presence of domestic dogs. We installed 16 camera traps in 2019 (January-March) and 16 cameras in 2021 (February-April), with a total effort effort of 640 trap days. We classified the activity of the species as diurnal, cathemeral, nocturnal and crepuscular. We found 274 records of 11 mammal species and overlapping activity between domestic dogs and terrestrial mammals. Coatis and agoutis were strictly diurnal in both years, while domestic dogs presented a catemanal activity pattern in 2021. Aguties and domestic dogs presented a uniform pattern, but coatis did not. Although our findings suggest a limited influence of domestic dogs on terrestrial mammals, vaccination or sterilization programs should be implemented to avoid an increase in the negative impact of dogs on native fauna.

Key words: exotic species, Brazil, protected area, Atlantic Forest, native fauna

1. INTRODUCTION

Invasive species are considered one of the main threats to global biodiversity (Mollot et al. 2017). The presence of invasive mammals, particularly potential predators, can contribute to the decline and extinction of native species in several ecosystems worldwide (Doherty et al. 2016, 2017; Mella-Méndez et al. 2019). One such species is the domestic dog (*Canis lupus familiaris* Linnaeus, 1758), due to it is opportunist feeding behaviors, behavioral flexibility, and high reproductive rates relative to other mammals (Leão et al. 2011; Gompper 2015). Thus, domestic dogs are considered the most successful and common carnivore species on Earth (Miklósi 2014; Gompper 2015). The high population density of domestic dogs results from a combination of natural aspects (e.g. high global population) of the species and human domestication (Vanak and Gompper 2009). Favorable conditions, such as food and shelter, associated with humans, appear to be responsible for this species' density (Gompper 2015). Additionally, dogs are commonly abandoned, or their owners allow them to move freely, facilitating their access to natural environments, where they negatively interact with native biodiversity (Zapata et al. 2016). Faced with local, native fauna, dogs predate or attack native animals (Lessa et al. 2016). Dogs may also affect the activity of terrestrial mesopredators (Massara et al. 2015) and transmit infectious diseases (Deem et al. 2008; Doherty et al. 2016). In some cases, the niche overlap is so broad that it leads to increased competition, and consequently, a reduction in the resources for native species. This entire process can result in a decrease in abundance and even the extinction of species (Ricklefs 2016).

This scenario of competition between exotic and native species can become even more accentuated in environments that have become small and isolated, such as areas of the Brazilian Atlantic Forest located in the region north of the São Francisco river, a narrow coastal strip known as the Pernambuco Endemism Center (Melo et al. 2012). Although Atlantic Forest patches are inserted into the highly fragmented landscape (Melo et al. 2013), they house a considerable level of biodiversity (Myers et al. 2000). Nevertheless, due to the occupation and economic exploration of the Brazilian Atlantic Forest since colonial times, more than 70% of its original vegetation cover has been lost (Rezende et al. 2018). In addition to vegetation suppression, associated fragmentation and isolation of native forest patches, other factors such as overhunting and the presence of exotic species have led to rapid population declines and local extinction of native mammals (Bogoni et al. 2018). The presence of exotic species, such as domestic dogs, can also reduce mammal diversity and modify the activity patterns and behavior of native species in these Atlantic Forest patches (Nayeri et al. 2022).

In the light of all the above, we evaluated the temporal activity pattern of domestic dogs and native terrestrial mammals in an Atlantic Forest patch in the Tapacurá Ecological Station, in northeastern Brazil. We expected native mammals to modify their temporal activity pattern to avoid the presence of domestic dogs, i.e., a low temporal overlap between dog and native mammal activity.

2. MATERIALS AND METHODS

2.1. Data collection

We did the study in the Tapacurá Ecological Station (08°02'17" S, 035°11'28" W, Datum SIRGAS 2000), a protected area located in an agricultural matrix area in the municipality of São Lourenço da Mata, State of Pernambuco, Brazil. The ecological station covers an area of 382 ha of semideciduous seasonal forest. For data collection, we installed 16 Amcrest ATC-1201 camera traps in 2019 and Suntek HC-801A camera traps in 2021, which operated for 45-50 consecutive days throughout two periods: i) January to March 2019 (hereafter 2019), and ii) February to April 2021 (hereafter 2021). The traps were distributed at a distance of 350 m between consecutive cameras on pre-existing trails to maximize detection, and to cover most of the study area (Figure 1). Each camera trap remained static, i.e., their location in the study area was not changed, at each site throughout each study period. The cameras were programmed to record videos for 30 seconds at 1-minute intervals. Each video was recorded using 1080p resolution in .AVI format. The total operating time of the cameras was 640 days, running continuously 24 hours a day. The total camera-trap effort comprised 7,839 camera-trap×days.

