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PRÓ-REITORIA DE PESQUISA E PÓS-GRADUAÇÃO

PÓS-GRADUAÇÃO EM ECOLOGIA E CONSERVAÇÃO DA BIODIVERSIDADE

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OS ATROPELAMENTOS REPRESENTAM A FAUNA ADJACENTE? PREDITORES DE ATROPELAMENTOS DE FAUNA SILVESTRE EM RODOVIAS DA CHAPADA DIAMANTINA (BA)

ILHÉUS – BAHIA

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Discente: Jefferson Eduardo Silveira Miranda

Orientador: Dr. Alexandre Schiavetti

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Ilhéus, 26 de fevereiro de 2025

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"O cara estuda tanto e ainda tem tanto pra aprender"

(Arnaldo Antunes, Paulo Miklos – Fim do dia)

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SUMÁRIO

RESUMO GERAL

As rodovias são responsáveis por grande parte do avanço econômico do Brasil, tendo em vista que facilitam a conexão entre regiões e o transporte de passageiros e cargas. No entanto, as rodovias são responsáveis por diversos impactos ambientais, pois modificam o ecossistema e afetam a fauna de diversas formas. Os principais efeitos das rodovias na fauna são o efeito barreira, efeito de evitamento e atropelamentos, que podem reduzir as populações locais. Esses efeitos podem ser agravados em regiões de Unidades de Conservação (UCs), visto que são áreas destinadas a proteção de espécies endêmicas e ameaçadas. Desse modo, o objetivo do presente trabalho foi compreender os impactos das rodovias na fauna no entorno de uma UC. A área de estudo foi o Parque Nacional da Chapada Diamantina (PNCD), pois se trata de uma região de grande relevância, principalmente por abrigar diversas espécies endêmicas e ter um grande fluxo de veículos, impulsionado principalmente pelo forte turismo da região. Assim, realizamos o levantamento de animais atropelados entre 2022 e 2023 nas rodovias do entorno da UC, posteriormente identificamos os *hotspots* de atropelamentos e, por fim, conduzimos o levantamento de avifauna e mastofauna no entorno das rodovias. Nossos resultados indicaram que há variação espacial de atropelamentos, de modo que a maioria dos *hotspots* se encontram fora da área do PNCD. Também reforçamos a necessidade de estudar os grupos taxonômicos separadamente e, se possível, realizar avaliações considerando os grupos funcionais. Ainda, descobrimos que a distância da rodovia pode não ter o mesmo efeito entre diferentes grupos funcionais, tendo em vista que encontramos efeitos significativos apenas para aves carnívoras.

Palavras-chave: Conservação; Biodiversidade; Malha viária; Impacto ambiental; Endemismo.

GENERAL ABSTRACT

Highways are responsible for much of Brazil's economic growth, as they facilitate connections between regions and the transportation of passengers and cargo. However, highways are responsible for several environmental impacts, as they modify the ecosystem and affect fauna in several ways. The main effects of highways on fauna are the barrier effect, the avoidance effect, and roadkill, which can reduce local populations. These effects can be aggravated in regions of Protected Areas (PAs), as they are areas designated for the protection of endemic and threatened species. Thus, the objective of this study was to understand the impacts of highways on fauna in the surroundings of a PA. The study area was the Chapada Diamantina National Park (PNCD), as it is a region of great importance, mainly because it is home to several endemic species and has a large flow of vehicles, driven mainly by the strong tourism in the region. Thus, we conducted a survey of animals roadkill between 2022 and 2023 on the highways surrounding the PNCD, subsequently identified the hotspots of roadkills and, finally, conducted a survey of birds and mammals in the near the highways. Our results indicate that there is spatial variation in roadkills, so that most of the hotspots are located outside the PNCD area. We also reinforce the need to study taxonomic groups separately and execute assessments considering functional groups. Furthermore, we found that the distance from the highway may not have the same effect among different functional groups, given that we found significant effects only for carnivorous birds.

Keywords: Conservation; Biodiversity; Road network; Environmental impact; Endemism.

INTRODUÇÃO GERAL

As rodovias são de grande importância para o desenvolvimento brasileiro, pois são responsáveis por aproximadamente quase todo o movimento de passageiros e mais da metade do transporte de cargas do país (BARROS; BAGGIO, 2022). Assim, o crescente investimento na pavimentação de rodovias do Brasil tem um impacto positivo na economia (FERREIRA et al., 2019). Embora as rodovias provoquem impactos positivos, pois facilitam o deslocamento e transporte de cargas, também causam impactos negativos, como a modificação do ecossistema que resulta em vários outros impactos ambientais (SALOMÃO et al., 2019).

As rodovias provocam impactos diretos e indiretos no ambiente, que inclui fragmentação de degradação ambiental, perda de habitat, atropelamentos e criação de novos ambientes (FORMAN; ALEXANDER, 1998; van der REE; SMITH; GRILO, 2015; KARLSON et al., 2019). Além disso, as rodovias podem impactar a fauna criando efeito barreira, e ficar inacessível para algumas espécies, efeito de evitamento, onde espécies evitam as rodovias principalmente devido aos ruídos, e o atropelamento, que elimina indivíduos das populações (JAEGER et al., 2005; COFFIN, 2007; BARRIENTOS et al., 2021; GRILO et al., 2021). Esses impactos podem reduzir o fluxo gênico e a abundância de populações, consequentemente pode aumentar o risco de extinção local para algumas espécies (JAEGER et al., 2005; JACKSON; FAHRIG, 2011).

