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The spatial and temporal movement patterns of domestic dogs and cats, and their potential impacts on wildlife in the Atlantic Forest, Brazil.

A camera trap study

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Scientific Summary

Invasive species pose a major threat to biodiversity and ecosystems worldwide. Domestic dogs and cats are recognized as impactful invasive species due to their roles in predation, competition, disturbance and disease transmission with native species. The Atlantic Forest is a biodiversity hotspot characterized by high species richness and numerous endemic species. However, this biome has become vulnerable due to forest fragmentation and habitat loss. As human activities have expanded, interactions between domestic animals and wildlife have intensified. This study aimed to understand the spatial and temporal movement patterns of domestic dogs and cats, and assess their potential impacts on wildlife within a protected area of the Atlantic Forest. To address the aim of this study, both camera traps and a questionnaire were conducted. Fourteen camera traps were installed and data were collected over four to five months. The questionnaire was conducted among dog and cat owners to gain insight into the local dog and cat population, including their behaviour and activities. The results indicated spatial and temporal overlap in movements between domestic animals and wildlife, thereby suggesting the possibility of interactions. Although no interactions were captured on camera in this study, previous studies have recorded both direct and indirect negative impacts of domestic animals on wildlife. When considered in combination with the behavioural and biological characteristics of dogs and cats, it is reasonable to conclude that they can pose a threat to wildlife. Given the unique and at the same time fragmented nature of the Atlantic Forest, it remains particularly vulnerable to such disturbances, highlighting the importance of effective management strategies. These can include promoting responsible pet ownership, creating awareness and educating local communities about the potential pressures on wildlife. While further research is necessary to come to definitive conclusions, this study provides valuable insights into the potential risks posed by domestic dogs and cats.

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1. Introduction

1.1 Problem statement

Invasive species are considered one of the most important environmental concerns of our time, with the capacity to radically alter ecosystems, threaten biodiversity and cause considerable economic damage (Lessa et al., 2016; Marbuah et al., 2014). Invasive species, often introduced by human activities, thrive very well in new environments without predators, where they can reproduce and spread rapidly, enabling them to outcompete and even displace native species (Marshall et al., 2023). In addition to competition, invasive species can alter entire food web systems and affect species diversity, which are crucial elements for a healthy ecosystem (Gutiérrez et al., 2014). The global distribution of humans has been accompanied by an expansion in human activities, including world trade and travel (Wilson et al., 2009). This process of globalisation has resulted in an increase in the movement of species outside of their natural habitats, which in turn has led to an increase in the number of invasive species (Padayachee et al., 2017). Invasive species are present across the globe, from the introduction of rose-ringed parakeets (*Psittacula krameria*) in Western Europe, where they compete with native birds (Shiels & Kalodimos, 2019), to the spread of the zebra mussel (*Dreissena polymorpha*) in North America, which degrades the aquatic ecosystem and impacts various water infrastructures (Evans et al., 2011). These effects emphasize the ongoing and expanding danger posed by invasive species across all ecosystems, a concern that is expected to persist even in the absence of new introductions in the future (Roy et al., 2024).

Domestic dogs (*Canis familiaris*) and cats (*Felis catus*) are seen as invasive carnivoran predators that interact with wildlife at multiple levels, frequently resulting in negative pressures such as predation, competition, disturbance and disease transmission (Paschoal et al., 2018; Vanak et al., 2013). In certain instances, the presence of domestic dogs and cats has largely contributed to the decline and even local extinction of native species (Gompper, 2014; Hughes & Macdonald, 2013; Loss et al., 2013; Loss & Marra, 2017). The negative impacts of domestic animals as invasive species are important challenges for conservation efforts as they are closely tied to people's social, economic and political values. To achieve successful outcomes, it is essential to engage in extensive collaboration and cooperation (Hughes & Macdonald, 2013).

The domestication of dogs and cats represents a critical point in the development of their behavioural traits. The dog is descended from Eurasian grey wolves (*Canis lupus lupus*) approximately 13,000 – 17,000 years ago. However, this estimate is highly debated (Derr, 2011). Since then, the dog has been supported and introduced globally as a household pet (Driscoll & Macdonald, 2010). Nowadays, dogs have become the most widespread carnivoran globally, occupying various roles within human societies, from guardian animals to beloved family pets (Gompper, 2014). The domestic cat is descended from the wildcat (*Felis silvestris*), and since its domestication around 10,000 years ago, the cat has followed humans to all corners of the globe, including the most remote archipelagos (Driscoll et al., 2007; Trouwborst et al., 2020). The large niche breadth and flexibility of dogs and cats facilitate their adaptability in terms of habitat, food and climate, enabling them to reach high densities in various places (Loss & Marra, 2017; Vanak et al., 2013). The combination of high survival and reproducing rates makes both animals one of the most successful and impactful invasive species worldwide (Loss & Marra, 2017; Weng et al., 2022). Dogs and cats could be problematic in rural or semi-rural areas where they are often permitted to roam freely, thereby increasing the likelihood of contact with native fauna (Hughes & Macdonald, 2013). The high mobility of the species increases the risk of invading different habitats, including protected areas (Sepúlveda et al., 2015). The predatory character and high densities of domestic dogs and cats can result in a very complex conservation issue (J. P. Ferreira et al., 2011; Loss & Marra, 2017; Woolley & Hartley, 2019).

The aforementioned issues have been researched on a global scale. For example, in Serengeti, Tanzania, there is evidence that domestic dogs have affected populations of African lions and wild dogs through the spread of canine distemper (Cleaveland et al., 2000; Roelke-Parker et al., 1996). Another study by Zapata-Ríos & Branch (2016) found that free-ranging dogs disturbed local mammal populations, causing them to alter their activity patterns and reducing their abundance in affected areas. Furthermore, domestic cats are responsible for killing billions of birds in the United States and contributing to the decline of native species (Loss et al., 2013). In addition to preying on birds, cats hunt a wide variety of species, including mammals and other vertebrates (Beutel et al., 2017; Eisenhauer, 2018; Franklin et al., 2021). Beyond direct predation, dogs and cats can also indirectly affect wildlife through the transmission of diseases and inducing a "fear effect" in prey species (Trouwborst et al., 2020).

1.2 Domestic dogs and cats in the Atlantic Forest

Although certain ecosystems are resilient to the presence of domestic dogs and cats, others, particularly those already under stress, are much more vulnerable to their impacts (Hughes & Macdonald, 2013; Silva-Rodríguez & Sieving, 2012) The Brazilian Atlantic Forest (*Mata Atlântica)* is highly endangered and extensively fragmented, yet it has a unique and diverse ecosystem, making it one of the most severely impacted tropical forests (Joly et al., 2014). The Atlantic Forest of Brazil is one of the global biodiversity hotspots characterized by high species richness and many endemic species (M. C. Ribeiro et al., 2011; Srbek-Araujo & Chiarello, 2008). However, the expansion of agriculture, followed by industrialization and urban development, has had a significant impact on this biome (Rezende et al., 2018). Habitat loss and fragmentation have resulted in a decline in biodiversity over the past few decades, making the Atlantic Forest also one of the “hottest” biodiversity hotspots (Trindade et al., z.d.; Zachos & Habel, 2011). The Atlantic Forest is particularly vulnerable to the impacts of domestic dogs and cats due to its high level of fragmentation and proximity to human activities, allowing these animals to easily enter forest patches and affect native wildlife (Srbek-Araujo & Chiarello, 2008). As urban areas expand, there is an increase in contact between domestic animals and wildlife, which in turn increases the potential threats to wildlife. Furthermore, when a significant number of species is already at risk, even minimal levels of predation or disturbance can result in adverse effects (Young et al., 2011).

Several studies have focused on the interactions between free-ranging dogs and wildlife distribution in the Brazilian Atlantic Forest. The distributions of species, for example, the armadillo (*Dasypus novemcinctus*), margay (*Leopardus wiedii*) and oncilla (*Leopardus tigrinus)* have been shown to change over time due to the presence of dogs (Cassano et al., 2014). Another study by Galetti (2006a) found that dogs kill or prey on several native species such as the Brazilian rabbit (*Sylvilagus brasiliensis),* and even caused the extinction of the paca (*Agouti paca*) and brocket deer (*Mazama guazoubira*) in a protected area. Cats have been found to predate on smaller animals such as amphibians, reptiles and birds (Assis et al., 2023; G. A. Ferreira et al., 2014). Furthermore, wild feline species have been detected carrying several diseases of domestic carnivores, especially dogs and cats (G. A. Ferreira et al., 2019). Due to the potential impact that domestic dogs and cats have on native wildlife and their broad distribution in association with people, attention is needed in areas where they can have a major impact on ecosystem functioning (Hughes & Macdonald, 2013).

Given the considerable documented impact of domestic dogs and cats on wildlife in various parts of the Atlantic Forest, it becomes crucial to investigate innovative and effective methods for monitoring these interactions. Camera traps represent one of those methods. The use of camera trapping is a valuable tool for monitoring wildlife, and it is highly essential in scientific research and conservation initiatives around the world (Galvis et al., 2014). Camera trapping provides researchers with a unique method of studying a variety of species, including rare ones, particularly in more remote areas with minimum human disturbance (Cordier et al., 2022). Furthermore, it provides the opportunity to identify possible interactions and impacts between wildlife and domestic dogs and cats. A number of studies have researched the interactions in the Atlantic Forest using camera traps

(Carvalho et al., 2019; de Cassia Bianchi et al., 2020; Paschoal et al., 2018; F. S. Ribeiro et al., 2019; Zanin et al., 2019). However, no studies have examined both domestic dogs and cats in the Atlantic Forest. In addition to camera trapping, conducting a questionnaire offers valuable insights into the local population of dogs and cats, providing detailed information on their movements, behaviours, and interactions with wildlife that may otherwise stay unnoticed through camera traps alone. Currently, no study has used both camera trap images and questionnaires in this particular area of the Atlantic Forest. This research, therefore, addresses a critical gap in the existing literature by combining these methods to gain a deeper understanding of the role of domestic dogs and cats in protected forest remnants.

1.3 Objectives and research questions

The aim of this study was to investigate the potential impacts of domestic dogs and cats on wildlife in the Atlantic Forest. The objective was achieved by: (1) understanding the habitat use of domestic dogs and cats, and (2) analysing their spatial and temporal movement patterns, including overlap with wildlife activity. After understanding the patterns and overlap, the next step involves (3) identifying potential direct and indirect interactions between domestic dogs, cats and wildlife. And finally, in line with the interactions, (4) developing management strategies that help to mitigate any potential negative impacts. The results of this novel study will expand the current knowledge about the potential impacts of domestic dogs and cats on wildlife, contributing to conservation planning strategies in areas where these domestic animals may affect native wildlife populations. This research is guided by the following question: *"What are the spatial and temporal movement patterns of domestic dogs and cats, and how could these patterns affect wildlife in RPPN Alto da Figueira, Atlantic Forest, Brazil?"*.

To address the research question, the study was structured around the following sub-questions:

1. In which specific areas or habitats within RPPN Alto da Figueira are domestic dogs and cats most frequently found?
2. What are the spatial and temporal movement patterns of domestic dogs and cats, and to what extent do they overlap with wildlife?
3. What are the potential direct and indirect impacts of domestic dogs and cats on wildlife, and are these impacts detected within RPPN Alto da Figueira?
4. What management strategies could be implemented to mitigate the potential impacts of domestic dogs and cats on wildlife (in RPPN Alto da Figueira)?

Based on previous studies conducted in similar ecosystems, it is reasonable to hypothesize that domestic dogs and cats are most frequently detected near the edges of the study area, particularly in locations close to human settlements and activities. Furthermore, there is likely to be a certain degree of spatial and temporal overlap between the movements of domestic dogs, cats and wildlife. Such overlap may indicate potential interactions, emphasizing the importance of understanding these interactions to develop effective management strategies.

2. Methodology

This study used an interdisciplinary approach to examine the movement patterns of domestic dogs and cats and to assess their potential impact on wildlife in the study area. Fieldwork was conducted to install camera traps and collect data. The questionnaire provided data regarding the population of domestic dogs and cats in the region. The majority of the data analyses were conducted using Excel (v. 2406), RStudio (v. 2023.12.1) and QGIS (v. 3.36.3).

2.1 Study Area

2.1.1 Atlantic Forest

The Atlantic Forest is characterized by high levels of endemism and outstanding species richness, which contribute to making this biome one of the most biodiverse regions on the planet (M. C. Ribeiro et al., 2011). This region is home to 264 mammals, over 750 species of reptiles and amphibian species, 1,000 bird species and almost 23,000 plant species (de Lima et al., 2020; Tabarelli et al., 2005). The Atlantic Forest primarily covers eastern Brazil, but also extends into parts of Paraguay, Argentina and Uruguay (Rezende et al., 2018). With a population of over 125 million, the Atlantic Forest biome serves as Brazil's main economic driver, contributing 70% of the country's gross domestic product (GDP) and two-thirds of the industrial economy. Additionally, it contains some of the most productive agricultural land in the country as well as some of the largest cities in South America, including São Paulo and Rio de Janeiro (Joly et al., 2014). This biome currently consists of an archipelago of small vegetated islands, interconnected within a matrix of degraded areas, pastureland, agriculture, forestry, and urban development (Tabarelli et al., 2005). The most recent estimates suggest that only between 11% and 16% of the original vegetation in the Atlantic Forest in Brazil is still intact (Rezende et al., 2018).

The area is typically characterized by a tropical climate, classified as Cfa in the Koppen system, due to its location within the Atlantic Forest biome (Boas et al., 2022). The region's average temperatures vary between 18 and 28 degrees Celsius, depending on microclimates and elevation. The mean annual precipitation is between 1,500 and 2,000 millimetres, with a distinction between a dry and rainy season (Lôbo et al., 2011). The rainy season usually occurs during the summer months (December to March), characterized by higher precipitation and humidity levels. The high humidity levels in the Atlantic Forest contribute to the diversity of flora and fauna in the region (Boas et al., 2022). The vegetation is predominantly montane and submontane rainforest (*Instituto Estadual do Ambiente*, z.d.). The Atlantic Forest is home to a wide variety of species, including the puma (*Puma concolor*), maned wolf (*Chysocyon brachyurus*), ocelot (*Leopardus pardalis*), tayra (*Eira Barbara)*, capybara (*Hydrochoerus hydrochaeris),* along with many more amphibians, reptiles, fish and arthropods (Boas et al., 2022).