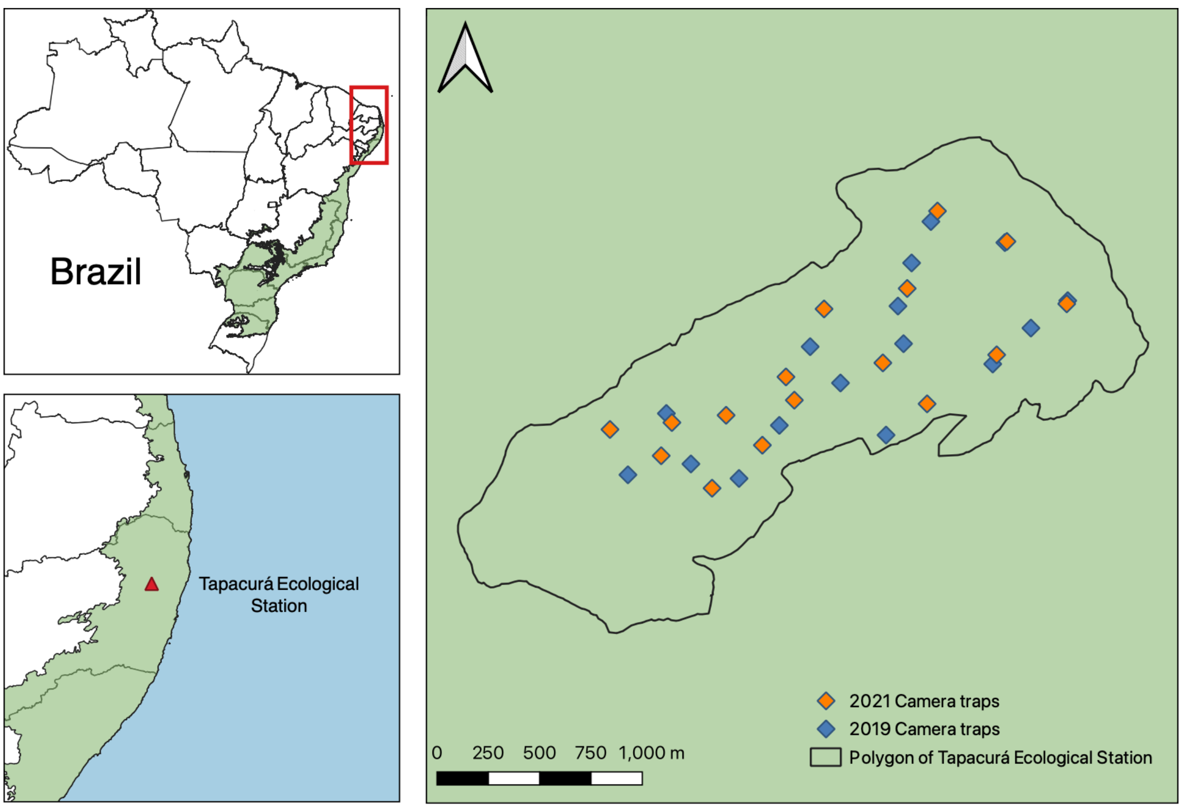

FIGURA 1. Map of Tapacurá Ecological Station, northeastern Brazil, with the location of camera traps in 2019 and 2021.

2.2. Data Analysis

Firstly, we performed two Mantel's correlations with 10,000 permutations using the *vegan* package (Oksanen et al. 2019) in RStudio version 1.1.46 (RStudio Team 2019), to verify the spatial autocorrelation between geographical coordinates and mammalian abundance in each year. There was no spatial autocorrelation for either year (2019: $r = 0.0014$; $p = 0.460$; 2021: $r = 0147$; $p = 0.893$). We then divided the independent records of each mammal species and those of domestic dogs into 1 h intervals over the 24 h circadian cycle. Thus, when there was more than one record of the same species in the same camera trap with a time interval of less than 1 hour, this data was discarded (Ridout & Linkie 2009). Due to variation in the sampling effort and in order to compare time periods, we normalized the data by dividing the number of records for each period by sampling effort and multiplying by 100 i.e., capture frequency. The uniformity of records throughout the circadian cycle was tested using Rayleigh's test with the *circular* package (Agostinelli & Lund 2017) in RStudio. This test shows that a large *r* sample must indicate a nonrandom population distribution. Thus, Rayleigh's test assumes a unimodal distribution or that the population does not have more than one mode. If a unimodal population distribution is assumed from the beginning, a significant Rayleigh test result indicates a concentration around the mean angle or direction, or a preferred direction (Batschelet 1981). For this analysis, we only used species with more than 10 records, as suggested by Ridout & Linkie (2009). We obtained the sunrise and sunset times for the day and month of each record in the study area, from the Time and Date website (www.timeanddate.com). Time and Date considers dates and geographic positions, thereby correcting for changes during winter and summer to make data comparable, since it accounts for solar time which compensates for the local time and daylight savings.