Os efeitos das rodovias, principalmente os atropelamentos, podem agravar a situação da fauna em Unidades de Conservação (UCs), pois concentram grande diversidade e abundância de espécies muitas vezes ameaçadas de extinção (BAGER et al., 2016). Além disso, diversas UCs recebem muitos visitantes, o que agrava o problema de atropelamentos, por aumentar o densidade de tráfego (GARRIGA et al., 2012). Por isso, reduzir os impactos das estradas em UCs é de grande importância, principalmente para prevenir e reduzir o declínio populacional das espécies mais afetadas (COLLINSON; MARNEWECK; DAVIES-MOSTERT, 2019). No Brasil esse processo pode ser agravado, pois há uma grande quantidade de UCs que não possui estudo de impacto ambiental das rodovias no entorno, o que aumenta a preocupação para o conhecimento sobre esses impactos nessas áreas (MIRANDA; SCHIAVETTI, 2024).

Nesse sentido, o primeiro passo para avaliar os impactos das rodovias é o levantamento de animais atropelados (PINTO; CLEVENGER; GRILO, 2020), que permite a criação de listas de espécies locais para conhecer os indivíduos diretamente afetados pela rodovia (BAGER; FONTOURA, 2013). Um outro passo importante é compreender os padrões espaciais e temporais dos atropelamentos para que gestores ambientais tomem decisões eficientes (GRILO

et al., 2009). Para compreender a distribuição espacial é comum identificar "*hotspots* de atropelamentos", os pontos com significativa agregação dos atropelamentos, juntamente com análise da paisagem no entorno das estradas (CLEVENGER et al., 2003; BAGER et al., 2007). Essas análises permitem encontrar combinações particulares e definir pontos críticos de mortalidade (FILIUS et al., 2020) para embasar a instalação de medidas mitigadoras, como passagem de fauna e redutor de velocidade, que reduzem os acidentes (GRILO et al., 2009; PAGANY, 2020) que podem causar danos tanto para a fauna quanto para a população humana e resultar em perdas ambientais e econômicas (SÁENZ-DE-SANTA-MARÍA; TELLERÍA, 2015; ABRA et al., 2019).

Ainda existem lacunas e questões a serem resolvidas para cada grupo taxonômico em ecologia de estradas (PAGANY, 2020). Os grupos taxonômicos de vertebrados respondem de maneira diferente aos efeitos das rodovias (HA; SHILLING, 2018) e, por isso, análises de *hotspots* de atropelamentos devem ser refinadas (MIRANDA; MELO; UMETSU, 2020; FILIUS et al., 2020). Embora identificar os *hotspots* de atropelamentos seja fundamental, é necessário novas abordagens para alcançar melhor compreensão e mitigação dos atropelamentos de fauna silvestre (PAGANY, 2020). Nesse sentido, trabalhar com uma abordagem diferenciando os grupos funcionais pode ser a chave para novos trabalhos com fauna atropelada. A biodiversidade tem múltiplas funções e a pressão antrópica exige que mais análises sejam feitas para melhor gestão do ecossistema (MACEL et al., 2012).

Embora o Brasil se destaque dentro da ecologia de estradas na América Latina e no mundo (PINTO; CLEVENGER; GRILO, 2020; SILVA; CRANE; SAVINI, 2021), alguns trabalhos de revisão (VIEIRA et al., 2019; SILVA; CRANE; SAVINI, 2021) não apontam estudos sobre a fauna ocorrente no entorno das rodovias. O principal foco dos trabalhos sobre ecologia de estradas no Brasil e no mundo é o atropelamento (OLIVEIRA et al., 2020). Assim, mesmo com diversos trabalhos realizando análise de características da paisagem no entorno das rodovias ou dos pontos de maior índice de atropelamentos (FREITAS et al., 2015; ARAUJO et al., 2020; FERREGUETTI et al., 2020; MIRANDA; MELO; UMETSU, 2020), ainda há uma lacuna sobre a ocorrência de espécies no entorno das rodovias do Brasil.

Além dessa lacuna de conhecimento, há duas lacunas geográficas que merecem atenção: a ausência de trabalhos no Nordeste do Brasil e a ausência de trabalhos em UCs (MIRANDA; SCHIAVETTI, 2024). O nordeste brasileiro é a região com o menor número de estudos no país (OLIVEIRA et al., 2020) e isso faz com que a região mereça atenção, principalmente por ser conhecida pelo grande potencial turístico que atrai pessoas de outras regiões e de fora do Brasil

(SOUZA; SILVEIRA-NETO, 2015; RABAHY, 2020). Certamente esse aspecto turístico aumenta o fluxo de veículo, contribuindo para o impacto ambiental das rodovias na fauna e enfatizando a necessidade de compreensão dos efeitos das rodovias na fauna da região.

Nesse contexto, a Bahia se destaca entre os três estados com mais ocupações pelo turismo (SOUZA; SILVEIRA-NETO, 2015) e tem Lençóis, na Chapada Diamantina, se sobressaindo entre os principais municípios com chance de receber turistas no estado (ALBUQUERQUE; LIMA, 2021). Acreditamos que o destaque da Chapada Diamantina na rota preferencial de turistas faz com que a região mereça atenção de pesquisadores em ecologia de estradas, tanto pelo fluxo de carros que deve ser inflado pelo turismo quanto pela existência do Parque Nacional da Chapada Diamantina (PNCD), que é delimitado e cortado por rodovias conforme se encontra no próprio Plano de Manejo (BRASIL, 2007).

Além da importância turística, a região da Chapada Diamantina tem grande relevância ecológica por abrigar diversas espécies endêmicas e ameaçadas de extinção (BRASIL, 2005). A região é propícia para trabalhar questões ecológicas e conservacionistas em área de proteção ambiental, principalmente pela presença de uma unidade de conservação federal, o PNCD. Assim, compreender a composição e padrões espaciais dos atropelamentos de animais silvestres e a influência das rodovias na fauna no seu entorno é fundamental para o planejamento ambiental e melhor eficiência na gestão do PNCD. Esse estudo possibilitará que novas informações sejam agregadas ao plano de manejo do PNCD para que se possa melhorar as condições do parque e sua zona de amortecimento, bem como auxiliar no planejamento cada vez melhor do turismo na região.