2.1.2 RPPN Alto Da Figueira

This study was conducted in collaboration with the ARAÇÁ project (*HOME | Araca Project*, z.d.). The ARAÇÁ project encompasses a research area called RPPN Alto da Figueira, which is the focus area of this study (Figure 1). RPPN Alto da Figueira is a privately owned reserve situated within the Macaé de Cima Environmental Protection Area (APA). APA Macaé de Cima is a state-protected area located in the state of Rio de Janeiro. Macaé de Cima covers approximately 35,000 hectares and borders the Três Picos State Park (*Instituto Estadual do Ambiente*, z.d.; 'Macaé de Cima Environmental Protection Area', 2021).

RPPN Alto da Figueira covers an area of 120 hectares and includes a variety of topographical features and microclimates. Elevation within the reserve ranges from 1,200 to 1,600 meters. The area is characterized by various microclimates, including open and dense forest, bamboo forest, and water valley (*HOME | Araca Project*, z.d.). Additionally, several man-made trails are distributed across the reserve, facilitating accessibility (Appendix: Figure 14). The research station of the ARAÇÁ project is located in the central area of the reserve and can be reached via an unpaved road.

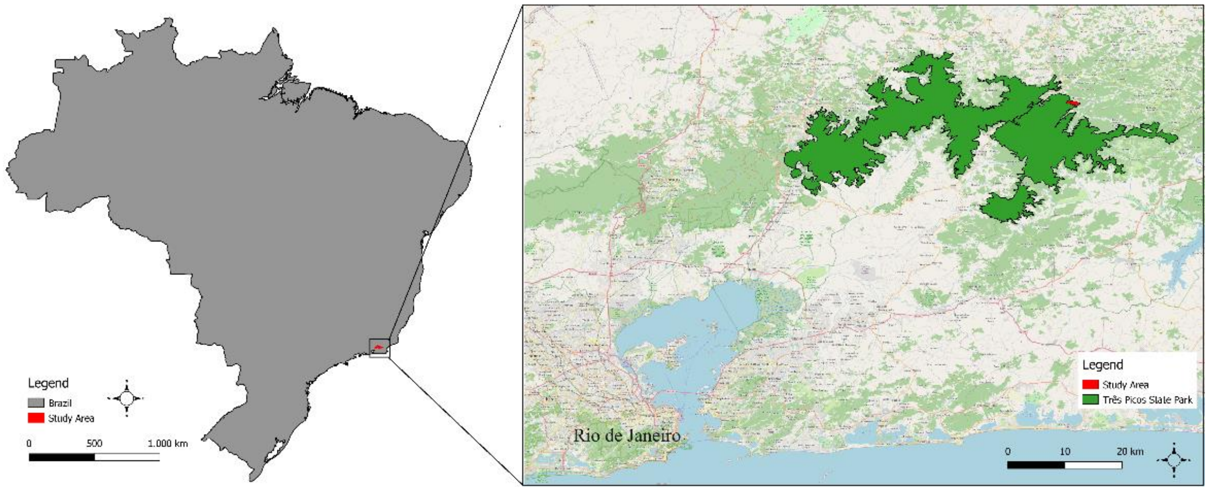


Figure 1: Location of the study area. On the left: the country of Brazil and the study area. On the right: More zoomed in into the study area, which borders the Três Picos State Park

2.3 Camera trap installation and collection

This study involved daily fieldwork from January 15th to February 22nd, 2024. The activities were conducted at RPPN Alto da Figueira and were together with fellow student Anne van ‘t Hoff. During the fieldwork, camera traps were installed and data was collected. The collaboration with the ARAÇÁ project provided access to their reserve for the research.

2.3.1 Systematic sampling design

To position the cameras, a systematic sample design was used, which involved placing them at regular intervals throughout the study area. For this study, 14 cameras were installed within the reserve's 120-hectare area. Achieving an appropriate balance between the number of cameras and the area covered was crucial to ensure that the sampling design was representative of the whole area without introducing bias. To accomplish this, grid cells were used to position the cameras at approximately the same distance apart, resulting in a 300-meter interval between them. Covering heterogeneous conditions such as roads, water bodies, and varying microclimates and elevations. The coordinates of the locations were put into the GPS device (Garmin GPSMAP65) to facilitate the precise locations during the installation process. The installation of the cameras on the locations designated by the grid cells was attempted, but this was not always feasible due to the terrain or the presence of very dense vegetation. The locations selected for the installation of camera traps were as close as possible to the correct coordinates. Figure 2 illustrates the locations of the 14 camera traps installed within the study area.

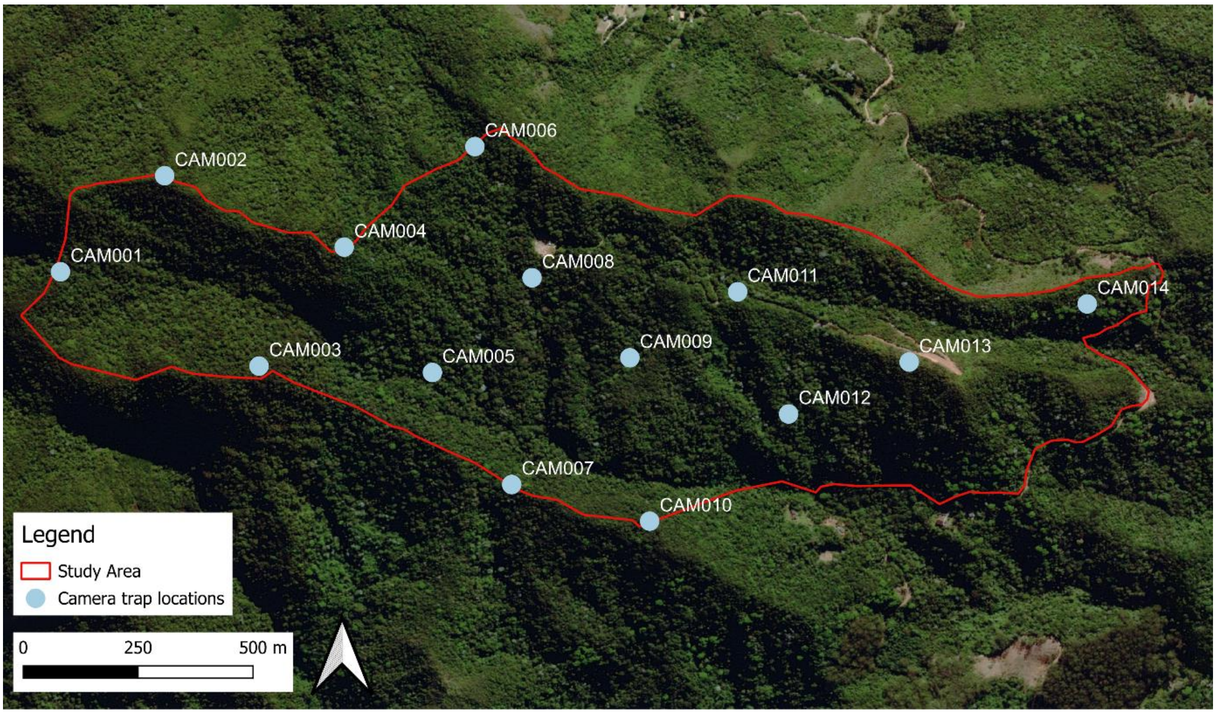


FIGURE 2: THE LOCATIONS OF THE INSTALLED CAMERA TRAPS IN THE STUDY AREA OF RPPN ALTO DA FIGUEIRA

2.3.2 Camera trap Installation

The optimal installation of camera traps is essential for collecting the highest quality and quantity of data. The optimal positioning of camera traps was determined to be on flat terrain; alternatively, the camera angle was adjusted to account for the slope of the ground, thereby maximizing detection. The camera traps were tied directly to a tree or a wooden pole. In general, the optimal height for medium-to-large mammals is 30-40 cm above ground level, depending on the slope (O'Connell et al., 2011; Rovero & Zimmermann, 2016). As a result, this height was used in this study. Any branches or other vegetation within the camera's detection range were removed to prevent false triggering. The use of bait was avoided to minimize potential bias. Additionally, notes and photographs were taken regarding installing the camera traps and environmental features.

The installation of the camera traps included a calibration process. Calibration is a valuable tool for a range of analyses, including estimating density without individual recognition, reconstructing animal movement paths, calculating total distance travelled, and estimating animal size (Rovero & Marshall, 2009; Rovero & Zimmermann, 2016). In order to calibrate the camera traps, a one-metre marked stick was placed and photographed at varying distances and angles from the camera. This procedure was carried out for each camera trap; however, due to the study's aim, the resulting calibration data was not used in further analyses and hence was not included in this study.

2.3.3 Camera traps

In this study, 14 Bushnell Prime Low Glow Trail Cameras were used. The camera is designed with 36 low-glow LEDs, 24 megapixels of resolution, and an automated sensor that ensures clear photographs both during the day and at night. The camera detector is programmed to respond to the presence of moving objects or those with a surface temperature that differs from the background temperature (Apps & McNutt, 2018). The cameras were set to operate continuously 24 hours a day. The cameras were put in camera mode and programmed to take five photos at each detection event, with an interval of one second between different detections. The cameras recorded the local time and date of each detection, which is visible on the images.

2.3.4 Environmental factors

Table 1 presents an overview of the environmental factors recorded for each camera trap. The environmental factors include elevation, canopy height, and distances to a water body, an unpaved road, a construction site, and one of the reserve's primary man-made trails, which includes the unpaved road. All variables are presented in metres. The elevation was calculated using the Quantum Geographical Information System (QGIS), while the distances to specific sites were determined using Google Earth Pro. A distance of zero indicates that the camera is situated close to a water body or on one of the trails.

The aforementioned environmental factors were selected for specific reasons. The proximity of construction sites is an important factor as human activities can disrupt the behaviour of animals, potentially leading to avoidance of these areas while simultaneously increasing the possibility of seeing dogs and cats (Paschoal et al., 2018). Trails and roads may facilitate the movement of dogs, cats and native species (Sepúlveda et al., 2015). Moreover, changes in elevation and canopy height can alter climatic and environmental conditions, thereby influencing the presence of animals (Roll et al., 2015).

Table 1: The environmental factors per camera trap (in metres)

Camera Trap	Elevation	Canopy height	Distance water	Distance roads	Distance construction	Distance trail
CAM001	1,532	12	200	1105	1050	0
CAM002	1,575	5	200	900	855	5
CAM003	1,475	10	156	730	680	27
CAM004	1,506	10	180	500	445	0
CAM005	1,310	24	32	430	380	0
CAM006	1,403	12	220	325	280	0
CAM007	1,298	19	145	575	545	0
CAM008	1,373	9	60	135	55	0
CAM009	1,299	22	0	200	300	211
CAM010	1,268	20	120	360	630	10
CAM011	1,336	12	70	0	310	0
CAM012	1,225	15	40	205	230	188
CAM013	1,305	5	120	25	80	0
CAM014	1,255	24	50	0	480	0

2.3.5 Data collection

The camera trap data were collected over five months between January and June 2024. The data were collected at approximately four-week intervals, except for the first collection, which was collected after 1.5 weeks as a preliminary test collection. The first three months were collected together with the Brazilian researchers from the ARAÇÁ project, while the final two months were collected solely by the Brazilian team. Data collection involved emptying and formatting SD cards, checking or replacing batteries, checking settings, and cleaning camera lenses.

The collection of all 14 camera trap data was not possible within a single day. Instead, this process was often distributed over several days, resulting in different data collection moments. Table 2 provides information about the collection moments of all the camera traps. CAM004 did not function during collection 5 and neither did CAM013 during collection 4. Also, some functional failures during the sampling periods have resulted in missing detections. No clear reason for how the malfunctions happened can be provided.

TABLE 2: THE DATES OF THE DIFFERENT DATA COLLECTION MOMENTS PER CAMERA TRAP.

Camera Traps	Collection 1 (C1)	Collection 2 (C2)	Collection 3 (C3)	Collection 4 (C4)	Collection 5 (C5)
CAM001	02-02-24	26-02-24	02-04-24	07-05-24	11-06-24
CAM002	01-02-24	26-02-24	02-04-24	07-05-24	11-06-24
CAM003	02-02-24	26-02-24	02-04-24	07-05-24	11-06-24
CAM004	01-02-24	26-02-24	02-04-24	07-05-24	
CAM005	01-02-24	27-02-24	03-04-24	09-05-24	11-06-24
CAM006	01-02-24	26-02-24	02-04-24	07-05-24	11-06-24
CAM007	05-02-24	27-02-24	03-04-24	09-05-24	11-06-24
CAM008	01-02-24	29-02-24	02-04-24	06-05-24	10-06-24
CAM009	07-02-24	29-02-24	04-04-24	06-05-24	10-06-24
CAM010	05-02-24	27-02-24	03-04-24	09-05-24	11-06-24
CAM011	01-02-24	29-02-24	02-04-24	06-05-24	10-06-24
CAM012	07-02-24	29-02-24	03-04-24	09-05-24	10-06-24
CAM013	01-02-24	27-02-24	03-04-24		10-06-24
CAM014	01-02-24	29-02-24	02-04-24	06-05-24	10-06-24

2.4. Data analysis

2.4.1 Organizing and identifying camera trap data

Wildlife Insights is a software program designed to organise and process all camera trap images (*Home | Wildlife Insights*, z.d.). Wildlife Insights generates a standardized output of the results and can safely archive the data. A sequences project was created to consider images separated by no more than 60 seconds as a single detection event. The project created on the platform contains 14 sub-projects, one for each camera trap. Each sub-project contains four to five deployments, depending on the number of data collection moments.

Wildlife Insights makes use of Artificial Intelligence to facilitate the identification of species observed in the images. Several possibilities are presented, ranging from an identified species to an order of species. If these are agreed, they must be accepted manually, resulting in all photographs being manually identified. All species recorded during the sampling process were identified to the lowest possible taxonomic level. When a species could not be fully identified, it was assigned to a family or order. Where feasible, domestic dogs and cats were identified based on phenotypic characteristics, including breed, sex, size, coat colour and pattern, and any other pertinent features. In instances where identification was not possible, the data was recorded in the dataset as "unidentified".

2.4.2 The relative abundance index

The relative abundance index (RAI) measures the frequency with which a species is observed in a given location, relative to the frequency of other species present. The RAI is calculated by dividing the total sampling effort by the number of detections and then multiplying the result by 100. A threshold of 30 minutes between detections was used for the RAI, to obtain solely independent detections. This analysis was performed using RStudio.