We classified species' activity periods, i.e, the routine activities of the species either during the light or the dark phase (van Schaik & Griffiths 1996), according to the phases of the day (Gómez et al. 2005). We did this by using relative frequencies (the multiplication of the number of records for a given period by 100 and divided by the total number of the sample): diurnal – when the percentage of records ranges between 0-29% during the dark period, cathemeral – when the percentage of records ranges between 30%-70% during the dark period (i.e., mammals that are active during both day and night), nocturnal – when the percentage of records is >70% during the dark period, and crepuscular - when the species present 50% of records during this period (i.e., corresponding to one hour before and one hour after sunrise and sunset, respectively).

We analyzed the activity overlap between domestic dogs and native mammals using the camera trap records. We used the *overlap* package (Meredith & Ridout 2018) in RStudio to perform the analyses. We then created a matrix using records of occurrence and the time of each record. This was then converted to a radian to adjust the data to circular kernel density and to estimate the level of activity of each terrestrial mammal species during each period. To test the degree of overlap between domestic dogs and terrestrial mammals, we used the *overlapEst* function. The Δ_1 coefficient of overlap was used, as recommended for small sample sizes (Ridout & Linkie 2009). Overlap values >0.70 were considered high, moderate when $0.45 < \Delta < 0.70$, and low when Δ was < 0.45 (Monterroso et al. 2014). Here, we used a bootstrap with 999 randomizations to resample the data. Subsequently, we used the *bootEst* and *boocCI* functions to estimate the overlap between each species pair based on the boot0 score and the 95% confidence interval for each pair, respectively.

3. RESULTS

A total of 640 trap×days (343 in 2019, and 297 in 2021) were obtained throughout the study period, resulting in 274 independent records for mammals and domestic dogs. A total of 11 native mammals were recorded (Supplemental Material I). Of these, only three species, coatis (*Nasua nasua*), red-rumped agoutis (*Dasyprocta iacki*), and domestic dogs had enough records to run the statistical analyses. Red-rumped agoutis and domestic dogs had a uniform pattern throughout the circadian cycle for both years (Table 1). The activity pattern of red-rumped agoutis was primarily diurnal in both years (Table 1). Coatis and domestic dogs also presented more records during the daylight than during the dark period (Figure 2); however, in 2021, domestic dogs demonstrated a cathemeral activity pattern (Figure 2). Coati activity pattern was highly diurnal both in 2019 and in 2021.

TABLE 1. Activity patterns of terrestrial mammals and domestic dogs in the Tapacurá Ecological Station, Pernambuco, Brazil (2019-2021) based on the total number of records. Species were classified into categories based on the percentage of records during different periods of the day. The values in parentheses refer to the number of records during the diurnal, nocturnal, and crepuscular periods, respectively. Rayleigh's test allowed to detect mammalian species' daily activity not different from a uniform distribution (ns = non-significant) or deviations from that distribution (**p*-value < 0.001).

		Rayleigh's test (*r*-value)		Activity pattern (% of diurnal/nocturnal/crepuscular)	
Species	Capture frequency (2019/2021)	2019	2021	2019	2021
Red-rumped agouti	39.6/5.7	0.5^{ns}	0.810^{ns}	Diurnal (97/1/2)	Diurnal (88/-/12)
Coati	5.2/4.7	0.620^{*}	0.763^{*}	Diurnal (89/-/11)	Diurnal (86/7/7)
Domestic dog	2.1/17.8	0.485^{ns}	0.741^{ns}	Diurnal (86/-/14)	Cathemeral (53/25/23)