Pensando nisso, a tese foi dividida em três capítulos. No primeiro, “Análise da produção científica e conhecimento sobre atropelamentos de animais silvestres em áreas protegidas do Brasil”, realizamos uma busca na literatura por trabalhos com fauna atropelada no Brasil e comparamos trabalhos que foram realizados em rodovia próxima (PPA) ou distante (NPA) de Unidade de Conservação (UC). Consideramos PPA aqueles que amostraram rodovias até 1km de Unidades de Conservação. Encontramos 126 artigos, sendo 57% PPA. Notamos que os artigos com fauna atropelada aumentaram nos últimos anos, com mais trabalhos em PPA. O grupo mais estudo foi dos mamíferos (108 artigos), depois répteis (79 artigos), aves (73 artigos) e anfíbios (58 artigos). No Cerrado está concentrada a maior parte dos estudos (54 artigos), seguido da Mata Atlântica (45 artigos). Nesses biomas se encontram o maior número de UCs, bem como o maior número de UCs não pesquisadas no entorno de rodovias. O aumento de pesquisas em PPA é positivo, mas notamos que precisa haver maior envolvimento de setores governamentais e

gestores das UCs. Incentivamos o aumento do levantamento de estradas próximas às UCs, o envolvimento de pesquisadores com agências ambientais e mais estudos com pequenos animais.

No segundo capítulo, "Ufa! Os *hotspots* de atropelamentos não estão relacionados com áreas protegidas", estudamos a distribuição temporal e espaciais dos atropelamentos, bem como da influência da paisagem e das características das rodovias nos atropelamentos que ocorrem no entorno do PNCD. Amostramos os atropelamentos por 16 meses, de forma quinzenal, em um veículo com dois observadores. Registramos 580 animais atropelados, 182 anfíbios, 185 répteis, 143 aves e 70 mamíferos. Quanto à riqueza, confirmamos 5 espécies de anfíbios, 20 de répteis, 36 de aves e 14 de mamíferos. Apenas anfíbios e répteis apresentaram diferença significativa entre seca e chuva, com maior abundância e riqueza no período chuvoso. A localidade dos *hotspots* de atropelamentos variou entre os grupos, com algumas regiões sobrepostas e outras em áreas diferentes entre os grupos taxonômicos. Além disso, a maioria dos *hotspots* de atropelamentos estão fora da área do PNCD. Com isso, acreditamos que deve-se ter cuidado com análises espaciais que agrupam indivíduos de diferentes grupos taxonômicos. Também incentivamos que pesquisas futuras sejam realizadas para compreender o motivo dos *hotspots* estarem localizados em sua maioria fora do PNCD.

No terceiro capítulo, "Entendendo os fatores que influenciam a ocorrência de espécies no entorno das rodovias", analisamos os fatores que influenciam a fauna no entorno das rodovias na região no PNCD. Para isso, amostramos aves e mamíferos no entorno de pontos de agregação de atropelamentos (*hotspots*) e pontos sem atropelamentos (*coldspots*). Amostramos as aves com cinco pontos de escuta, um a cada 250m a partir da rodovia, até 1000m de distância da rodovia. Os mamíferos amostramos com armadilha fotográfica, sendo uma a 500m da rodovia, outra a 1500m e a última a 2500m da rodovia. Utilizamos cada ponto de escuta e ponto com armadilha fotográfica como amostra e coletamos informações sobre a paisagem no entorno para análises. Ainda, separamos as aves e mamíferos por grupo trófico: herbívoro, onívoro e carnívoro. Nossos resultados apontaram que 16% das aves que ocorrem no entorno são atropeladas, enquanto 50% dos mamíferos do entorno são atropelados. Os efeitos da rodovia podem variar de acordo com o grupo, sendo que a distância da rodovia é importante apenas para aves carnívoras, em que se tem o aumento de aves carnívoras com o aumento da distância da rodovia. Registramos maior abundância de mamíferos nos *coldspots*, indicando que mais pesquisas devem ser realizadas sobre os ambientes no entorno das rodovias e não somente com a paisagem.

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CAPÍTULO 1 – Análise da produção científica e conhecimento sobre atropelamentos de animais silvestres em áreas protegidas do Brasil

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Analysis of scientific production and knowledge about wildlife roadkill in Brazilian protected areas

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Significance Statement

Brazil is a mega-biodiverse country and has a large number of protected areas with loss of wildlife diversity run over by motor vehicles. In this manuscript, we mainly seek to understand which protected areas are neglecting the problem of roadkill fauna. For this, we surveyed all works published up to the year 2021 as well as used geospatial tools to identify where these protected areas are located and which region deserves more attention from environmental managers. So, we believe that this work is fundamental to indicate the spatial gaps in the death of wild vertebrates particularly vulnerable to roadkill events in protected areas as well as the protected areas that need more attention from researchers, environmental managers, and government. With our review, it is also possible to understand how work on roadkill fauna is being prepared, which allows for drawing up plans for the future of research, especially research involving protected areas directly affected by roads. Thus, the work also indicates knowledge gaps that will serve as a guide for government environmental managers.