2.4.3 Temporal activity

For the temporal activity analysis, each species captured by a camera trap was treated as a single detection event. The temporal distribution of detections of each species (or group) was used to provide the daily activity patterns. The activity patterns of all the animals were obtained using the time stamps associated with the images. The activity time was calculated as the time difference from the start of the day, expressed in minutes, which was subsequently converted to radians. The activity hours were classified into diurnal (active from 06:00 to 18:00) and nocturnal (active from 18:00 to 06:00), which represent the day/night time in SE Brazil during the majority of months of the year (Guedes et al., 2020). The package “overlap” was used to integrate the activity patterns of two species and to identify any instances of overlap. The degree of overlap between the density functions of the species was estimated using the overlap coefficient and the estimator Δ^1 (Dhat1), which is appropriate for studies with small sample sizes of data (<50). The coefficient ranges from 0 (indicating no overlap) to 1 (indicating complete overlap) (Durán-Antonio et al., 2020; Ridout & Linkie, 2009).

The daily activity of domestic dogs was compared to that of prey species or species that could potentially compete with domestic dogs. Multiple studies have reported rodents, didelphis, and bird species as prey species, making them a subject of interest for comparison (dos Santos et al., 2018; Guedes et al., 2020; Hughes & Macdonald, 2013; Lessa et al., 2016). The various felid species, as native carnivores, can compete with domestic dogs and are vulnerable to disease transmission Additionally, the tayra may also be influenced by domestic dogs through competition. Furthermore, the armadillo is regarded as a potential prey species for domestic dogs (Guedes et al., 2020; Lessa et al., 2016). For the domestic cat, primary prey species are birds and rodents; however, they are also capable of hunting small species of didelphis (Assis et al., 2023; Escobar-Aguirre et al., 2019; G. A. Ferreira et al., 2014). In addition to predation, domestic cats may threaten other carnivores, such as felids, due to the potential transmission of disease or the disruption through competition for territory (Craft et al., 2017).

2.4.4 Spatial activity

The results of the spatial analysis were visualised using QGIS and examined in RStudio. In RStudio, the GLM (generalized linear model) function was used for response variables displaying a non-normal distribution. A binomial family was used to conduct a presence analysis. The presence analysis was conducted to test whether environmental factors impact the presence of domestic dogs and cats, and subsequently, whether dogs and cats influence the presence of native species. The influence was first determined using single predictor models, which were then followed by a multiple predictor model. The package “Stargazer” was valuable in the creation of overview tables of the various GLM models. The Akaike information criterion (AIC) was used to compare the relative efficacy of each model in explaining the presence of domestic dogs and cats. The null model was included for comparison, to determine the effect of the absence of predictors.

The full dataset for this analysis was transformed into a presence-absence dataset. To increase the probability of species detection and to improve the significance of covariates, the number of samples was expanded to include five different data collections. In the event of a species (or group) being detected during the period in a given data collection, a value of 1 was assigned (indicating that the species was present), while a value of 0 was used when no detection occurred. Furthermore, QGIS was used to visualize and map the spatial distribution and activity of the focus species. Maps were created using the graduate function to demonstrate the value in different sizes.

2.4.5 Spatial overlap

The spatial overlap between native species and domestic animals was investigated by observing whether native species were frequently detected on camera traps where dogs and cats were recorded. Accordingly, camera traps 4, 6 and 14 were included in this analysis as these cameras captured dogs and a cat. Percentages were calculated by dividing the number of detections of a given species on a given camera trap by the total number of detections on all cameras. A high percentage indicates a high frequency of occurrence of a particular species, increasing the likelihood of interacting with domestic dogs and cats.

2.4.6 Questionnaire

As a complementary approach to camera trapping, a questionnaire was conducted among dog and cat owners in the Macaé de Cima Valley (R. Hans Garlip & Estr. Macaé de Cima). This initiative focuses on the behavioural patterns, outdoor activities and health status of domestic dogs and cats. The findings of this questionnaire can be used to design management strategies to preserve the health of both pets and wildlife, consequently reducing the risk of potential negative impacts.

The questionnaire was conducted using a door-to-door approach, which was conducted by two locals between the 5th and 18th of June, 2024. People were asked to participate in this survey and they were informed that by answering the questions they would help gain more knowledge about the health of domestic dogs and cats in the area, as pets can transfer diseases and parasites to wildlife. The participation was fully voluntary and all responses were anonymous. Furthermore, when respondents completed the questionnaire, they would receive free parasite treatment for their pet(s).

The questionnaire included questions about the age, sex, breed, color and size of each pet. In addition, questions were asked about health care provided by the owners; neuter status, health management and treatments, and the type of food provided and how often. Furthermore, details about each pet's behavior, outdoor activities, and whether or not the pet has ever chased wildlife or been attacked by an animal were asked. The full questionnaire can be found in the appendix (Appendix.2). The questionnaire data were analysed using Excel and Rstudio. In Rstudio, Generalized Linear Models, using binomial family, were performed to identify statistically significant variables. Additionally, an ANOVA test was conducted to examine differences between dogs and cats, as well as male and female pets. A t-test was used for continuous variables, such as assessing the pets' ages.

3. Results

The results will be presented in this section, starting with a broad overview and progressing to more detailed and sophisticated outcomes. The findings will begin with a summary of the sampling results, including all identified species and species groups in the study area. Subsequently, the recorded domestic dogs and cats will be discussed, followed by analyses of their spatial and temporal patterns. Finally, the results of the questionnaire will be presented.

3.1 Basic results

The overall sampling effort of the 14 camera traps was 1,836 days. In total, 3,233 detections were obtained, resulting in 567 species records after excluding detections that included humans, vehicles or blank images. A total of 17 species was identified, comprising 15 wild species and two types of domestic animals. The objective was to identify the species according to their lowest scientific classification system. However, due to time constraints and a lack of knowledge, not all species could be identified by their species names. Consequently, four species groups were established according to species class, order and family. Those species that could not be fully identified have been allocated to one of the species groups. Each group comprises at least two distinct species, distinguished by their respective characteristics. The four species groups comprise birds (Class: *Aves*), squirrels (Family: *Sciuridae*), rodents (Order: *Rodentia*) and didelphis species (Order: *Didelphimorphia*). A separate category was established for squirrels, as they were frequently identified and thus not included in the rodent group. The spix's guan has been separated from the birds due to its frequent detection, making this species important enough to analyse individually. Table 3 presents a comprehensive list of all identified species and species groups during the sampling period, accompanied by their respective relative abundance indices (RAIs).

A focus on the RAI of identified species reveals that the spix's guan shows the highest relative abundance index (RAI = 4.5), followed by the nine-banded armadillo (RAI = 2.6) and two felids, the margay and tiger cat (RAI = 1.6, both). Additionally, domestic animals were observed, showing an RAI of 1.3 for the domestic cat and 0.8 for the domestic dog, respectively. Some species, such as the grey-headed kite and black capuchin monkey, were only detected on a single occasion, resulting in a low RAI of 0.1. The group of bird species demonstrated the highest RAI overall, followed by the didelphis species and squirrels.

TABLE 3: THE COMMON AND LATIN NAME PER IDENTIFIED SPECIES AND SPECIES GROUP, AND THEIR CORRESPONDING RELATIVE ABUNDANCE INDEX (RAI)

Species	**Latin name**	**RAI**
Birds unidentified	*Aves*	8.0
Spix's guan	*Penelope jacquacu*	4.5
Didelphis unidentified	*Didelphimorphia*	3.6
Squirrels unidentified	*Scuridae*	3.2
Nine-banded armadillo	*Dasypus novemcinctus*	2.6
Margay	*Leopardus wiedii*	1.6
Tiger cat	*Leopardus guttulus*	1.6
Tayra	*Eira barbara*	1.5
Domestic cat	*Felis catus*	1.3
Domestic dog	*Canis familiaris*	0.8
Ocelot	*Leopardus pardalis*	0.6
Rodents unidentified	*Rodentia*	0.4
Ring-tailed coati	*Nasua nasua*	0.3
Crab-eating raccoon	*Procyon cancrivorus*	0.3
Puma	*Puma concolor*	0.2
Four-eyed opossum	*Philander opossum*	0.1
Grey-headed kite	*Leptodon cayanensis*	0.1
Lesser grison	*Galictis cuja*	0.1
Black capuchin	*Sapajus nigritus*	0.1
Spotted paca	*Cuniculus paca*	0.1
Collared peccary	*Dicotyles tajacu*	0.1
Others unidentified	*Unidentified*	0.6

Figure 3 depicts the identified species and species groups with more than one detection. The number of detections provides an alternative method of determining the most abundant species (or groups) in the study area, presented in absolute numbers rather than relative. Here, the number of detections is used as a proxy for abundance. It should be noted that this figure does not correspond exactly to the number of species observed on the detections, as some images show a group size of more than one.

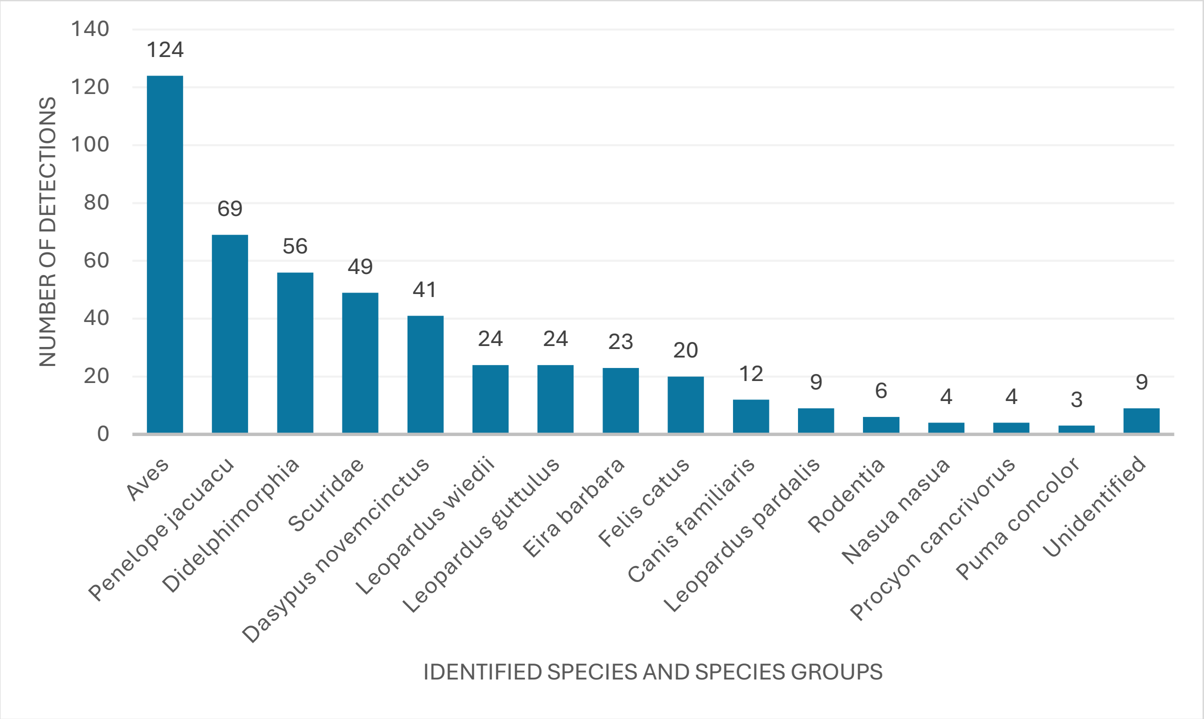


FIGURE 3: THE NUMBER OF DETECTIONS PER IDENTIFIED SPECIES AND SPECIES GROUP. THIS GRAPH ONLY INCLUDES IDENTIFIED SPECIES THAT WERE DETECTED MORE THAN ONCE.

3.2 Distribution of the total amount of species and species groups

This section will present the findings regarding the distribution of species and species groups for each camera across the study area. An increased frequency of different species and species groups may increase the probability that domestic dogs and cats will encounter one of the species, thereby enhancing potential threats to wildlife. It is important to note that this distribution provides insight into the species classification used in this study and does not reflect the overall species richness of the area.

3.2.1 Total species distribution

Figure 4 illustrates the distribution of the total number of identified species and species groups within the study area. The average number of identified species and species groups per camera is 7.6, ranging from 0 to 12 species. Camera trap 14 had the highest number of identified species, situated close to the unpaved road and the borders of the reserve. Furthermore, camera traps 1, 2, and 6 also show a considerable number of identified species. Camera trap 11, which is likewise located next to the unpaved road but further into the reserve, did not record any species at all. Additionally, camera traps 5 and 9 have not identified many species (4 and 5, respectively). The camera traps with the highest number of detected species are predominantly situated toward the reserve’s borders, whereas those with the lowest number of detected species are located closer to the center of the reserve. Furthermore, the camera traps with the highest number of detected species are primarily concentrated in the northern region of the reserve.

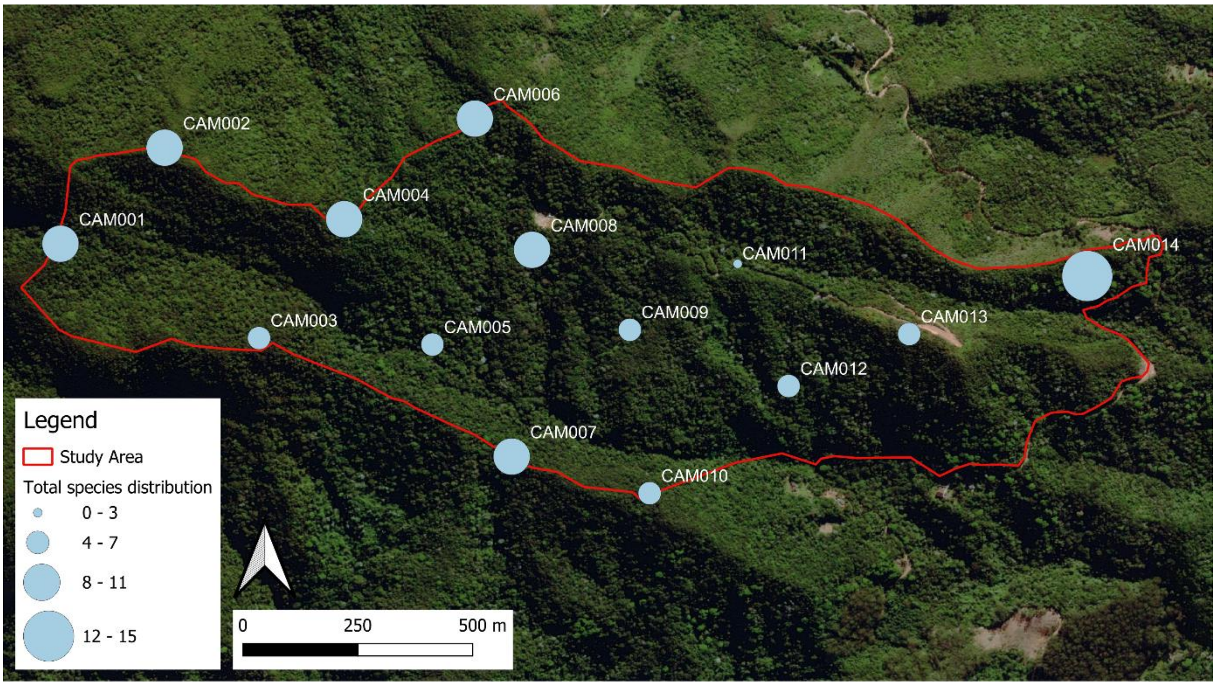


Figure 4: The map displays the distribution of the total number of identified species and species groups per camera trap. Circle size corresponds to the number of species and species groups identified.