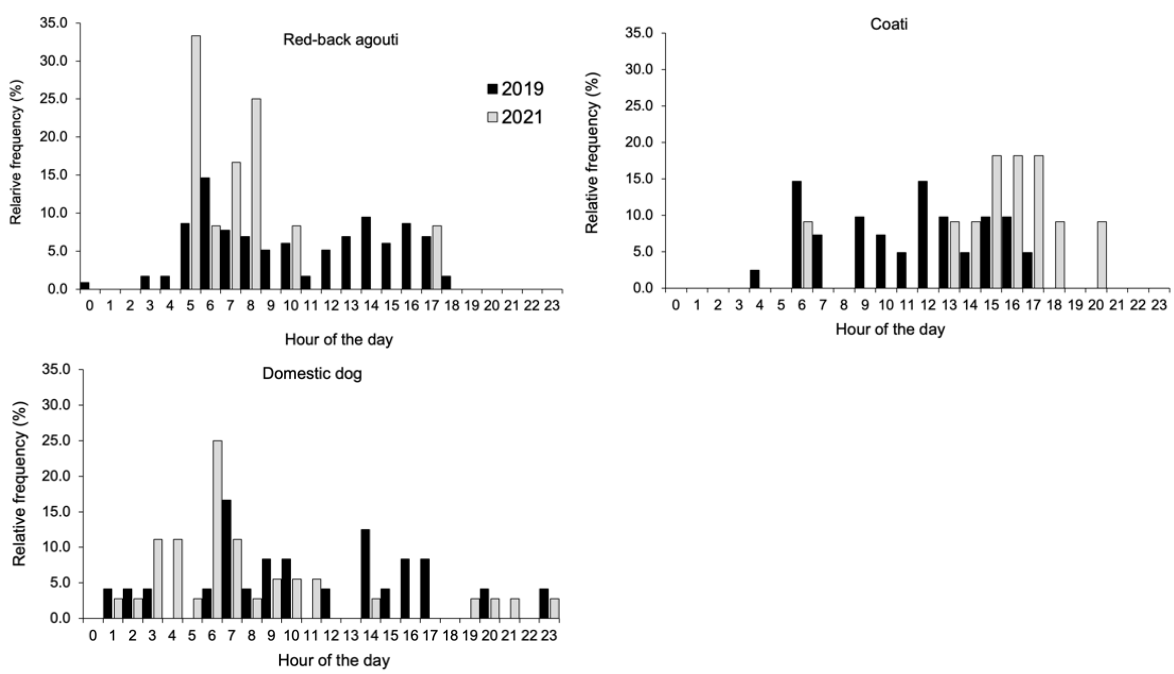

FIGURE 2. Activity patterns of *Dasyprocta iacki* (red-rumped agoutis), *Nasua nasua* (coatis), and domestic dogs in the Tapacurá Ecological Station, northeastern Brazil (2019-2021).

The paired comparisons between red-rumped agoutis, coatis, and domestic dogs indicated an average degree overlap between 0.51 and 0.63, i.e., a moderate to high overlap in daily activity (Figure 3). In 2019, the time overlap between red-rumped agoutis and domestic dogs (Δ= 0.63) occurred during the day, whereas in 2021 (Δ= 0.63) the time overlap occurred mainly in the morning (Figure 3). In 2019, coatis presented greater levels of daily activity in the morning and a few hours in the afternoon (unimodal pattern for both periods), thus the overlapping with domestic dogs (Δ= 0.51) occurred mainly in the morning (Figure 3). In contrast, in 2021, both species appeared to have different daily activity patterns, coatis were more active in the morning, whereas domestic dogs were more active at night (Δ= 0.63). The daily activity pattern of domestic dogs changed from bimodal in 2019 to unimodal in 2021.