Abstract

Roads are responsible for great biodiversity loss, especially in protected areas (PAs). Thus, considering the great risk of roads to PAs and the lack of knowledge about these areas, we aimed to analyze the scientific production on wildlife roadkill in Brazil and compare the studies that surveyed roads with and without PAs. We searched for papers in five databases: SciELO, Google Scholar, Reet Brasil, Scopus and Plataforma Lattes. Studies considered to be near PAs (PPA) collected data within a radius of 1 km of PAs and the other studies were considered to have no PA (NPA). We found 126 studies that surveyed wildlife roadkill in Brazil, of which 57% are PPA. Publications on wildlife roadkill have increased in recent years, with a greater number of PPA studies than NPA studies ($W = 618$, $p = 0.5992$). Mammals are the most-studied group ($n = 108$), followed by reptiles ($n = 79$), birds ($n = 73$) and amphibians ($n = 58$). Most of the studies took place in the Cerrado (54) and the Atlantic Forest (45), where are the greatest number of surveyed PAs, greatest number of PAs and greatest number of PAs without studies. Only 18 papers suggest specific mitigation measures for the study site. The increase in PPA studies is positive, but researchers need to increase contact with PA managers to produce scientific knowledge and develop more efficient mitigation measures for these areas. We encourage increased surveying of roads near PAs, involvement of researchers with environmental agencies, and more studies with small animals.

Keywords: Local extinction, biodiversity, road ecology, wildlife vehicle collisions.

Introduction

Anthropogenic activities cause major problems for protected areas, including through the fragmentation of adjacent habitats, which reduces patch connectivity, and contamination of protected areas as a result of pollution in surrounding areas (Lovejoy 2006). Protected areas (PAs) are affected by a range of impacts, such as illegal harvesting of plants, poaching, invasive species, fires, deforestation and construction of roads (Schulze et al. 2017). Furthermore, PAs located near roads are more likely to be colonized by alien species and to be deforested, due to the ease of access (Mcdonald et al. 2009; Pfaff et al. 2015). Other effects of roads on PAs include habitat loss, alteration of the biotic community, changes to species' behavior, edge effects, and the division and isolation of populations (Spellerberg 1998).

Roads are one of the main factors that isolate PAs, by restricting the movement and dispersion of animals (Newmark 2008). This problem is even worse with more developed roads (i.e., 4-lane paved roads are more developed than single-lane paved roads, which are more developed than dirt roads), which increase the risk to PAs and reduce the efficiency of PAs closer to roads in maintaining biodiversity (Lupinetti-Cunha et al. 2022). Thus, the expansion of the road network puts these areas at risk, as it tends to favor deforestation and habitat loss (Aguirre et al. 2021), mainly by making the regions more accessible, which drives deforestation (Barber et al. 2014). Furthermore, construction of roads leads to an increase in the number of collisions between vehicles and wild animals (Oddone-Aquino and Nkomo 2021).

Roadkill is the most visible negative effect of roads on biodiversity (Forman and Alexander 1998; Ferreira et al. 2023; Oliveira et al. 2023), and one that can cause major environmental impacts, such as extinctions of local populations (Barrientos et al. 2021; Tres et al. 2024). Therefore, it is considered a major problem for PAs (Collison et al. 2019). Roadkill can increase the loss of biodiversity in PAs (Bager et al. 2016), as they tend to have a higher diversity than unprotected areas and, consequently, higher collision rates than other areas (Garriga et al. 2012; Kioko et al. 2015). Thus, due to the serious threat and likelihood of occurrence it is essential to monitor roadkill on roads near PAs (Saranholi et al. 2016), especially in a megadiverse country such as Brazil, which has great biodiversity, including two conservation hotspots (Rylands and Brandon 2005).

We have numerous examples of the occurrence of wildlife-vehicle collisions in PAs in Brazil. One study in the region of the Sooretama Biological Reserve showed that the BR-101 highway offers a major risk to the local population of Lowland Tapir (*Tapirus terrestris*, Mammalia, Perissodactyla), given that this site is considered one of the last refuges for viable populations of this species in the Atlantic Forest (Banhos et al. 2021). Diniz and Brito (2013) state that the death of Giant Anteater (*Myrmecophaga tridactyla*, Mammalia, Pilosa) by roadkill is the greatest threat to population viability in the Brasília National Park, located in the Cerrado. Smaller animals are also strongly affected by the roads that surround protected areas, such as the Sooretama Biological Reserve, which has one of the highest rates of roadkill bat biodiversity in the world (Damásio et al. 2021).

Considering the impact of roads on PAs (Garriga et al. 2012; Bager et al. 2016) and the scarcity of knowledge about biodiversity inside and outside of PAs in Brazil, new steps need to be taken to maintain the efficiency of PAs in maintaining biodiversity (Oliveira et al. 2017). Thus, we need to understand what is already known about roadkill inside and outside of PAs in order to suggest steps to take in both environments.

Given the above, the present study aimed to analyze the research on roadkill and to compare studies of areas near to and far away from PAs in Brazil. We believe that the majority of studies occur near to PAs, but they are limited to the more developed regions because these regions have the easiest access. We presumed that studies near to PAs would suggest mitigation measures, and we analyzed the presence of these measures. Finally, we pointed out gaps in areas without surveyed roads near to PAs.

Material and Methods

Bibliographical research

We created a database of scientific papers about wildlife roadkill in Brazil published up to 2021 and available in journal databases and on a curriculum platform (**Table 1**). We used broad keywords (**Table 1**) because we preferred to refine the data manually. We prioritized Google Scholar due to the efficiency of the platform (Prins et al. 2016; Martín et al. 2018), carrying out two searches, one in Portuguese and one in English. To increase the scope of papers published in English we also searched on Scopus (see Martín et al. 2018). We chose SciELO because it grouped papers from Brazilian journals, Plataforma Lattes because it grouped the Curriculum (CV) of researchers from Brazil, and the list of papers available on the Rede Brasileira de Especialistas em Ecologia de Transportes (REET Brasil - Brazilian Network of Specialists in Transport Ecology).