3.3 Basics of domestic dogs and cats

3.3.1 Domestic dogs

A total of 23 detections of domestic dogs have been recorded, existing of seven unique individuals (Figure 5). The individuals were identified based on their fur pattern, body size, breed, and other unique characteristics. The age of the dogs could not be determined only based on the images, but they were all adults and of medium to large size. Four of the dogs have been identified as male, while the sex of the remaining three is unclear. The number of recaptures per individual dog ranged from one to nine records.

Figure 5: The identified individual domestic dogs with their name.

The domestic dog recordings are distributed across three camera traps: cameras 4, 6, and 14, with camera 14 having the highest number of records (Figure 6). Camera traps 4 and 6 are located along a (man-made) trail, while camera 14 is located along the unpaved road near the border of the reserve. Furthermore, cameras 4 and 6 are positioned at the border of the reserve, indicating that the dogs may enter the reserve via the unpaved road and trails close to the borders. Most of the dogs recorded by camera 14 appear to be leaving the reserve via the unpaved road, rather than entering it. It is also noteworthy that all of the recorded dogs were only spotted in the northern region of the reserve.

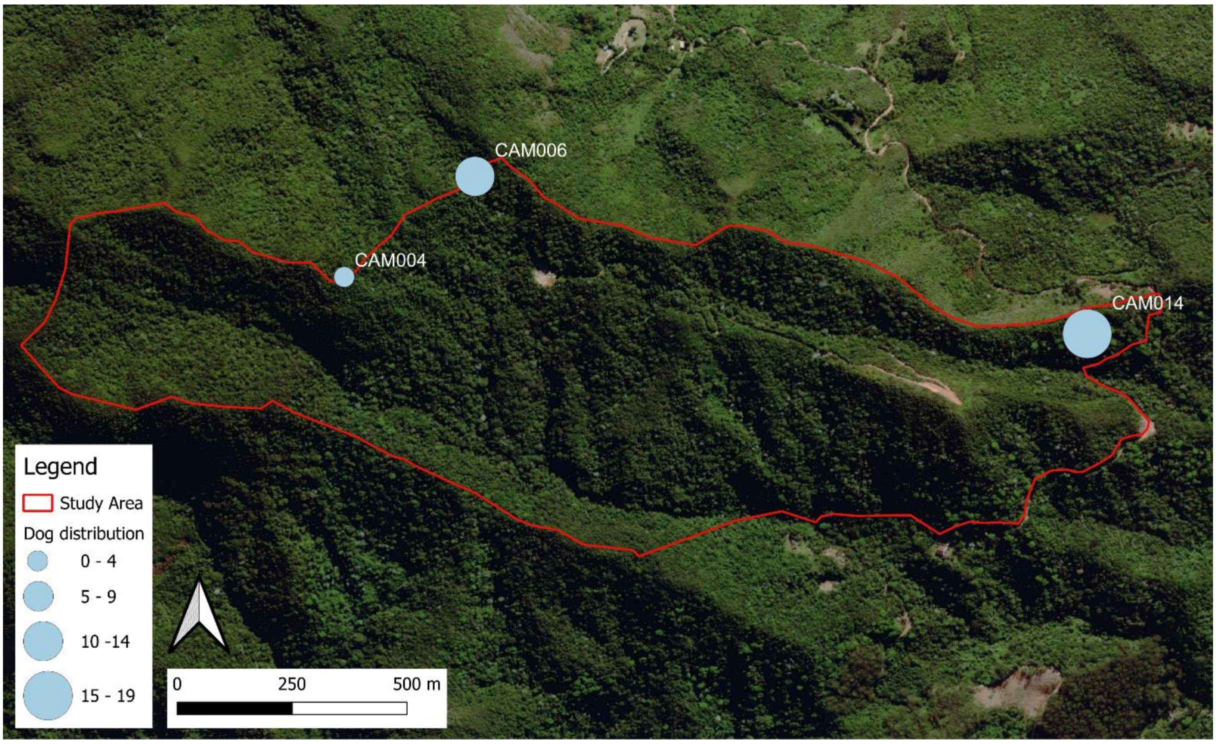
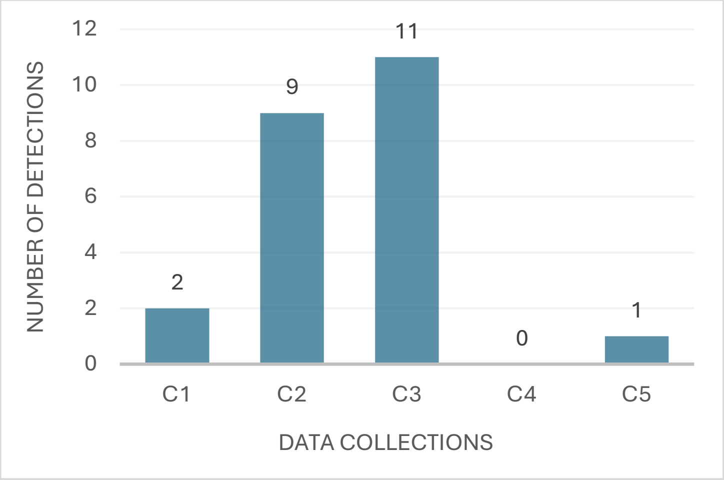


FIGURE 6: THE CAMERA TRAP LOCATIONS WHERE THE DOMESTIC DOGS WERE DETECTED. THE SIZE OF THE CIRCLES CORRESPONDS TO THE NUMBER OF DOMESTIC DOG DETECTIONS.

The records of dogs in groups of two to four individuals or solidarity show only minor differences. However, it is noteworthy that several dog records were recorded minutes apart, indicating that the dogs may have entered or left the forest together but passed the camera alone. Dogs Ind01 and Ind02 were observed together several times, and Ind05 and Ind06 were seen wandering together for the majority of the recordings. No records of dogs showing interesting behaviour, or interaction with wild species were identified. None of the dogs showed any direct signs of hunting behaviour or carried prey. However, it appears that the dogs engage in sniffing around the forest, potentially in search of other dogs or potential prey. Figure 7 illustrates the number of detections of domestic dogs during the various data collection moments. The highest frequency of dog records occurred during data collection C2. In contrast, data collection C4 did not detect any dogs, and data collection C6 recorded only one dog. It is important to note that detections do not account for group size, and therefore some detections may include multiple dogs.

FIGURE 7: THE NUMBER OF DOMESTIC DOG DETECTIONS PER DATA COLLECTION PERIOD C1, C2, C3, C4 AND C5



3.3.2 Domestic cats

The domestic cat was identified on 22 recordings, yet only a single individual was documented. The cat observed in the footage is believed to have dark fur (Figure 8) and was consistently recorded on camera 14, a camera trap situated along the unpaved road. The cat typically walks towards the camera in the late evening or night, returning a few hours later in a direction away from the camera. No evidence of hunting behaviour was observed, and the cat was never seen carrying prey. The cat was always observed alone, and it seems that it used the unpaved road to access the reserve. However, the cat was never recorded on camera 11, which is also situated along the same road but at a greater distance into the reserve. The number of detections of the domestic cat increased over time during the different data collections (Figure 9). Furthermore, the cat was always observed twice each night, resulting in an even number of detections. During the first data collection (C1) no domestic cats were recorded. In contrast, during the last data collection (C5), the domestic cat was recorded ten times.

FIGURE 8: THE IDENTIFIED DOMESTIC CAT

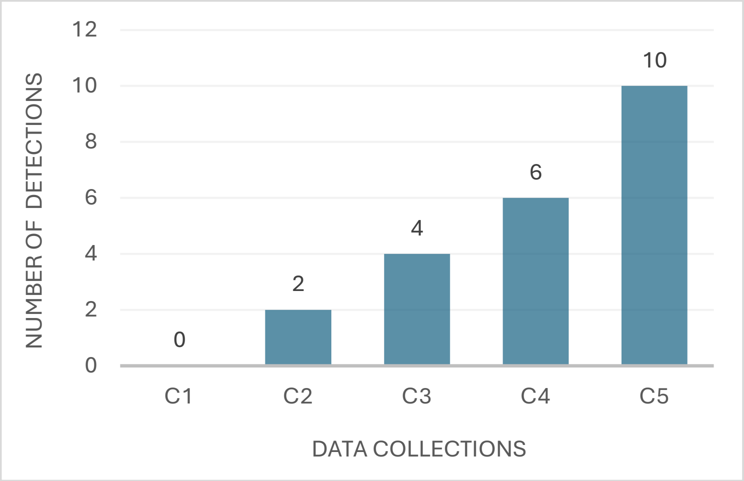


FIGURE 9: THE NUMBER OF DOMESTIC CAT DETECTIONS PER DATA COLLECTION PERIOD.

3.4 Temporal analysis

3.4.1 Daily activity pattern of domestic dogs and cats

It was not possible to examine the individual daily activity patterns of the dogs, as none of the identified dogs had sufficient records to provide a reliable outcome for each individual. Consequently, a general description of the species' activity pattern will be provided. Furthermore, as there is only one record of a domestic cat, the provided daily activity of the domestic cat represents that of a single individual. Figure 10 illustrates the daily activity patterns of the domestic dogs and the domestic cat. Individual detections are represented as short vertical lines above the X-axis. The greater the number of detections occurring around a specific time, the higher the density will appear on the graph.

The majority of domestic dogs were detected in the morning between 06:00 and 12:00, with core activity occurring around 10:00 (Figure 10). Additionally, some detections were recorded at night, but the overall activity of the domestic dogs was predominantly diurnal. While domestic dogs are most active during the (early) morning, the domestic cat is more active during the night and can be called a nocturnal species. The core activity of the domestic cat was observed between 11:00 and 6:00, with a few detections of activity occurring around 19:00 (Figure 10).

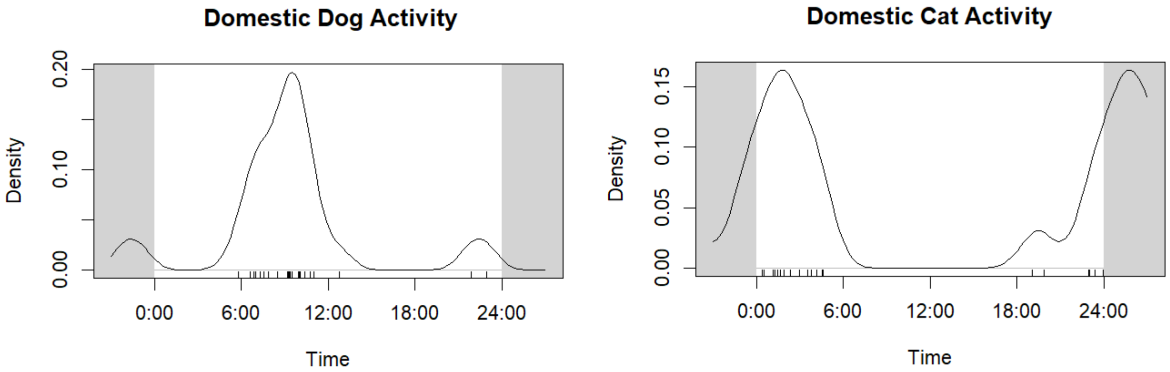


FIGURE 10: THE DAILY ACTIVITY PATTERN FOR THE DOMESTIC DOG (LEFT) AND DOMESTIC CAT (RIGHT).

3.4.2 Daily activity overlap domestic dogs

A daily activity graph, including activity overlap with domestic dogs, was created for the following species: the armadillo, didelphis and bird species, the tayra, ocelot and tiger cat (Figure 11). There is minimal overlap between the daily activity patterns of dogs, the armadillo and didelphis species. Both species are most active during the evening and night, while dogs have their core period in the early morning. On the contrary, bird species show a degree of overlap with the domestic dog during the morning hours. The remaining carnivores, namely the tayra, ocelot and tiger cat are most active during daylight hours, which coincides with the morning activity period of domestic dogs. This is particularly the case for the tiger cat during the dawn hours. The total activity overlap, indicated by the overlap coefficient (Δ), between domestic dogs and the different species (groups) is illustrated in Table 4. The highest overlap coefficients are observed for the bird species and the ocelot (Δ0.56 and Δ0.53 respectively). The lowest levels of overlap were observed for the armadillo, rodent, and didelphis species, with overlap coefficients close to 0.1.