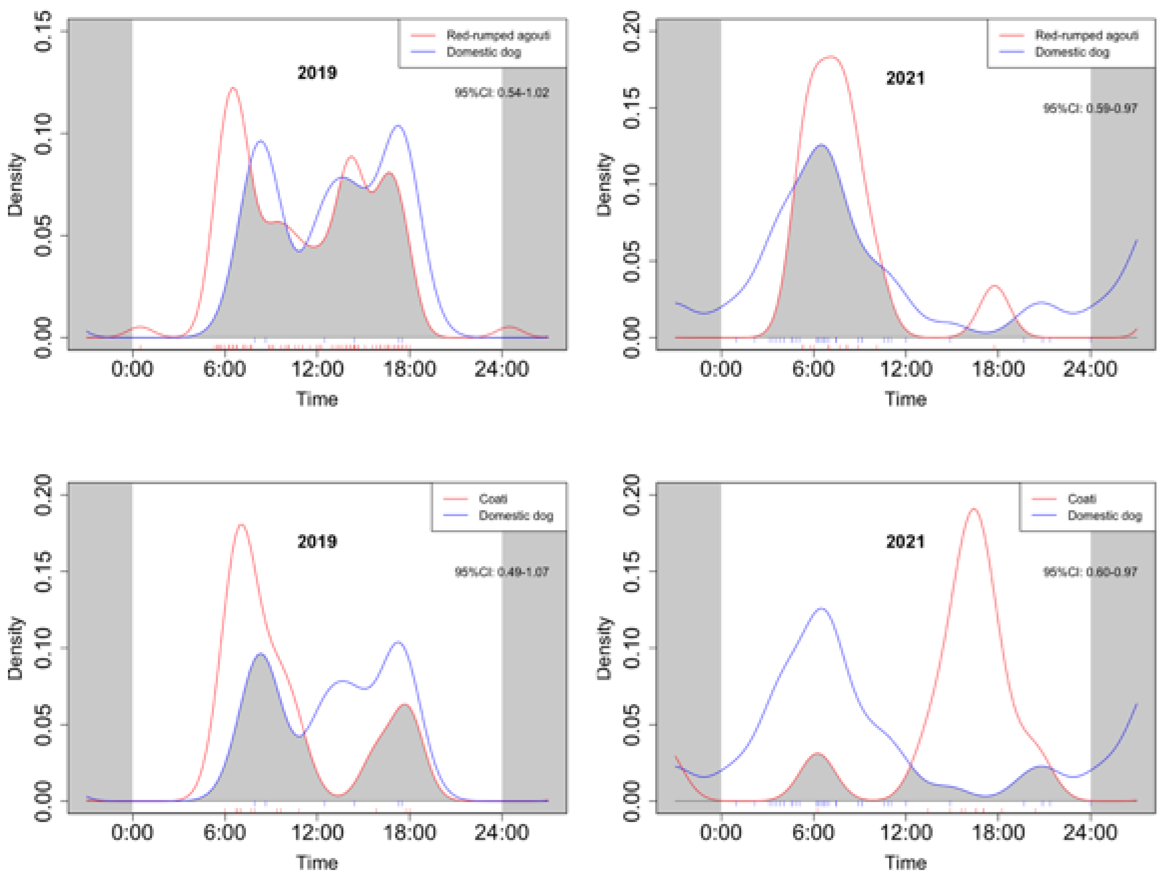

FIGURE 3. Activity pattern overlap between domestic dogs, red-rumped agoutis, and coatis in 2019 and 2021 in the Tapacurá Ecological Station, northeastern Brazil.

Coatis and domestic dogs demonstrated inter-year variation in their activity patterns. Coatis demonstrated strongly unimodal behavior in both years, where they presented a more diurnal activity pattern in 2019, which then seemed to change to crepuscular in 2021. Domestic dogs showed the inverse inter-year behavior. In 2019, dog's activity pattern was bimodal with peaks occurring between 06:00 and 08:00, and around 18:00. Contrarily, in 2021 domestic dogs demonstrated unimodal behavior, with an activity peak at 06:00. When analyzing the overlap of daily activity between years, coatis presented a low overlap of daily activity with Δ= 0.33 (95% CI = 0.19-0.70), whereas domestic dogs presented a moderate level of overlap with Δ= 0.45 (95% CI = 0.19-0.70) (Figure 4).

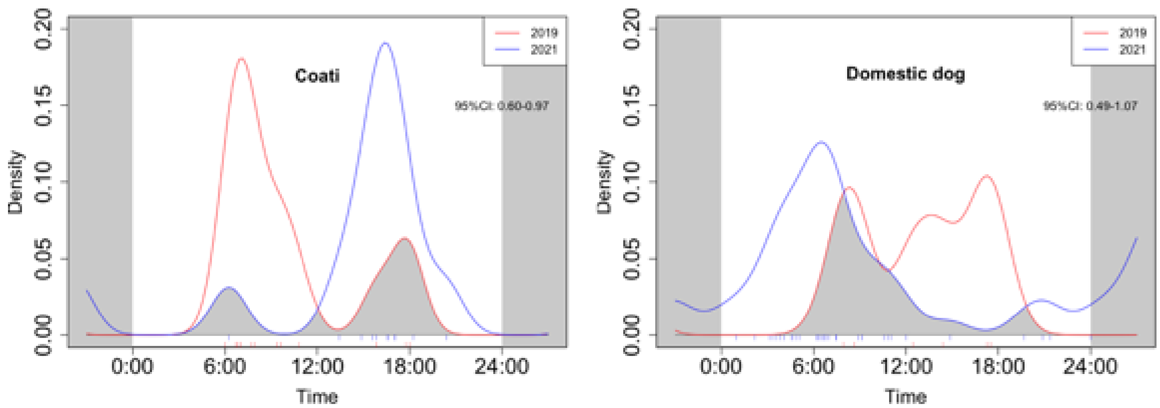

FIGURE 4. Overlap of activity patterns between years (2019 and 2021) for domestic dogs and coatis in the Tapacurá Ecological Station, northeastern Brazil.