Table 1. Description of how the research was carried out, including databases, predictors, date, and results before selection of the papers. Databases are organized according to the research date.

Databases	Link	Search	Date	Results
REET Brasil	https://reetbrasil.wixsite.com/reetbrasil	The site provides a list of papers	07/04/2022	42 papers
SciELO	https://www.scielo.br/	"roadkill"	07/04/2022	28 papers
Google Scholar	https://scholar.google.com.br/	"roadkill" + "Brazil"	12/04/2022	2130 papers
		"fauna atropelada" + "Brasil"	03/05/2022	196 papers
Scopus	https://www.scopus.com/	"Roadkill AND Brazil", in title, abstract and keywords	15/04/2022	99 papers
Plataforma Lattes	https://lattes.cnpq.br/	"Roadkill"	16/04/2022	160 curriculum / 164 papers

We only included scientific articles, excluding books, monographs, theses, dissertations, and abstracts. We only considered papers that focused on surveying or monitoring of wildlife roadkill, i.e., those papers that actively searched for animals that had been killed on a stretch of road, either with roadkill as the main focus or as a secondary method for sampling fauna in a region. As a result, we discarded papers related to the use of roadkill specimens for biological description, taxonomy, parasitology, and occurrence notes. Duplicate papers were excluded.

Collection and analysis of literature data

Firstly, we defined which papers surveyed roads with direct influence on a PA. For this, we considered the road to have a 1 km radius of direct influence (see Ibisch et al. 2016; Lupinetti-Cunha et al. 2022), and all studies conducted with protected areas within this radius were considered as being near to protected areas (Presence of Protected Areas – PPA), while studies with no PA within a 1 km radius of the surveyed road were considered as being far from a PA (No Protected Areas – NPA). We selected the PPA studies by using Google Earth to draw the surveyed routes, which were exported in ".kmz" and opened in QGIS 3.16.10 (QGIS 2021). We

then created a 1 km zone around the surveyed roads and recorded any PAs. We used the outlines of Brazil's Protected Areas provided by the Ministério do Meio Ambiente (MMA - Ministry of the Environment), which contains every PA in Brazil, updated with PAs created up until the beginning of 2022 (BRASIL, 2022). After selecting the papers, we collected the information described in **Table 2**.

Table 2. Description of literary variables collected and analyses performed. PA = Protected Area; PPA = Presence of Protected Areas; NPA = No protected Areas.

Variable	Description	Analysis
a. Presence of PA **Used to record the PPA and NPA papers.**	The minimum distance between the surveyed road and PAs. We counted the PAs within a 1 km radius of the road (see Ibisch et al. 2016; Lupinetti-Cunha et al., 2022), and separated the papers into two categories: - With the presence of protected areas (PPA) - No protected area (NPA)	We used QGIS and Google Earth to measure distance and group papers into two categories: PPA and NPA
b. Year **Used to analyze the number of studies per year, and to test the difference between the NPA and PPA studies over the years.**	Paper publication date.	- Correlation between year and total number of papers, PPA and NPA - Mann-Whitney to analysis the difference in production between PPA and NPA papers
c. Approaches **Used to find out the topics studied in the articles, comparing the PPA and NPA studies to see which of those groups used more approaches, and to test whether the papers with more approaches were in the journals with highest IF.**	What approaches the papers adopted, divided into: - Descriptive, when the paper only described roadkill species and the state of conservation; - Temporal, when analysis was performed to compare seasonality; - Spatial, when analysis was carried out to find points with higher rates of wildlife roadkill; - Landscape, when analyzing the landscape around the road or the carcasses; - Modeling, when using some model of occupation or situations (e.g. to predict roadkill or create landscapes to study animal movement); - Method proposal, when studying and proposing methods for future research; - Biological aspects, when considering aspects of the species, such as size, diet and behavior; - Mitigation, when studying the efficiency of mitigation measures; - Monetary, when studying the expenses and costs of roadkill animals; - Fauna in the surroundings, when the roadkill species and the species around the roads were analyzed; - DNA analysis, when DNA analysis was performed for populations or to identify species; - Carcasses, when the focus was on aspects of carcasses, such as length of time on the road.	- PERMANOVA to see the difference between PPA and NPA - Correlation between the number of approaches and IF, to discover whether more approaches are present in studies with higher IF (see "e") - Graph with the approaches per year
d. Biological group **Used to compare the number of papers per group, and find the most studied group in PPA and NPA.**	The groups studied in each study. We recorded the number of studies per group, therefore, a paper that studied all groups was counted once for each group. We considered four groups: - Amphibians; - Birds; - Mammals; - Reptiles.	- Mann-Whitney for group, to test the difference between PPA and NPA studies, using the number of studies per group - Maps of groups and biomes
e. Journal Impact	Journal's impact factor over the last two years, using the	- Correlation between