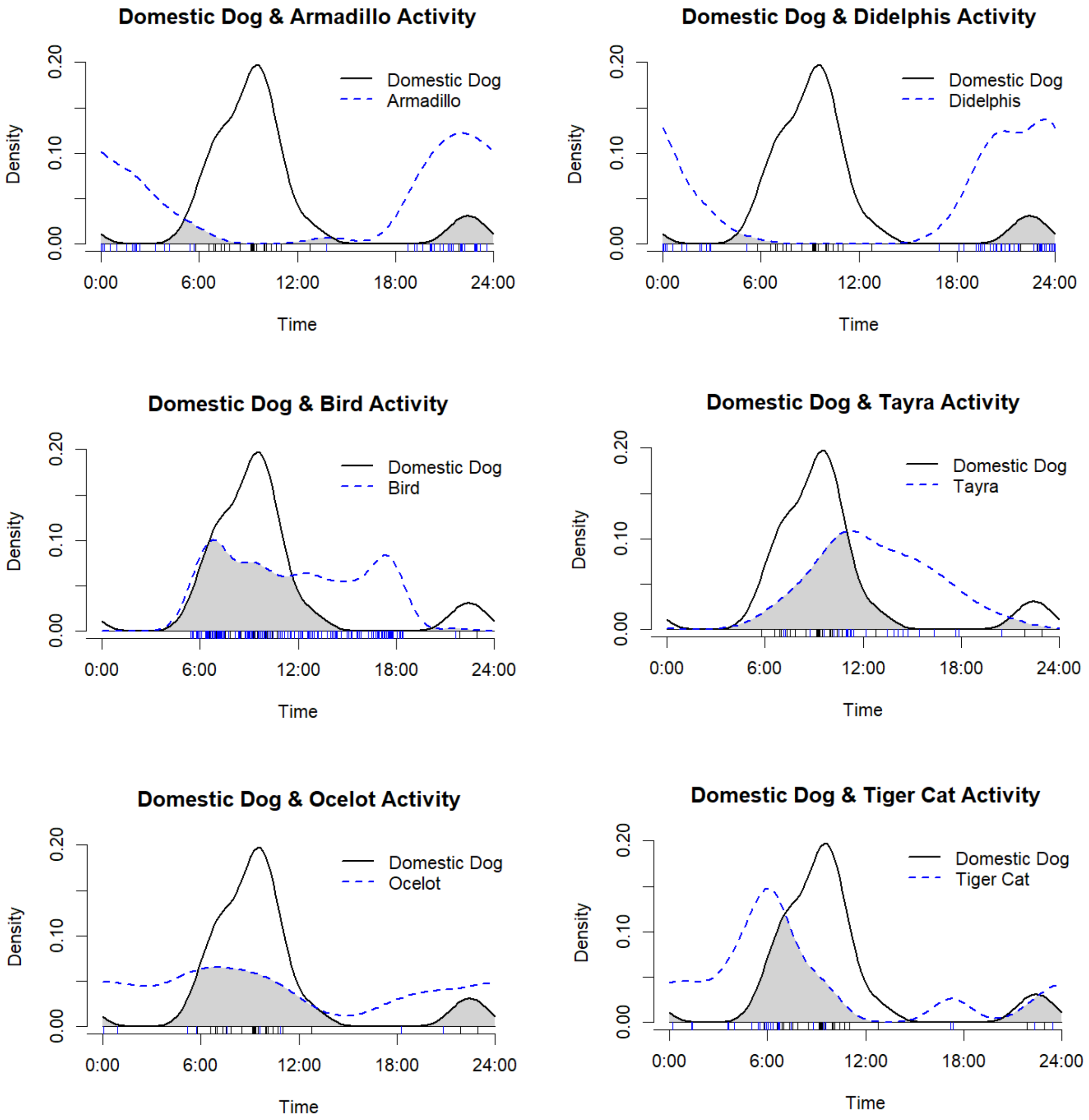


Figure 11: The daily activity pattern of the domestic dog compared to the daily activity pattern of several native species. The area in grey indicates the temporal overlap between the species.

3.4.3 Daily activity overlap domestic cat

A daily activity, including activity overlapping with the domestic cat, was created for the following species: the margay, tiger cat, ocelot, birds, didelphis and rodents (Figure 12). The nocturnal activity pattern of the domestic cat is similar to that of the didelphis and rodent species, which also thrive during night hours. On the contrary, bird species, including the penelope bird, seem to be diurnal and show minimal temporal overlap. The felids show some overlap degree during nocturnal hours, with the margay displaying the highest overlap. coefficient (Table 4). Furthermore, the didelphis and rodent species demonstrate even a higher coefficient of overlap (Δ0.54 and Δ0.51 respectively), compared to the margay and other felids.

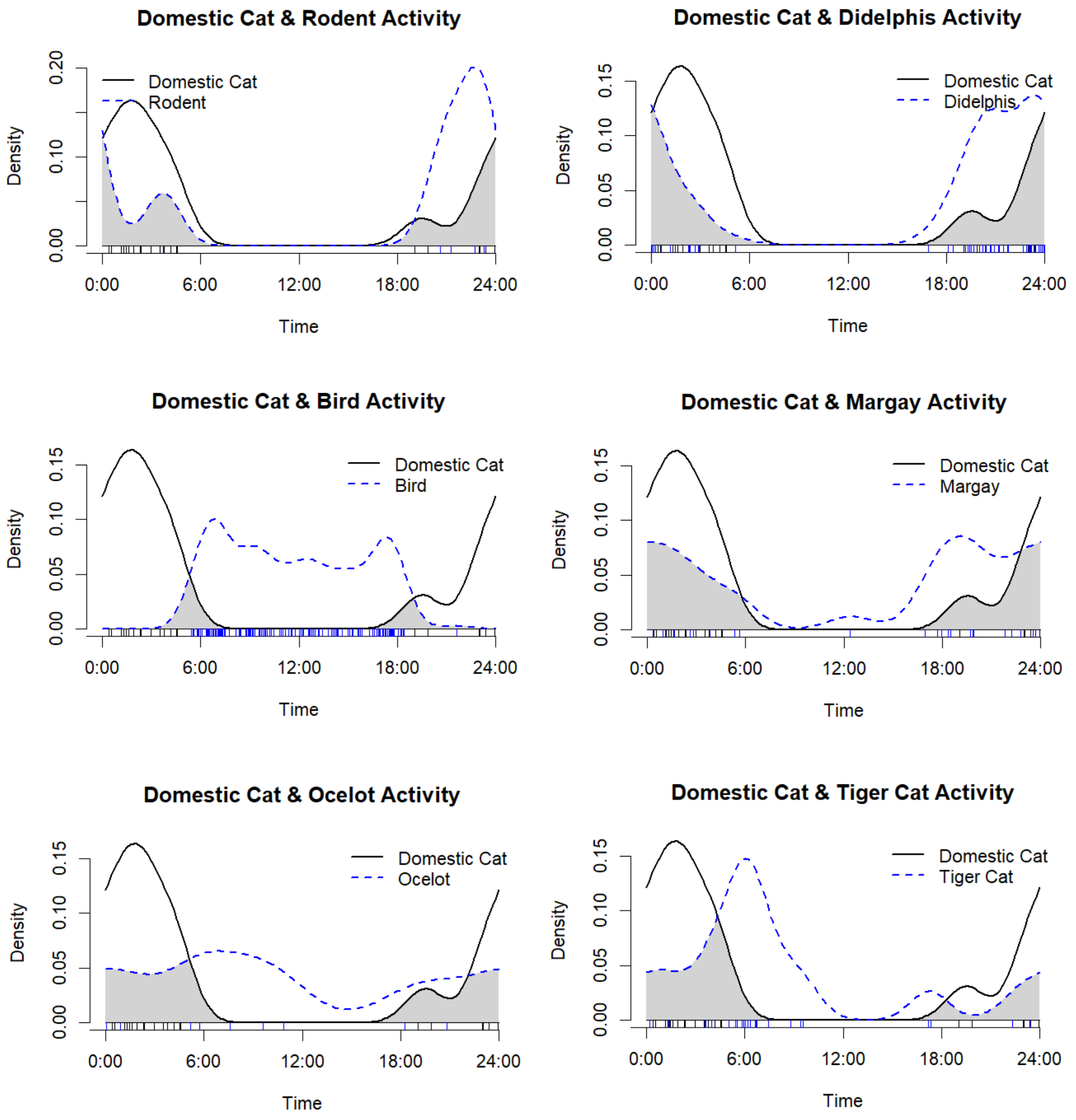


FIGURE 12: THE DAILY ACTIVITY PATTERN OF THE DOMESTIC CAT COMPARED TO THE DAILY ACTIVITY PATTERN OF SEVERAL NATIVE SPECIES. THE AREA IN GREY INDICATES THE TEMPORAL OVERLAP BETWEEN THE SPECIES.

TABLE 4: THE OVERLAP COEFFICIENT BETWEEN THE DOMESTIC DOG, CAT, AND DIFFERENT SPECIES (GROUPS). THE HIGHER THE OVERLAP COEFFICIENT THE HIGHER THE TEMPORAL OVERLAP IN MOVEMENTS

Species (groups)	Domestic Dog	Domestic Cat
Armadillo	Δ 0.15	Δ 0.63
Birds	Δ 0.56	Δ 0.11
Didelphis	Δ 0.10	Δ 0.54
Rodents	Δ 0.11	Δ 0.51
Margay	Δ 0.20	Δ 0.60
Ocelot	Δ 0.53	Δ 0.49
Tiger Cat	Δ 0.46	Δ 0.45
Penelope	Δ 0.4	Δ 0.07
Tayra	Δ 0.47	Δ 0.11
Domestic Dog	-	Δ 0.14
Domestic Cat	Δ 0.14	-

3.5 Spatial analysis

To explore the individual effects of environmental factors on the presence of domestic dogs, and the presence of dogs on wildlife, generalized linear models (GLM) were used. First, a series of single predictor models were conducted to analyse the predictors separately. To better understand the combined effects of factors and wildlife species on the presence of domestic dogs, a multiple predictor model was conducted. The outcomes of these models are summarized below.

3.5.1 Spatial analysis of domestic dogs - environmental factors

Some environmental factors seem to help explain the presence of domestic dogs (Table 5). The presence of dogs appears to increase as the distance to water increases. On the contrary, although not significant as well, the distance to a road and a construction site plays a negative role in the abundance of domestic dogs. The number of dogs seems to decrease in areas located at a greater distance from a road and/or construction site. Also, elevation may play a negative role in dog abundance. Lastly, the distance to a trail shows a very high standard error, suggesting some statistical issues, however, the high influence relates to the data as the cameras with domestic dogs detected are located on, or very close to, a trail. Model 5 (distance to trail) and model 3 (distance to road), show the lowest AIC values compared to the null model, indicating that these models explain the presence of dogs best.

Table 5: Generalized linear models showing whether different environmental conditions influence domestic dog's presence. All models include one environmental condition

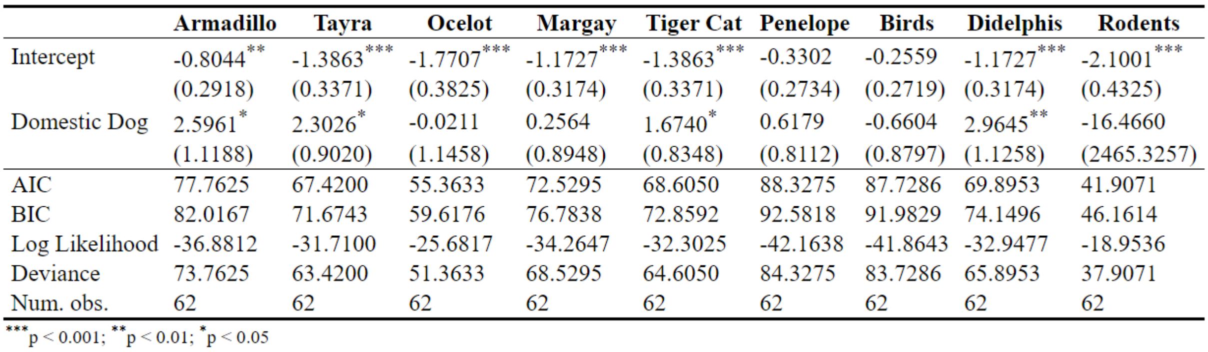
	Null model	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Intercept	-2.0614^{***}	-0.4228	-2.8487^{**}	-1.0153	-1.5664^{*}	-1.4881^{***}
	(0.4013)	(5.1562)	(0.9261)	(0.6088)	(0.7427)	(0.4185)
Elevation		-0.0012				
		(0.0038)				
Distance to Water			0.0062			
			(0.0060)			
Distance to Road				-0.0034		
				(0.0020)		
Distance to Construction					-0.0012	
					(0.0016)	
Distance to Trail						-3.3398
						(539.6367)
AIC	45.7153	47.6120	46.5816	43.5209	47.1410	40.3066
BIC	47.8424	51.8663	50.8359	47.7751	51.3953	44.5609
Log Likelihood	-21.8576	-21.8060	-21.2908	-19.7604	-21.5705	-18.1533
Deviance	43.7153	43.6120	42.5816	39.5209	43.1410	36.3066
Num. obs.	62	62	62	62	62	62

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

3.5.2 Spatial analysis of domestic dogs – native species

In addition to environmental factors, species also influence each other's presence (Table 6). Domestic dogs appear to be positively related to the presence of the armadillo, tayra, tiger cat and didelphis species. Interestingly, the relatively high coefficients of the armadillo and didelphis species indicate that they are more likely to be present when domestic dogs are around as well. The presence of the ocelot and bird species seems to be negatively influenced by domestic dogs, although the magnitude of the factors is small.

TABLE 6: SUMMARY OF BINOMIAL GLM MODELS SHOWING THE INFLUENCE OF THE DOMESTIC DOG ON THE PRESENCE OF SEVERAL NATIVE SPECIES. THE DIFFERENT MODELS ALL INCLUDE ONE SPECIES (GROUP).