4. DISCUSSION

Our findings demonstrate that domestic dogs had bimodal activity in 2019, and unimodal activity in 2021. This variation in the activity pattern of domestic dogs contributes to an increased activity overlap with coatis and red-rumped agoutis in both years. The differentiation in the diets of the recorded species may explain the high levels of temporal overlap. Coatis are basically arboreal-frugivorous and exploit pulp fruits, whereas agoutis are frugivorous, hard hoarders and scatter seed reserves (Forget 1996; Alves-Costa et al. 2004). This level of specificity regarding species' temporal activities is probably more relevant in areas that are as highly disturbed and fragmented as our study area, due to decreased food availability. Small and disturbed forest fragments tend to present biotic homogeneization (Lôbo et al. 2011). Consequently, reducing the diversity and abudance of food resource available. Thus, dietary-specific species may forage on similar periods. The difference between the peak presence of coatis (diurnal) and domestic dogs (crepuscular) in 2021 could be associated with the influence of food availability or the regular activity pattern of the species. Coatis and domestic dogs are primarily diurnal (Srbek-Araujo & Chiarello 2007; Bianchi et al. 2016; Silva et al. 2018). As such, the coati activity pattern observed here was in accordance with the literature. Although our findings for 2021 demonstrated a crepuscular activity pattern for domestic dogs, any comment on this finding needs to be analyzed with caution. A long-term study designed to verify the lack of temporal overlap between these species as well as reduce the wide confidence interval needs to be performed in order to determine whether our proposal is supported.

The low variation in coati daily activity pattern between years could be influenced by food resource availability and forest type (Costa et al. 2009; Santos et al. 2018). Gómez-Ortiz et al. (2019) classified coatis as diurnal, due to their activity between 06:00 h and 18:00 h. Thus, it is likely that these peaks of activity in both years can be linked to intrinsic factors such as the distribution and availability of food resources in the study area. Non-feral dogs are usually diurnal (Silva et al. 2018). On the other hand, feral dogs are completely wild and independent of human sources of food (Vanak et al. 2014), demonstrating a nocturnal and crepuscular activity period (Zapata-Ríos & Branch 2016). Although dog were recorded to occur during the crepuscular period in this study, specifically in 2021, it is not possible to assume that they are feral. These animals live in areas close to the study site and receive food-provisions from humans (D. Ramos, pers. obs.), contradicting the defining features proposed by Zapata-Ríos & Branch (2016). One potential reason for this outcome is the presence of different individuals in 2019 and 2021, resulting in the observation of possible different lifestyles. Although this was not evaluated, these records were performed two years after the first year of monitoring, hence we suggest that these dogs may not have been completely habituated to the humans inhabiting the region.

In summary, red-rumped agoutis demonstrated moderate levels of temporal segregation from domestic dogs in both years, whereas coatis showed so in 2021. Additionally, domestic dogs were more commonly active during the daytime which suggests that they were not feral animals. Feral dogs often have nocturnal activity patterns and generally keep their distance from human settlements (> 50 km), demonstrating avoidance and aggression towards people, as well as presenting good body conditions (Zapata-Ríos & Branch 2016). However, given that dogs and native mammals are likely to encounter at the station, there is a need for management strategies aiming to control the presence of exotic mammals such as elimination, vaccination, and sterilization programs in surrounding areas, in addition to educational activities aimed at local communities Also, due the human pressure that jeopardize the Atlantic Forest fragments, action plans are urgent to identify which management actions should be applied or optimized (ICMBio Normative Instruction No. 21/2018). Our study shoud be considered preliminary, and our findings should help highlight the critical condition of the Atlantic Forest patch and draw attention to achieve the goals proposed in the national action plan.

5. ACKNOWLEDGMENTS

We thank field team members Felipe Pessoa da Silva, Rogério Lira Gomes, Sybelle Montenegro, Joel Francolino, José Filipe, and Túlio Queiroga Faustino for their support in the research and the Tapacurá Ecological Station team for their logistical support and participation in the expeditions. We also thank the “Research in Movement” Program of the Federal Rural University of Pernambuco for their support with transportation during the expeditions. Coordination for the Improvement of Higher Education Personnel - Brazil (CAPES), Financing Code 001, National Council for Scientific and Technological Development (CNPq), and Fundação de Amparo à Ciência e Tecnologia do Estado de Pernambuco (FACEPE) in the form of grants and other financial support (APQ-0313-2.04/16). JPS-A was supported by FACEPE (BFP-0149-2.05/19). We also are grateful to two anonymous reviewers and Francisco Sánchez for their valuable comments and suggestions for the manuscript.