Factor (IF) **Used to find the possible correlation between IF and approaches**	"Academic Accelerator" website in October 2022 (https://academic-accelerator.com/)	the number of approaches and impact factor (see "c") - Mann-Whitney between IF and PPA and NPA
f. Surveying **Used to find out how the papers collected data, and verify differences in the PPA and NPA surveyed roads**	We analyzed the type of surveying, separated into: - Systematic, when it followed a surveying routine (e.g., monthly or weekly); - Not defined, when the authors are not clear about the surveying - Occasional, when the authors reported surveying being occasional or sporadic; - Various methods, when the authors collected data over several periods in different ways; - Not systematized, even when collected periodically, if it was not systematized and changed several times over a week or month, depending on the authors; - Seasonal, involving data collection campaigns using the seasons as a parameter.	- We organized the data in a table, separating PPA and NPA
g. Surveying time **Used to find out the surveying time for NPA and PPA**	We counted the number of months when surveys were conducted to find the overall data collection time for the study, and analyzed the difference between NPA and PPA. If the study collected data once or twice in a month we considered it as a sampled month, regardless of the number of times the road was covered.	- Mann-Whitney between PPA and NPA - Box-plot graphic
h. Biomes	We separated the papers by biome (Amazonia; Caatinga; Cerrado; Atlantic Forest; Pantanal; Pampa) to find the number of works per biome	- Number of papers in each biome to create a map
i. Surveyed roads **Used to locate the areas where the studies collected data**	We traced the route covered by the authors to record where the research took place	- We used Google Earth to draw the routes, which were saved in ".kmz" and exported to QGIS. - Afterwards, we created a map displaying the surveyed road
j. Departure and arrival points	We marked the start and end points of each surveyed route to find the most-studied areas using spatial analysis	- Points used to create the heatmap (Kernel) with QGIS
k. First year of surveying **Used to find the difference from the year of the PA's creation**	The year of the first survey for each study	- We calculated the difference between the year of creation of PAs within a 1km radius and the initial year of data collection in the area (see "l")
l. Year of PA's creation **Used to see the difference from the first year of surveying**	Year informed in the PA outlines provided by the Brazilian Ministry of Environment	- We calculated the difference between the year of the PA's creation and the first year of surveying in the area (see "k")
m. Authors' affiliation **Used to find the involvement of government agents in the research**	Authors' institutions used to identify studies involving government agencies, e.g., Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA - Brazilian Institute of the Environment and Renewable Natural Resources) and Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio - Chico Mendes Institute for Biodiversity Conservation)	- Description of papers with author from government agency

n. Mitigation measures	Analysis of which measures were recommended in the conclusion and/or final considerations	- We organized the data in the form of a table

We performed all tests using R 4.1.1 (R Core Team, 2021), including PERMANOVA (Anderson 2001) with 9999 permutations, using the "vegan" package (Oksanen et al. 2022). We created a boxplot with the "Ggplot2" package (Wickham 2016). The other tests (correlation and Mann-Whitney) did not require a package. We considered the 5% confidence limit for all tests.

Spatial analysis

We summarized the papers by biome: Amazonia, Atlantic Forest, Caatinga, Cerrado, Pampa and Pantanal. For this, we used the outlines available on the website of the Instituto Brasileiro de Geografia e Estatística (IBGE - Brazilian Institute of Geography and Statistics) (IBGE 2019), overlaid the routes covered by each study, and manually recorded which regions the surveyed roads were located in. As such, some papers surveyed two or more biomes and were considered for all of the biomes that they surveyed. The data were organized in maps that indicate the number of studies per biome and per group (birds, mammals, amphibians and reptiles). This data enables us to find which regions contained the most PPA studies and which animal groups within PAs are most studied by biome.

We used the spatial location of the start and end points of the routes covered by the studies to create a kernel density map with a radius of 130 km and pixel size of 300m, because the average route length surveyed per study was 130km. This indicated whether there were locations covered by more than one study.

To find the longest length of road surveyed, we intersected the outline of roads in Brazil provided by the IBGE (2022) and the outline of roads surveyed in the country up until the year 2021. The outcome of the analysis is a map with points of intersection between the two outlines (Brazilian roads and surveyed roads), indicating where the lines cross. Thus, locations with a greater number of lines crossing each other had more points. We used the intersection outline to perform kernel density analysis, with a radius of 500 km and a pixel size of 300m. We conducted all the spatial analysis and created the maps in QGIS 3.16.10 (QGIS 2021).

Analysis of PAs in the area of influence of surveyed roads

We counted the number of PAs within the area of direct influence of the roads for each study and classified them by type (federal, state and municipal). We organized the data in a table containing the number of PAs in the area of influence in each biome. We also computed the existing PAs in each biome using the outlines mentioned above and added them to the table.

We recorded the first year of the first paper carried out in each biome and compared it with the year of creation of the PAs within a 1 km radius of each study. This provided us with information as to when the surveying started and when the PAs were created, if there were any studies before the creation of the PAs, and how long after creation the roads closer to the PAs were surveyed. These data were organized in a table.

Results

We found 237 papers related to wildlife roadkill in Brazil, with the first record being from 1988. However, only 126 papers actually involved a survey of wildlife roadkill (Supplementary Table S1). The remaining papers related to wildlife roadkill are publications in several areas,

including data reviews, analysis of the length of time the carcass remains on the road, parasite studies and use of roadkill animals to obtain physiological and morphological data.

Publications about Brazilian wildlife roadkill

Of the 126 studies that surveyed wildlife roadkill, 57% (n = 72) collected data on roads with at least one PA within a radius of 1 km. The number of studies with protected areas within a 1 km radius (PPA) and the number of studies without protected areas within a 1 km radius (NPA) have both increased. However, roads near to PAs were surveyed more than roads far away from PAs, although this difference is not statistically significant (W = 618; p = 0.5992). We noticed two moments when there was an increase in the number of studies: after 2014, with the creation of the "Urubu mobile app" and after 2019, with the creation of the Rede Brasileira de Especialistas em Ecologia de Transportes (REET Brasil - Brazilian Network of Specialists in Transport Ecology). Other important events that may have encouraged research in the area include the publication by Forman and Alexander (1998) that serves as a reference for road ecology, the enactment of the Law establishing the Sistema Nacional de Unidades de Conservação da Natureza (SNUC – Brazilian System of Protected Areas) and the creation of the Centro Brasileiro de Estudos em Ecologia de Estradas (CBEE - Brazilian Center for Studies on Road Ecology) (**Figure 1**).