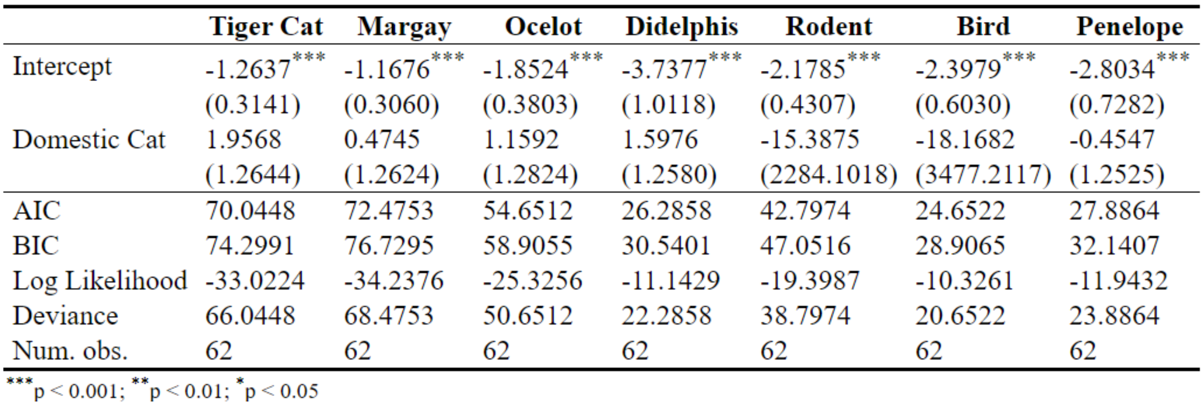
	Armadillo	**Tayra**	**Ocelot**	**Margay**	**Tiger Cat**	**Penelope**	**Birds**	**Didelphis**	**Rodents**
Intercept	-0.8044^{**}	-1.3863^{***}	-1.7707^{***}	-1.1727^{***}	-1.3863^{***}	-0.3302	-0.2559	-1.1727^{***}	-2.1001^{***}
	(0.2918)	(0.3371)	(0.3825)	(0.3174)	(0.3371)	(0.2734)	(0.2719)	(0.3174)	(0.4325)
Domestic Dog	2.5961^{*}	2.3026^{*}	-0.0211	0.2564	1.6740^{*}	0.6179	-0.6604	2.9645^{**}	-16.4660
	(1.1188)	(0.9020)	(1.1458)	(0.8948)	(0.8348)	(0.8112)	(0.8797)	(1.1258)	(2465.3257)
AIC	77.7625	67.4200	55.3633	72.5295	68.6050	88.3275	87.7286	69.8953	41.9071
BIC	82.0167	71.6743	59.6176	76.7838	72.8592	92.5818	91.9829	74.1496	46.1614
Log Likelihood	-36.8812	-31.7100	-25.6817	-34.2647	-32.3025	-42.1638	-41.8643	-32.9477	-18.9536
Deviance	73.7625	63.4200	51.3633	68.5295	64.6050	84.3275	83.7286	65.8953	37.9071
Num. obs.	62	62	62	62	62	62	62	62	62

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

3.5.3 Spatial analysis of domestic cat

The amount of data from the domestic cat is scarce therefore the data shows no significant relation with environmental factors or the presence of other species. The domestic cat (one individual) was exclusively spotted on camera trap 14, leaving no valid models applicable regarding environmental factors. The correlation between the domestic cat and other species was difficult to interpret; yet, some marginal explanations can be suggested (Table 7). Even though the modelling results are not significant, the penelope species' negative estimate coefficient is worth noting. The tiger cat, margay and didelphis species show positive estimate coefficients. Nevertheless, those results are not statistically significant and can therefore not explain the influence of the domestic cat on species' presence within the sampled data.

TABLE 7: SUMMARY OF BINOMIAL GLM MODELS SHOWING THE INFLUENCE OF THE DOMESTIC CAT ON NATIVE SPECIES. THE DIFFERENT MODELS ALL INCLUDE ONE SPECIES.



	Tiger Cat	**Margay**	**Ocelot**	**Didelphis**	**Rodent**	**Bird**	**Penelope**
Intercept	-1.2637^{***}	-1.1676^{***}	-1.8524^{***}	-3.7377^{***}	-2.1785^{***}	-2.3979^{***}	-2.8034^{***}
	(0.3141)	(0.3060)	(0.3803)	(1.0118)	(0.4307)	(0.6030)	(0.7282)
Domestic Cat	1.9568	0.4745	1.1592	1.5976	-15.3875	-18.1682	-0.4547
	(1.2644)	(1.2624)	(1.2824)	(1.2580)	(2284.1018)	(3477.2117)	(1.2525)
AIC	70.0448	72.4753	54.6512	26.2858	42.7974	24.6522	27.8864
BIC	74.2991	76.7295	58.9055	30.5401	47.0516	28.9065	32.1407
Log Likelihood	-33.0224	-34.2376	-25.3256	-11.1429	-19.3987	-10.3261	-11.9432
Deviance	66.0448	68.4753	50.6512	22.2858	38.7974	20.6522	23.8864
Num. obs.	62	62	62	62	62	62	62

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

3.5.4 Spatial overlap

The presence of domestic pets may influence the presence of native species. The higher the frequency of species being detected on cameras 4, 6 or 14, the higher the likelihood of encountering a domestic dog or cat, making it an important factor to include. Bird species are frequently present on camera 4 (7.8%) but show almost no detections on cameras 6 and 14. Didelphis species have a higher frequency shown on cameras 6 and 14 (20.3% and 28.8% respectively) than on other cameras, also the tayra is most often detected on camera 6 (29%). The armadillo shows a medium presence on cameras 6 and 14 (15.2% and 17.4% respectively), similar to the spix's guan on camera 6 (9.5%). On the contrary, the squirrel is not detected on any of the cameras where dogs were detected. Similar to squirrels, the margay is also not showing a high presence on the three cameras (0%, 7.7% and 3.8%).

Records of native species just before or after records of domestic dogs and cats were barely visible. There was only one instance in which a domestic cat was detected, followed by a tiger cat two hours later. One hour later, the domestic cat was observed wandering back towards the entrance of the reserve. However, there is no more evidence that other animals encountered each other.

3.6 Questionnaire

3.6.1 Basics questionnaire

The questionnaire has a sample size of 27 households, covering a total of 68 pets. The number of pets per household ranges from one to eight, with an average of 2.5 pets per household. The average household size is 2.4 persons, with fewer persons under the age of 18 (16.7%) compared to adults (83.3%). Of the 68 recorded pets, 49 are dogs and 19 are cats. In general, more male pets (55.9%) than female pets (44.1%) were recorded (Figure 13).

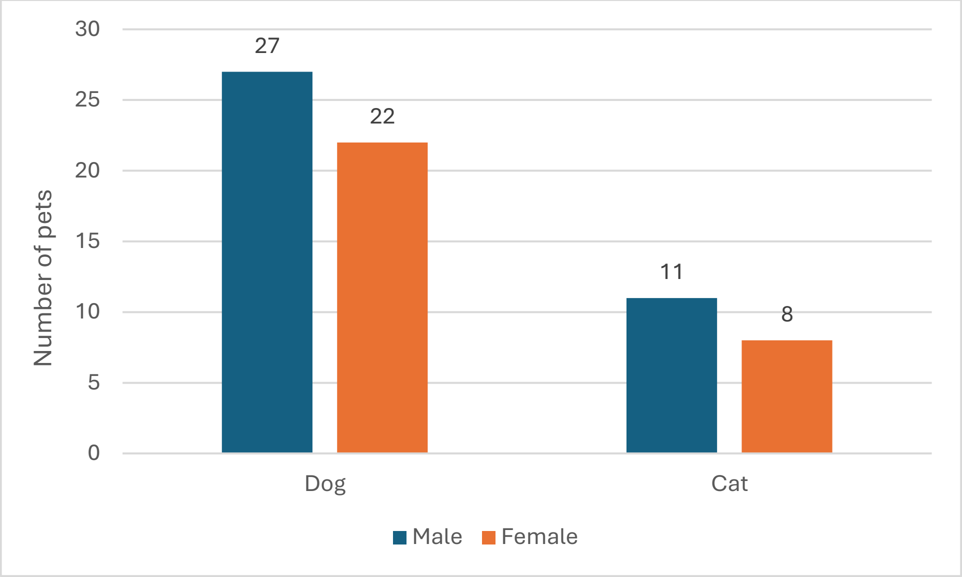


FIGURE 13: THE NUMBER OF PETS INCLUDED IN THE QUESTIONNAIRE, SHOWED BY PET TYPE AND SEX

3.6.2 Identifying domestic dogs and cat

All seven of the dogs captured on the camera traps are also pets of the households that were surveyed during the questionnaire. Four of the dogs belong to the household that is closest to the reserve, giving them easier access to the forest and the reserve. Four dogs were identified as males, two dogs as females and the sex of one dog remains unidentified. The dogs are all adults with ages ranging between three to ten years. The dog owners stated that their dogs were often outdoors and in the forest, including some owners who admitted that their dogs had chased wildlife or been attacked by wildlife. The dogs are classified as medium-to-large-sized dogs and half of the dogs can be considered hunting breeds, including mixes with pit bulls, beagles, and American foxhounds. In addition to the identified dogs, it is not possible to determine with certainty whether the captured domestic cat also belongs to one of the households surveyed, due to the dark conditions in which the images were taken.

3.6.3 Domestic dogs and cat

The average pet age is about 6 years old, ranging from 3 months to 17 years old. More than half of the owners stated that their pet(s) went into the forest (59%) and/or chased wildlife (65%), however, a smaller number of pets were also seen bringing dead animals home (19%). Neutered and unneutered pets are equivalent (50%), but female pets seem to be neutered more frequently than male pets (p= 0.0002), indicating a higher likelihood of neutered pets being female. The sex of pets does not seem to be relevant in explaining any other variables.

Comparing the questionnaire answers about dogs and cats between the variables shows several interesting outcomes. Dogs seem to be more frequently kept only outdoors than cats who spend time both indoors and outdoors (p=0.0013). Furthermore, dogs are more likely to go into the forest in groups compared to cats (p=0.0008). Cats prefer to wander around alone. Although cats seem to act more often alone, they chase wildlife (p=0.0452) and go into the forest (p=0.0424) more frequently than dogs. This corresponds to the outcome that cats bring more dead animals to their home than dogs, a statistically significant difference (p = 0.0478). In addition, the influence of different feeding patterns on the likelihood of going into the forest was tested. The findings suggest that dogs who are fed twice a day are more likely to enter the forest than dogs fed once or three times a day (p=0.0392), although the type of food does not seem to play a difference. In contrast, none of the feeding variables influence the likelihood of cats going into the forest. Overall, the outcomes suggest that there may be behavioural differences between domestic dogs and cats.

Pets organized in a group seem to be much more likely to explore the forest (p=0.007) and engage in chasing wildlife (p=0.018) compared to those wandering alone. Pets with both indoor and outdoor access show a higher likelihood to chase wildlife than pets who just spend time either indoors or outdoors (p=0.021). In contrast, the likelihood of pets, with both indoor and outdoor access, entering the forest is not statistically significant at the 0.05 level (p=0.088). The variables age and sex do not seem to influence the likelihood of going into the forest or chasing wildlife.

3.6.4 Behaviour characteristics

Behavioural characteristics do not seem to play a big role in explaining variables such as chasing wildlife and bringing dead animals home. According to the owners, dogs with hunting behaviour may be an explanatory factor for bringing dead animals home (p=0.0279). In addition, playful dogs appear to have a marginally lower effect on the probability of chasing wildlife (p=0.0982). Overall, while some trends were observed looking at behavioural characteristics, there was no strong evidence to explain chasing wildlife and bringing dead animals home.

4. Discussion

The results show that domestic dogs and cats have been detected on camera traps within the study area, indicating their presence in the area. The findings demonstrate temporal and spatial overlap with potential prey, although no direct interactions were identified on any of the images captured during this study. The camera traps recorded the presence of domestic dogs and cats on three of the fourteen cameras, but only in the northern region. This indicates that human activities can be a contributing factor in the increased presence of those animals, given the proximity of human activity to the border in the north of the reserve. The daily activity patterns of dogs and a cat correspond to the activity hours of several wild species. Additionally, spatial overlap was apparent for dogs, which increases the likelihood of interaction between dogs and wildlife. Furthermore, the findings indicate that certain environmental factors, such as proximity to human activity, increase the likelihood of the occurrence of dogs. These findings are partially consistent with the hypothesis that the movement patterns of domestic animals intersect with wildlife activity. However, no concrete evidence was found to support any direct interaction or disturbance.

4.1 Temporal movements

4.1.1 Temporal analysis of domestic dogs

The temporal distribution of the domestic dog indicated a predominantly diurnal activity, with peak hours occurring between 06:00 and 12:00. These peak times align with the core activity periods identified in other studies conducted in the Atlantic Forest (Azevedo et al., 2018; Zanin et al., 2019). The use of GPS collars in Australia enabled the determination of the daily activity hours of domestic dogs, with peak times found between 10:00 – 11:00 and between 05:00 – 06:00 (Maher et al., 2019). A bimodal activity pattern, meaning two distinct periods of high activity within a 24-hour cycle, has been reported in other studies (Carvalho et al., 2019; Griss et al., 2021), although this was not observed in this study.

The daily activity pattern of prey species of domestic dogs, such as the armadillos, rodents and didelphis species differ from the activity hours of the dogs, as the prey species are primarily nocturnal. Bird species, including the Penelope bird, show a more diurnal activity that coincides with that of the dogs. This overlap increases the likelihood of encounters between species and consequently the risk of predation. Several studies have observed that birds serve as prey (dos Santos et al., 2018; Guedes et al., 2020), although it was also noted that rodents and didelphis species are preyed upon. This is an interesting finding, as the temporal distribution of activity hours of dogs and rodents and didelphis species does not match, suggesting that interactions between these species are unlikely. In addition to their role as predators, dogs in the tropics may compete with wild carnivores. Some felids interfere with the activity hours of the dogs in this study, which has also been discussed by Guedes et al. (2020) and may result in competition for resources and space. In a related study by Sparkes et al (2022), the daily activity patterns of individual dogs were examined, with a particular focus on seasonal variations to determine any changes throughout the year. However, due to the lack of a substantial dataset of dog records, this analysis was not feasible in this study. Nevertheless, it would be a valuable contribution to future research.

4.1.2 Temporal analysis of domestic cat

The findings indicate that the domestic cat is a nocturnal species. This finding is supported by previous research, which has demonstrated that cats were most active during night hours (Herrera et al., 2022; Merčnik et al., 2023). However, the single cat observed in this study is not a representative sample of the potential population in the study area. It is therefore not possible to draw any consistent conclusions regarding this study based on the temporal distribution of the domestic cat.

4.2 Spatial movements

4.2.1 Spatial analysis of domestic dogs

Despite the absence of concrete evidence of direct or indirect interactions between domestic dogs and native species, several studies have observed spatial disturbance by dogs. The high occurrence of domestic dogs has been found to result in a decreased detection of the tayra, raccoon and felid species (Cassano et al., 2014). Moreover, similar to the study of Massara et al. (2015), the results of this study observed a decline in ocelot presence in areas where dogs were present, suggesting that dogs may have disturbed their activity patterns. Another finding of this study indicates that the presence of domestic dogs may positively affect the presence of the armadillo, tayra, tiger cat and didelphis species. Although not statistically significant, the presence of birds and rodent species seems to be negatively influenced by the presence of dogs. The presence of dogs can have a negative influence on the behaviour of the affected species, and in some cases, may even result in local extinction of species in areas where dogs are present (Lacerda et al., 2009; Vanak & Gompper, 2010).