6. REFERENCES

Alves-Costa CP, Da Fonseca GA, Christófaro C. 2004. Variation in the diet of the brown-nosed coati (*Nasua nasua*) in southeastern Brazil. Journal of Mammalogy 85:478-482. https://doi.org/10.1644/1383945

Agostinelli C, Lund U. 2017. Circular: Circular Statistics. https://CRAN.R-project.org/package=circular. Accessed on 07 March 2022.

Batschelet E. 1981. Circular statistics in biology. London, United Kingdom: Academic Press.

Bianchi RDC, Olifiers N, Gompper ME, Mourão G. 2016. Niche partitioning among mesocarnivores in a Brazilian wetland. PLoS One 11:e0162893. https://doi.org/10.1371/journal.pone.0162893

Bogoni JA, Pires JSR, Graipel ME, Peroni N, Peres CA. 2018. Wish you were here: How defaunated is the Atlantic Forest biome of its medium-to large-bodied mammal fauna?. Plos One 13(9):e0204515. https://doi.org/10.1371/journal.pone.0204515

Costa EMJ, Mauro RDA, Silva JSV. 2009. Group composition and activity patterns of brown-nosed coatis in savanna fragments, Mato Grosso do Sul, Brazil. Brazilian Journal of Biology 69:985-991. https://doi.org/10.1590/S1519-69842009000500002

Doherty TS, Dickman CR, Glen AS, Newsome TM, Nimmo DG, Ritchie EG, Vanak AT, Wirsing A. 2017. The global impacts of domestic dogs on threatened vertebrates. Biological Conservation 210:56-59. https://doi.org/10.1016/j.biocon.2017.04.007

Doherty TS, Glen AS, Nimmo DG, Ritchie EG, Dickman CR. 2016. Invasive predators and global biodiversity loss. Proceeding of National Academy of Science 113:11261-11265. https://doi.org/10.1073/pnas.1602480113

Forget P-M. 1996. Removal of seeds of *Carapa procera* (Meliaceae) by rodents and their fate in rainforest in French Guiana. Journal of Tropical Ecology 12:751-761. http://doi.org/10.1017/S0266467400009998

Gómez H, Wallace RB, Ayala G, Tejada R. 2005. Dry season activity periods of some Amazonian mammals. Studies on Neotropical Fauna and Environmental 40:91-95. https://doi.org/10.1080/01650520500129638

Gómez-Ortiz Y, Monroy-Vilchis O, Castro-Arellano I. 2019. Temporal coexistence in a carnivore assemblage from central Mexico: temporal-domain dependence. Mammal Research 64:333-342. https://doi.org/10.1007/s13364-019-00415-8

Gompper ME. 2015. Free-ranging dogs and wildlife conservation. New York, USA: Oxford University Press.

Leão TCC, Almeida WR, Dechoum MS, Ziller SR. 2011. Espécies exóticas invasoras no Nordeste do Brasil: Contextualização, Manejo e Políticas Públicas. Recife, Brasil: Cepan.

Lessa I, Guimarães TCS, Bergallo HG, Cunha A, Vieira EM. 2016. Domestic dogs in protected areas: A threat to Brazilian mammals?. Natureza & Conservação 14:46-56. https://doi.org/10.1016/j.ncon.2016.05.001

Lôbo D, Leão T, Melo FP, Santos AM, Tabarelli M. 2011. Forest fragmentation drives Atlantic forest of northeastern Brazil to biotic homogenization. Diversity and Distributions 17:287-296. https://doi.org/10.1111/j.1472-4642.2010.00739.x

Marques RV, Fabián ME. 2018. Daily activity patterns of medium and large neotropical mammals in an area of Atlantic rain forest at altitude. Brazilian Journal of Zooscience 19:38-64. https://doi.org/10.34019/2596-3325.2018.v19.24736

Massara RL, Paschoal AMO, Doherty PF, Hirsch A, Chiarello AG. 2015. Ocelot population status in protected Brazilian Atlantic Forest. Plos One 10:e0141333. https://doi.org/10.1371/journal.pone.0141333

Mella-Méndez I, Flores-Peredo R, Bolívar-Cimé B, Vázquez-Domínguez G. 2019. Effect of free-ranging dogs and cats on medium-sized wild mammals assemblages in urban protected areas of Mexican city. Wildlife Research 48:669-678. https://doi.org/10.1071/WR19074

Melo FPL, Arroyo-Rodríguez V, Fahrig L, Martínez-Ramos M, Tabarelli M. 2013. On the hope for biodiversity-friendly tropical landscapes. Trends in Ecology & Evolution 28:462-468. https://doi.org/10.1016/j.tree.2013.01.001

Melo FPL, Pinto SRR, Brancalion PHS., Castro PS, Rodrigues RR, Aronson J, Tabarelli M. 2013. Priority setting for scaling-up tropical forest restoration projects: Early lessons from the Atlantic Forest Restoration Pact. Environment Science Policy. 33:395-404. https://doi.org/10.1016/j.envsci.2013.07.013

Meredith M, Ridout M. 2021. overlap: Estimates of Coefficient of Overlapping for Animal Activity Patterns. https://CRAN.R-project.org/package=overlap. Accessed on 17 May 17 2021.