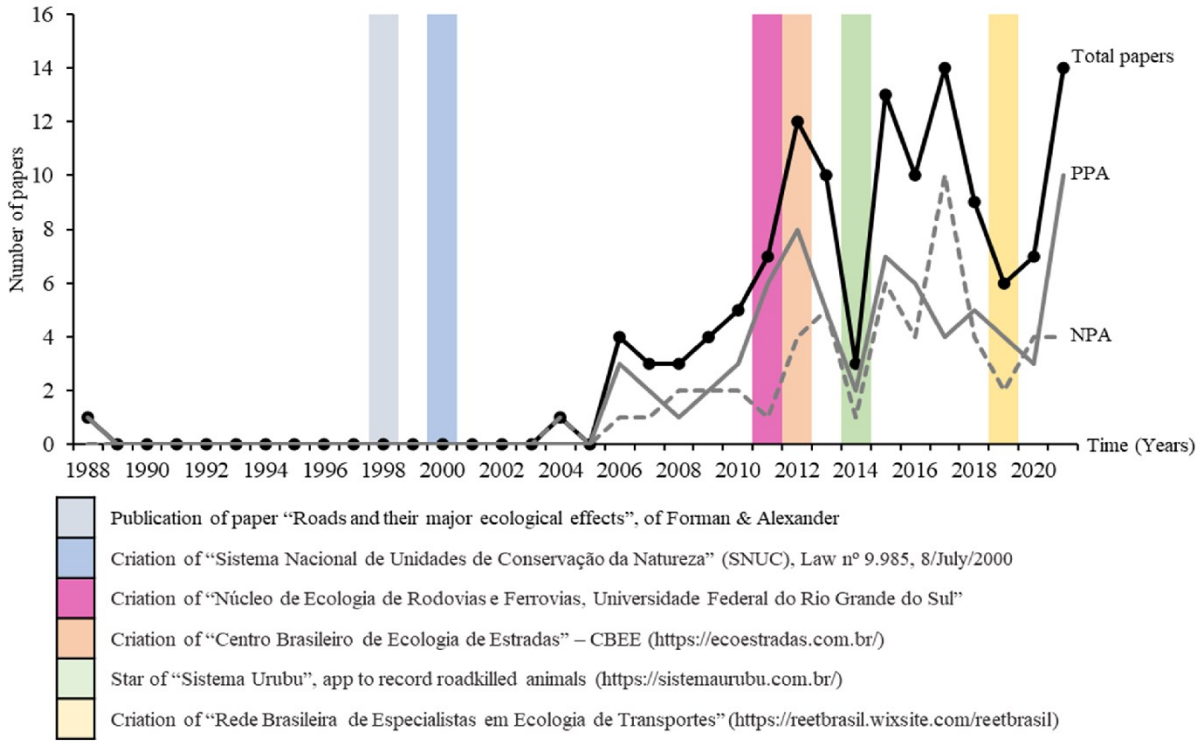

Figure 1. Number of studies that collected data on wildlife roadkill in Brazil published up until 2021 and some important events, with total number of studies (Total studies), only studies from near to protected areas (PPA) and only studies far from protected areas (NPA).

We observed that in 2016 (n = 7), 2017 (n = 7), 2018 (n = 8) and 2021 (n = 10) studies were published with different approaches, in addition to the description and listing of wildlife roadkill and spatiotemporal analyses. However, publications with descriptive and temporal analyses appeared every year. Only in 2018 and 2021 were there publications that used data

collection on wildlife roadkill to present methodological proposals, while DNA analyses also appear only in two years: 2016 and 2017 (**Figure 2**).

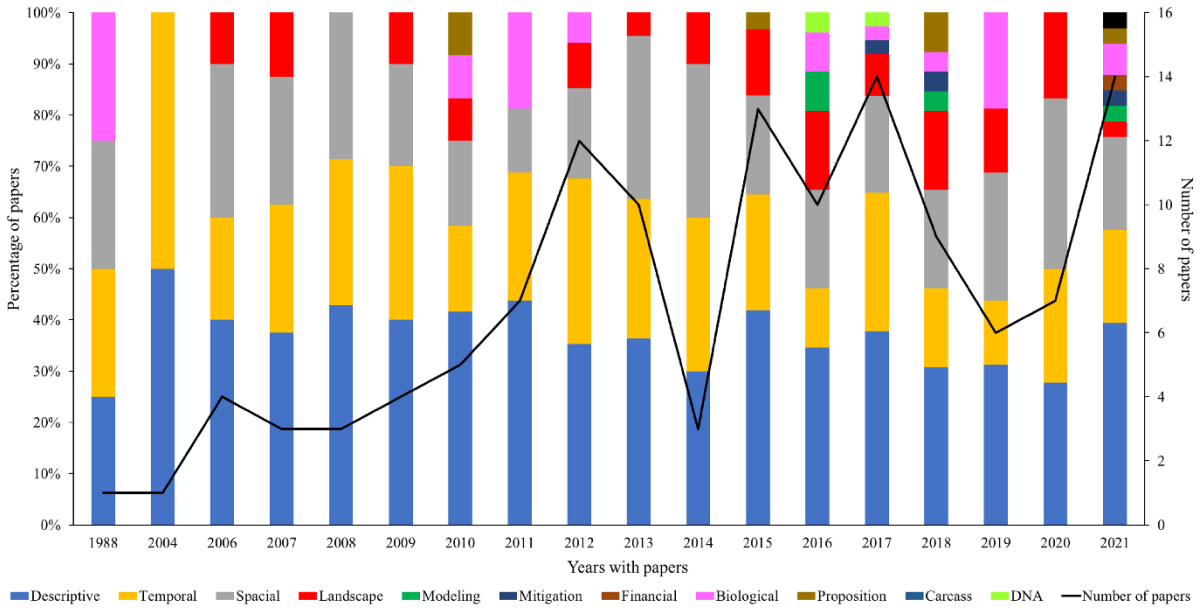

Figure 2. Demonstration of the approaches carried out by papers on wildlife roadkill in Brazil up until 2021, by year. Years missing from the graphic indicate that there were no publications.