In addition to the influence of dogs on native species, environmental conditions may also have an impact on dog occurrence in the study area. The influence of environmental conditions does not seem to be associated with the presence of domestic dogs. The analysis found no statistically significant results for any of the environmental factors, although other studies observed some correlations. Their results suggested that dogs were more likely to use areas with more agricultural activity and a higher housing density (Paschoal et al., 2018; Vanak & Gompper, 2010). This finding was also reported by Lacerda et al. (2009) and Paschoal et al. (2016), who observed a higher dog presence in locations closer to houses and human activities. Several studies have demonstrated that domestic dogs use trails and roads to move within protected areas, indicating a positive correlation between the presence of roads and trails and the occurrence of dogs in these areas (Sepúlveda et al., 2015; Silva-Rodríguez & Sieving, 2012; Srbek-Araujo & Chiarello, 2008). However, another study by Paschoal et al. (2012) reached a contradictory conclusion, indicating no significant correlation between the distance to the nearest road. This is likely due to the presence of multiple trails within the area, which provide alternative routes for dogs instead of using roads.

Although the results of this study do not show a statistically significant correlation, some similarities between other studies can be observed. The presence of dogs appears to increase when closer to construction sites, which is consistent with the findings that housing density and human activity have a positive effect on the presence of dogs. This helps explain the distribution of domestic dogs in the study as dogs were only captured on camera traps in the northern region, near the border of the reserve. These camera traps are situated in locations that are closest to houses and human activity (outside of the reserve), thereby suggesting that the proximity to humans and their activities can have an impact on the spatial distribution of dogs. Moreover, following the findings of previous studies, this study also observed a higher frequency of dogs closer to roads and trails, which may indicate their use of these corridors for movement within the reserve.

An environmental factor, such as distance to the border of the protected area was not included in this study but the findings of a study by Paschoal et al. (2018) suggest a positive association between the number of dogs and cats and the border. The Atlantic Forest is highly vulnerable to edge effects as a large part of the Atlantic Forest is comprised of isolated and fragmented patches. This was also highlighted in a study by Galetti et al. (2006a), which found that species living close to the edge (edge dwellers) are more vulnerable to disturbance by dogs than species living in the centre of a forest patch. This is due to the likelihood that dogs are more often present close to an edge because of human activities. As a consequence of increasing anthropogenic pressures, the abundance of domestic dogs and cats, along with their potential impact will increase. Therefore, incorporating the edge effect as an environmental factor would be a valuable addition to future research.

4.2.2 Spatial analysis of domestic cat

In a similar pattern to that observed in dogs, cats also show a higher spatial abundance close to the edge of the area, as observed in a study by Woolley and Hartley (2019). Moreover, an additional study demonstrated that cat detections occur close to human settlements, followed by areas that are situated a maximum of 200 meters from a road (J. P. Ferreira et al., 2011). The single cat observed in this study was captured on the camera trap along the unpaved road closest to human settlements, which is consistent with the findings of the aforementioned studies.

4.3 Interactions between domestic dogs, cats and native animals

The results do not indicate any direct interactions between domestic dogs and cats and native species. However, previous studies have reported that dogs and cats hunt various prey, ranging from small to large. For example, black capuchin monkeys are particularly vulnerable when they are moving on the ground; consequently, a killing of a black capuchin monkey by a domestic dog was reported in studies by Galetti and Oliveira et al (2006b; 2008). Moreover, dogs are known to prey on armadillos and rodents (Galetti, 2006b; Hughes & Macdonald, 2013; Lacerda et al., 2009). Additionally, the predation of 14 terrestrial vertebrate species in the Cerrado and Atlantic Forest biomes was observed in the study by Assiss et al. (2023).

A comparison of detection rates among species indicates that the domestic dog is locally more abundant in the study area than the puma, which is the top predator in the area. Nonetheless, other carnivore species, such as the felids and the tayra are more abundant than domestic dogs in this study. Other studies from natural areas in Brazil have presented different findings, with domestic dogs frequently standing out as the most abundant species (Lacerda et al., 2009; Paschoal et al., 2012; Srbek-Araujo & Chiarello, 2008). Although the population densities are not investigated in this study, the results suggest that domestic dogs may be sufficiently present to potentially impact the local fauna. On the contrary, it is also the case that wild species can harm dogs. As stated by Farrel et al. (2000), pumas have been found hunting domestic dogs, as their remains were found within puma scats in Venezuela. Another study suggests that dogs can serve as prey for top predators (Hughes & Macdonald, 2013). This could be considered positive as it represents a natural mechanism for controlling dog populations in specific habitats. However, it also presents a potential risk for disease transmission from domestic dogs to native mammals (Srbek-Araujo & Chiarello, 2008).

It has been documented that felids worldwide have been found to carry diseases that are transmitted by domestic carnivores, primarily dogs and cats. A study by Nava et al. (2008) pointed out that this "spill-over effect" is mostly likely to occur between larger, local, infected dog or cat populations and smaller wild carnivore populations. The feline leukemia virus was transmitted between domestic cats and Florida pumas as a result of interactions (Brown et al., 2008). The risk of disease transmission is most apparent when there is overlap in both time and space, additionally, this risk is further increased by the free movement of the pets. The dogs and cats included in the questionnaire were not tested for any diseases, yet they show similarities in movement patterns with other wild carnivores, suggesting that they may act as carriers of pathogens. This situation is also discussed in numerous studies, highlighting the importance of higher vaccination rates among domestic animals to mitigate their potential as pathogen carriers (G. A. Ferreira et al., 2019; Woodroffe et al., 2012).

Although previous research largely focused on the negative impacts of domestic dogs and cats on wildlife, the possibility of neutral or minimal impacts is rarely discussed. However, it is important to consider that domestic dogs and cats do not necessarily always result in negative pressure on wildlife. The presence of small numbers of dogs and/or cats in protected areas may not significantly disrupt ecosystems and could have a neutral impact, especially if their appearance is limited and controlled. Nevertheless, in highly vulnerable ecosystems already under pressure from habitat loss and fragmentation, negative effects impacts are more likely.

4.4 Questionnaire

The questionnaire provides interesting outcomes, supporting the findings of the camera trap data. The survey was conducted among households located close to the study area. However, it should be noted that not all responses can be considered entirely accurate due to potential variations in respondents' understanding or interpretation of certain questions. Additionally, some participants may have had limited knowledge or awareness regarding this topic, which may have influenced the reliability of the data. Furthermore, not all questions were fully answered.

One of the results indicated no significant difference between sexes and age groups concerning the behaviour of dogs going into the forest and their tendency to chase animals. This is a different pattern from that observed in other studies, wherein male dogs tend to forage for a longer duration. Additionally, older dogs were found to engage in more intensive foraging and show more aggressive behaviour than younger dogs (Saavedra-Aracena et al., 2021; Sparkes et al., 2014). In addition to hunting time, home range sizes can explain the probability of predation. Some studies indicate that male dogs have a larger home range than female dogs (Dürr et al., 2017; Sparkes et al., 2014) and the study by López-Jara et al. (2021) concluded that younger dogs have a higher maximum distance travelled. Furthermore, male cats that are not neutered seem to show larger home range sizes (Kays et al., 2020). This study did not include an analysis of home ranges due to the lack of dog and cat detections and the absence of GPS (Geographic Positioning System) data. In future research, it would be very interesting to include GPS collars to enhance the understanding of the spatial movements of domestic dogs and cats.

It was observed that dogs were more frequently captured together with another dog than alone. This finding aligns with the results of the questionnaire, which indicated that pets tend to forage in groups rather than alone. This is in contrast with the results from other studies where single individuals were more frequently recorded on camera traps than packs of dogs (Paschoal et al., 2012; Srbek-Araujo & Chiarello, 2008). This result may be explained by the observation that dogs from the same household engage in foraging activities collectively, while in other studies dogs do not have an owner or a pack with other dogs. Dogs that hunt in packs appear to enhance their efficiency and pose a considerable threat to native wildlife. Packs of dogs can target larger species compared to solitary dogs, which hunt upon smaller species or scavenge for food (Galetti, 2006a; Paschoal et al., 2018; Silva-Rodríguez & Sieving, 2012).

The data of this study indicate that feeding patterns do not seem to influence domestic cats. On the contrary, the feeding pattern of dogs plays a higher role in explaining foraging time. Dogs that are fed twice a day are more likely to go into the forest than those that are fed just once or three times. In general, the amount of food provided by humans is regarded as a highly explainable factor (Hall et al., 2016). The provision of more food can reduce the likelihood of dogs and cats engaging in predatory behaviour, nevertheless, they may still engage in hunting even when their hunger is satisfied due to their natural hunting instinct (Baker et al., 2005; Silva-Rodríguez & Sieving, 2012; Thomas et al., 2012). Another aspect of the cat's instinct is the tendency to bring prey back to its territory, which is often the animal's home. This finding aligns with the results from the questionnaire, which indicated that cats bring more dead animals home than dogs. While cats return prey to their territory more often than dogs, this does not necessarily indicate that prey is always brought back. The return rate of prey can underestimate the predation intensity of domestic cats (Seymour et al., 2020). In a study conducted by Loyd et al. (2013), animal-borne video cameras were used to document instances of predation and assess potential inconsistencies in return rates. The authors indicated that only 18% of the prey were returned to their homes. The majority of studies do not account for prey that has been consumed or abandoned, resulting in an underestimation of the impact of domestic cats on certain species groups.

4.5 Management strategies

The outcomes of this study do not provide evidence of direct interaction between domestic dogs and cats with native species. However, multiple dogs and a cat were detected in the study area. The observed overlap of temporal and spatial movement of domestic dogs and cats with wild species, in combination with their behavioural and biological characteristics, presents them as a potential threat to native animals. Other studies have found evidence of negative interactions and have evaluated the potential risks posed by domestic dogs and cats (Assis et al., 2023; Galetti, 2006b; Hughes & Macdonald, 2013). Moreover, the introduction of pets in protected areas can diminish the value of the park in conserving native species (de Cassia Bianchi et al., 2020; Paschoal et al., 2016; Silva-Rodríguez & Sieving, 2012). To mitigate the negative impacts, it's necessary to formulate effective management strategies that simultaneously guarantee the conservation of native species and ensure the well-being of domestic animals.

Humans are an important element in the long-term management strategies of protected areas. The dogs detected in this study are probably not feral, indicating that humans can play a significant role in controlling the impact of domestic dogs. One potential strategy for addressing the issue is to promote responsible dog and cat ownership by raising awareness. The creation of residential awareness can be achieved by implementing educational and communication programs. It is recommended that educational initiatives provide dog and cat owners with information regarding the importance of neutering, vaccinations, anti-parasite treatments and adequate diets. Communication programs will help people to learn more about the ecological impacts their pets may have on wildlife and human health. Once individuals start to understand the negative consequences, it will be easier to address issues about their pets, with the ultimate goal of minimizing the impacts.

In addition to the aforementioned strategies, it is recommended that specific management strategies for RPPN Alto da Figueira should be implemented to mitigate the risk of impacts by domestic dogs and cats in the area. The stimulation or even the mandatory neutering of animals should be considered a priority. The questionnaire findings indicate that female pets are more frequently neutered than male pets, suggesting that the neutering rate of male pets needs improvement. A targeted campaign could increase awareness among pet owners and encourage more widespread neutering. Additionally, reducing the number of unaltered pets could decrease the amount of abandoned pet populations, a significant concern in the area. It appears that while dogs are often rescued, cats are more likely to become feral. Another strategy that would be beneficial to implement is the promotion of vaccination for a greater number of diseases. This would enhance the safeguarding of both pets and wildlife. The municipality has already implemented a program of free rabies vaccinations on an annual basis, which is an excellent starting point. Nevertheless, rabies vaccination alone is insufficient to ensure a reduction in disease transmission. The promotion of other vaccinations against diseases such as distemper, adenovirus and parvovirus is therefore important (Butler et al., 2004; Cleaveland et al., 2006; Filoni et al., 2006). Furthermore, restricting the pet's movement will reduce interaction with wild species. The Brazilian environmental laws prohibit exotic species in protected areas. Consequently, owners are required to keep their pets fenced, although this is frequently not the case (Brasil SNUC, 2000). Restricting movements is a challenging strategy when the properties of the owners are not enclosed and the practice of keeping pets inside the house is not a cultural norm. Therefore, it is important to implement educational initiatives and ensure strict enforcement of the law. The combination of these strategies will contribute to reducing the number of (feral) dogs and cats, as well as the extent and intensity of their potential negative impacts in RPPN Alto da Figueira.

4.6 Challenges of the research and future recommendations

The main objective of this study was to identify spatial and temporal movements of domestic dogs and cats and assess whether they affect local fauna in the study area. The methods and analyses used in the study show that there is a likelihood that interactions can happen due to overlap in movements between dogs, cats, and native species. However, adding more camera trap data and including more nuanced and advanced analyses would increase the accuracy of the findings. This study used four to five months of data and can be considered a pilot study since the camera trap project will last at least a year. Some recommendations for future research will be suggested in the following section.

It is recommended for future research to aim to improve the identification of species. Those species that could not be identified within the time constraints were placed in a species group organized according to their respective family, class or order. All species that could be identified at the species level were placed separately. A potential limitation of this study is the comparison of species groups with fully identified species. However, the intention was to use as many identified species as possible, combined with unidentified species groups, which would be the optimal approach for this study. Camera traps are the most reliable method for analysing medium-to-large-sized mammals. However, the classification system used in this study focused on mammals as well as birds and rodents as they are potential prey for domestic dogs and cats. Including these species seemed therefore to be a logical approach. It would be beneficial for future research to emphasize more on the identification of all species, which would improve the quality and interpretation of the study.

In consideration of the statistical analyses, it was determined that the models were not robust enough to fully rely on the analysis outcomes. Generalized linear models (GLM) were used instead of the occupancy model as the latter proved to be too complex in relation to the dataset. The environmental factors included in the GLMs had no significant or marginal effect on the presence of domestic dogs and cats. The limited sample size of the study can be a significant contributing factor to the lack of significant outcomes. Domestic dogs were detected on three camera traps, while the domestic cat was only detected on one camera trap. The limited number of detections reduces the reliability of the results for the entire study area. Furthermore, the presence-absence analysis could be more robust by including more detections. Therefore, it is recommended that a future study with a larger data set, of at least one year's duration, should re-examine the influence of environmental factors on the presence of domestic dogs and cats, as well as employing an occupancy model instead of a presence-absence analysis.