Miklósi A. 2014. Dog behaviour, evolution, and cognition. New York, USA: Oxford University Press.

Mollot G, Pantel JH, Romanuk TN. 2017. The effects of invasive species on the decline in species richness: A global meta-analysis. Advances in Ecological Research 56:61-83. https://doi.org/10.1016/bs.aecr.2016.10.002

Monterroso P, Alves PC, Ferreras P. 2014. Plasticity in circadian activity patterns of mesocarnivores in southwestern Europe: implications for species coexistence. Behavioral Ecology and Sociobiology 68:1403–1417. https://doi.org/10.1007/s00265-014-1748-1

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

Nayeri D, Mohammadi A, Qashqaei AT, Vanak AT, Gompper ME. 2022. Free-ranging dogs as a potential threat to Iranian mammals. Oryx 56:383-389. http://doi.org/10.1017/S0030605321000090

Oksanen J, Blanchet FG, Friendly M, Kindt R, Legendre P, McGlinn D, Minchin PR, O'Hara RB, Simpson GL, Solymons P, Stevens MHH, Szoecs E, Wagner H. 2019. Package 'vegan'. Community ecology package, version, 2:1-30.

Rezende CL, Scarano FR, Assad ED, Joly CA, Metzger JP, Strassburg BBN, Tabarelli M, Fonseca GA, Mittermeier RA. 2018. From hotspot to hotspot: An opportunity for the Brazilian Atlantic Forest. Perspective in Ecology and Conservation 16:208-214. https://doi.org/10.1016/j.pecon.2018.10.002

Ricklefs R, Relyea R. 2014. Ecology: The economy of nature. 7nd ed. New York, USA: W.H Freeman.

Ridout MS, Linkie M. 2009. Estimating overlap of daily activity patterns from camera trap data. Journal of Agriculture, Biological and Environmental Statistics 14:322–337. https://doi.org/10.1198/jabes.2009.08038

R Team Devolpment Core. 2019. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. https://www.R-project.org

Santos CL, Le Pendu Y, Giné GA, Dickman CR, Newsome TM, Cassano CR. 2018. Human behaviors determine the direct and indirect impacts of free-ranging dogs on wildlife. Journal of Mammalogy 99:1261-1269. https://doi.org/10.1093/jmammal/gyy077

Silva KVKA, Kenup CF, Kreischer C, Fernandez FAS, Pires A. 2018. Who let the dogs out? Occurrence, population size and daily activity of domestic dogs in an urban Atlantic Forest reserve. Perspectives in Ecology and Conservation 16:228–233. https://doi.org/10.1016/j.pecon.2018.09.001

Srbek-Araujo AC, Chiarello AG. 2007. Armadilhas fotográficas na amostragem de mamíferos: considerações metodológias e comparação de equipamentos. Revista Brasileira de Zoologia 24:647–656. https://doi.org/10.1590/S0101-81752007000300016

Vanak AT, Gompper ME. 2009. Dogs Canis familiaris as carnivores: their role and function in intraguild competition. Mammal Review 39:265-283. http://doi.org/10.1111/j.1365-2907.2009.00148.x

Vanak AT, Dickman CR, Silva-Rodriguez EA, Butler JR, Ritchie EG. 2014. Top-dogs and under-dogs: competition between dogs and sympatric carnivores. In: Gompper M, editor. Free-ranging dogs and wildlife conservation. Oxford, USA: Oxford University Press. p. 69-93.

van Shaik CP, Griffiths M. 1996. Activity periods of Indonesian rain forest mammals. Biotropica 28:105-112. https://www.jstor.org/stable/2388775

Zapata-Ríos G, Branch LC. 2016. Altered activity patterns and reduced abundance of native mammals in sites with feral dogs in the high Andes. Biological Conservation 193:9-16. https://doi.org/10.1016/j.biocon.2015.10.016

Editor: Francisco Sanchez
Received 2023-06-24
Reviewed 2023-08-25
Accepted 2023-10-29
Published 2024-02-02