In addition to the small sample size, technical issues with the camera traps also limited the study. Problems such as unforeseen battery drainage and SD-card errors caused several cameras to malfunction. Two cameras were completely inoperative during one of the collection periods and on some occasions, camera traps did not function for several days. Consequently, some missing data was not incorporated into the analyses, which may have resulted in biases. While such technical difficulties are an unfortunate and unavoidable aspect of fieldwork, they must be acknowledged and accounted for. One potential solution to this issue is to invest in more advanced and costly camera traps.

Besides the possibility of missing data, it is also likely that interactions were not captured by the camera traps, even though they occurred during sampling. The cameras were systematically placed to ensure representative coverage of heterogeneous environments and minimize bias, although it is still possible that important movement corridors or key areas of activity may have been missed. During certain periods, dogs were observed or heard within the study area; however, they were not captured on any of the camera traps. This suggests that they use alternative routes that do not pass the cameras. Consequently, the absence of recorded species and interactions does not necessarily indicate that none occurred, highlighting the limitations of camera trap coverage in fully capturing wildlife behaviour.

In addition to the included methods, another method for collecting more detailed information on the movements of domestic dogs and cats is using GPS data. The use of GPS radio collars for dogs and cats will give more fine-scaled locations of their movements when they leave the property of the owner. A study conducted in Chile, by Sepúlveda et al. (2015) found that during forays, movements are primarily focused on human-dominated landscapes, particularly where roads facilitate access to the forest. The findings of this study indicate that dogs and cats use the unpaved road within the reserve as a gateway for entering the forest. However, a more detailed understanding of their specific movements, including the locations at which they are observed, would facilitate a more comprehensive analysis of their spatial and temporal movement patterns.

Furthermore, incorporating the collection and analysis of domestic dog scats will improve specific knowledge about prey species. The analysis of dog faeces can provide information about the dog's feeding habits. The identification of prey species in scats can be achieved through extracting DNA and performing molecular analyses, or through the expertise of (taxonomic) experts and the local population in identifying prey components such as hairs, bones, and feathers (Carrasco-Román et al., 2021; Shehzad et al., 2012). Additionally, collecting scats is a non-disruptive method of gathering data about the distribution of dogs in a given area. The results can provide insight into the hunting behaviour of these animals, and thus inform conservation management strategies

This study provides a valuable foundation for understanding the potential impacts of domestic dogs and cats on wildlife. However, to gain a more complete and representative understanding of this topic, further studies are necessary to build upon this pilot study. This will result in a more detailed and nuanced set of findings, which will in turn facilitate the development of more targeted management strategies.

5. Conclusion

This study aimed to examine the spatial and temporal movement patterns of domestic dogs and cats and assess their potential impacts on wildlife in RPPN Alto da Figueira, Brazil. The findings, based on the camera trap data and questionnaire, indicated the presence of domestic dogs and cats close to the border in the northern part of the study area. The results of the study demonstrated that the daily activity patterns of dogs and cat overlap with those of prey species and other carnivores. This suggests the possibility of predation and competition between species. Furthermore, there is some relationship found in spatial movements between domestic animals and native species. However, there is currently no evidence to suggest that wildlife actively avoid areas used by dogs or cats. The questionnaire provided insights into the local dog and cat populations, including their activities and characteristics. Although the study did not establish direct interactions between domestic animals and wildlife, it did provide valuable outcomes about the presence and movement patterns of domestic dogs and cats. In addition to the findings concerning the movements, behavioural and biological characteristics of dogs and cats, and the documented negative interactions in similar studies, it is evident that there is a need for caution. The Atlantic Forest, being a unique and highly fragmented ecosystem, is particularly vulnerable to disturbances, making the potential impacts of domestic animals an important conservation concern.

In conclusion, although this study did not link domestic dogs and cats to direct harm to wildlife in RPPN Alto da Figueira, it does highlight important patterns that are worthy of further investigation. The study highlights the importance of developing management strategies and further research, particularly as increasing human activity in the region increases the likelihood of pets encountering wildlife. Possible management strategies could include promoting responsible pet ownership and educating local communities about the potential pressures on wildlife. It is recommended that for future research the duration of camera trapping and monitoring is extended to provide a more comprehensive understanding of these interactions and inform conservation efforts in this critical biodiversity hotspot.

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7. Appendix

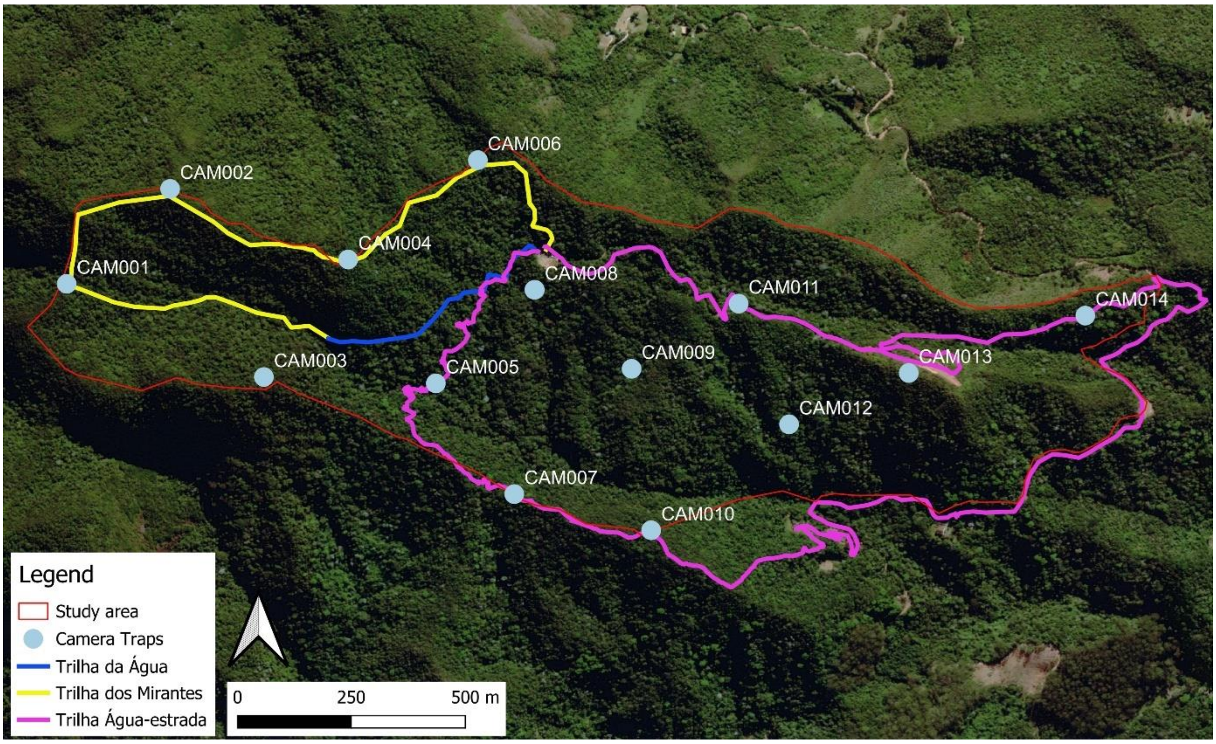

Figure 14: Overview of the study area including the various trails

Table 8: This table illustrates the camera traps and data collection periods when identified dogs were detected

	C1	C2	C3	C4	C5
CAM004	Ind01				
	Ind02				
	Ind03				
	Ind04				
CAM006	Ind03			Ind01	
	Ind04			Ind02	
				Ind03	
				Ind05	
CAM014		Ind01		Ind01	Ind03
		Ind02		Ind02	
		Ind03			
		Ind04			
		Ind05			
		Ind06			
		Ind07			

Appendix. 1 Camera trap protocol

Installing camera traps:

1. Check for suitable spots (open spaces with cam height 30-45cm), some cams on the trail, some not, near water, roads, different environments, etc.
2. Use a pole (when there is no good tree to hang the camera)
3. Hang the camera (30-45cm height/be aware of slope/very tight to the pole)
4. Check the camera view on iPad
5. Remove branches/vegetation that could trigger the camera
6. Take a photo from the canopy above the camera
7. Measure the height of the canopy
8. Clean lens of the camera
9. Take a photo of the whiteboard (stating the camera name, date, and time)
10. Take a photo with the whiteboard (environment, height of camera)
11. Take a photo of the camera view
11. Turn on the camera and change the settings to video and 60s video time
12. Calibrate:
    1. Place measuring tape in the middle of the camera view
    2. Use measuring tape to measure 1, 2, 3, 4, 6, 8, and 10 meters (if possible) and measure at 3 points per ‘meter’: in the middle of the camera view (on the measuring tape), right from the middle point and left from the middle point.
    3. Use an angle of 14 degrees to find out the distance between two points → see distances from the measuring tape (and thus between the points) in this table:
    4. Do this using the 1-meter calibration stick we made with markings every 10 centimeters. Make sure the stripes are visible and use your fingers (1, 2, 3, 4, etc.) to indicate the meters we are away from the camera.

1 meter	25 centimeters
2 meters	50 centimeters
3 meters	75 centimeters
4 meters	100 centimeters
6 meters	150 centimeters
8 meters	200 centimeters
10 meters	250 centimeters

13. Check calibration on the iPad.
14. Change settings back to original (photo and 10s video), check date and time, and camera name.
15. Write down all relevant info on the info sheet (phone): near human activities, installation process, type of environment, type of place, everything that comes to mind.

Checklist for data collection camera traps

What to bring into the field:

- Spare batteries
- Spare camera (CAM002)
- SD2 cards
- Handheld GPS
- Umbrella
- Cloth + soap to clean the camera
- Machete
- SD card containers labeled as “collected ” and “emptied”
- Marker
- Tape
- Walkie talkie

- Plastic bags (dog poop)
- Pocketknife
- Tie-wrap

Data collection steps:

- Make sure you don’t move the camera
- Open the camera
- CAM011 & CAM014: cut the tie-wrap
- Turn camera off
- Take SD1 card out
- Put the SD1 card in the waterproof container labeled as “collected”
- Get an SD2 card out of the waterproof container labeled as “emptied”
- Take off the tape from SD2 card
- Put SD2 card in the camera
- Format the SD2 card when in the camera
- Check camera settings (see Table 2)
- Check battery
- Clean the lens
- Clear the surroundings (leaves etc)
- TURN CAMERA ON
- Wait until you see “0” on the camera countdown, then close the camera and walk away
- CAM011 & CAM014: lock the camera with a tie-wrap

SD card instructions:

SD1 card is in the camera and you take it out of the camera to put the data on the hard drive. SD2 card is the SD card you take into the field to put in the camera.

Waterproof container 1 is labeled ‘’collected’’
Waterproof container 2 is labeled ‘’emptied’’

SD1 card procedure:

- Take SD1 out of the camera
- Put SD1 in a waterproof container
- Connect SD1 to your computer
- Put data of SD1 on the hard drive
- Disconnect SD1 from your computer
- Label SD1 with a blanco tape
- Put SD1 with the blanco tape in the waterproof container that is labeled ‘’collected’’
- The SD1 card now becomes an SD2 card

SD2 card procedure:

- Get the waterproof container that is labeled ‘’emptied’’
- Take out SD2, this card is labeled with a blanco tape
- Take off the blanco tape
- Put SD2 in the camera
- Format the camera
- The SD2 card now becomes an SD1 card

Putting data on the hard drive:

- Put SD1 card in the converter (SD with laptop)
- Navigate to the hard drive
- Navigate to the correct folder (= cameratraps)
- Navigate to the right camera trap number
- Make a new folder with the date on which the data was collected from the camera (i.e. 02FEB24)
- Put all the data in this folder

Transferring data to Marre & Anne:

- Use WeTransfer
- 1 WeTransfer link per camera per date

Table 1: dates on which data needs to be collected from the cameras.

Round	**Week of collecting data**	**Who**
1	Week 9 (26th of February..)	Anne
2	Week 13 (25th of March..)	Karine/Thomas
3	Week 17 (22nd of April..)	Karine/Thomas
4	Week 21 (20th of May..)	Karine/Thomas
5	Week 25 (17th of June..)	Karine/Thomas
6	Week 29 (15th of July..)	Karine/Thomas
7	Week 33 (12th of Augustus..)	Karine/Thomas
8	Week 37 (9th of September..)	Karine/Thomas
9	Week 41 (7th of October..)	Karine/Thomas
10	Week 45 (4th of November..)	Karine/Thomas
11	Week 49 (2nd of December..)	Karine/Thomas
12	Week 1 (30th of December..)	Karine/Thomas
13	Week 5 (27th of January..)	Karine/Thomas

Camera settings that must be checked in the field:

Settings CAM002 – CAM014

Set Clock	Brazilian Time (date + time)
Mode	Camera (so **not** video)
Capture number	5 Photos

Settings CAM001

Set Clock	Brazilian Time (date + time)
Mode	Hybrid (so **not** camera or video)
Capture number	5 Photos
Video length	10 seconds

Appendix 2. Questionnaire

Date (dd/mm/aa) ____________

Household

How many people live in the house? Under 18 y.o. ______ Over 18 y.o. ______.

General questions (Dogs/Cats)

How many dogs do you have?

DOG/CAT	AGE	SEX	SIZE (KG)	BREED	NEUTERED	COLOR	PHOTO

Diseases and parasites

Is your dog(s)/cat(s) vaccinated	
Do you know against which disease?	

Does your dog(s)/cat(s) have a vaccination card?	
When was the last time your dog(s)/cat(s) was vaccinated?	
Has your dog(s)/cat(s) have had any diseases lately? Or in the past	
Which ones?	
Is your dog(s)/cat(s) treated for parasites?	
If so, how often do you treat them?	

Feed

Do you feed your dog(s)/cat(s)?	
If yes, how often do you feed them?	
Do you feed them pet food or human food?	

Behavior

How do you describe your dog(s)/cat(s)'s character (ex. calm, playful, angry, violent, etc)?	
Does your dog(s) bark for other people?	

Forest

Does your dog(s)/cat(s) stay at home or outside?	
If outside, do they go to the forest?	
If so, how long do they spend time in the forest?	
Do they go to the forest alone or with other dog(s)/cat(s)?	

Chase wildlife

Does your dog(s)/cat(s) sometimes chase wildlife (ex. birds, lizards, insects, etc)?	
If so, has your dog(s)/cat(s) ever brought home dead wildlife?	

Attacked

Have your dog(s)/cat(s) ever attacked or have been attacked by wildlife (snakes, wildcats, other dogs)?	

If so, have you ever seen your dog(s)/cat(s) with fight wounds?	