Mammals were the most studied group (n = 108), followed by reptiles (n = 79), birds (n = 73) and amphibians (n = 58). When comparing the PPA and NPA studies, it was observed that only mammals have more studies near to PAs, but the difference between the groups is not significant (**Table 3**).

Table 3. Description of the studies conducted near to (PPA) and far from (NPA) of protected areas according to the variables (biological group, approaches, journal impact factor, sampling, and data collection time) and the test value.

Variables		**PPA papers (n = 72)**	**NPA papers (n = 54)**	**All papers**	**p-value**	**Test value**	**Test**
Biological group (Frequency)*	Amphibian	25	33	58	0.882	588.5	Mann-Whitney
	Bird	35	38	73	0.582	617.5	
	Mammal	58	50	108	0.822	595.0	
	Reptile	38	41	79	0.626	543.0	
Approaches studied in the papers (%)	1 approach	13.9	14.8	14.3	0.0852	$F_{(1, 124)} = 2.4313$	Permanova**
	2 approach	26.4	38.9	31.7			
	3 approach	40.3	35.2	38.1			
	4 approach	18.1	11.1	15.1			
	5 approach	1.3	0	0.8			
Journals Impact Factor (IF)***	Minimum	0.385	0.347	0.347	0.0002	1226.5	Mann-Whitney**
	Maximum	7.963	4.677	7.963			
	Average	2.290	1.370	2.020			
	Standard deviation	2.190	1.310	2.000			
Sampling	Systematic	68.06	74.07	70.63	-	-	-

(%)	Not defined	9.72	7.41	8.73			
	Occasional	8.33	5.56	7.143			
	Various methods	8.33	5.56	7.143			
	Not systematized	4.17	1.85	3.175			
	Seasonal	1.39	5.56	3.175			
Time collected (months)	Minimum	3	2	2			
	Maximum	120	108	120			
	Average	32.9	15.6	25.5	0.00002	2798.5	Mann-Whitney**
	Standard deviation	28.1	18.1	25.7			

* We use frequency because a paper may have worked with more than one group; ** Test performed between PPA and NPA papers; *** Papers without IF were disregarded

Most of the studies used a descriptive approach, usually followed by a temporal and/or spatial approach, with the same pattern observed for studies inside and outside PAs. The studies described the species most often killed on roads and the conservation status of these species, in addition to temporal analyses to indicate in which season more carcasses were recorded and spatial analyses to indicate points of greater risk of collision with animals. This last factor was sometimes related to landscape analysis, as a predictor of roadkill (**Table 3**). Only one study addressed the financial costs of wildlife roadkill, with an emphasis on the expense for drivers (see Ascensão et al. 2021). There was no difference in the composition of analyses between the PPA and NPA studies (**Table 3**), and there was a low correlation between the number of approaches and the impact factor (IF) of the journals in which the papers were published ($r = 0.365$; $p < 0.000026$).

We observed that there was a significant difference between the impact factor (IF) of the journals in which the PPA and NPA studies were published (**Table 3**). The PPA studies were published in higher IF journals ($\bar{X}$= 2.29; sd= 2.19) than the NPA studies ($\bar{X}$ = 1.37; sd = 1.31). While 32% (n = 23) of PPA studies did not have IF, 61% (n = 33) of the NPA studies did not have IF. Most PPA papers involved three or more approaches, while most NPA papers involved two approaches.

Most of the 126 studies found (n = 89) collected data systematically (e.g., monthly or weekly). Of the others, nine made only occasional records, generally taking advantage of trips for other purposes, nine varied the collection methods, four did not systematize the data collections, four made collections during campaigns that considered the seasonality of the region and 11 studies did not make it clear how data was collected (**Table 3**). The PPA studies showed the same result, with the majority (68.06%) performing systematic sampling.

In general, studies involving wildlife roadkill in Brazil collected data over a total period of between 2 and 120 months (**Table 3**). However, we observed that the difference between the total data collection time is greater for PPA than NPA studies ($W = 2798.5$; $p = 0.00002$). Thus, we noticed that there is a greater variation (**Figure 3**) in the collection time between PPA papers.

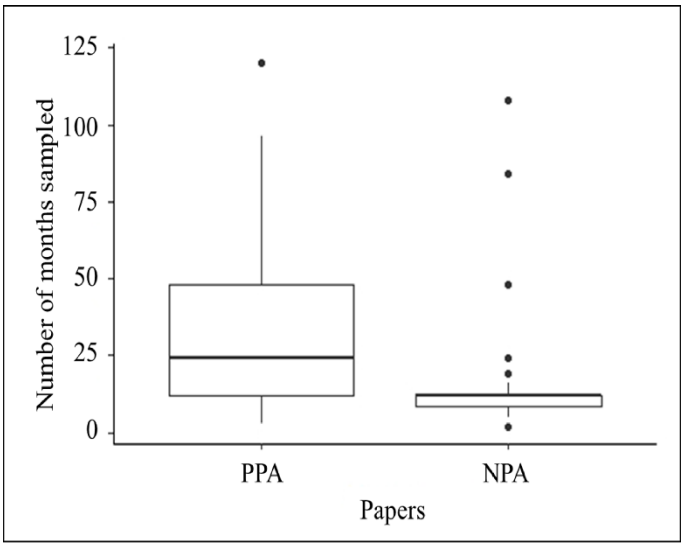

Figure 3. Number of months sampled for studies that surveyed wildlife roadkill in Brazil, near to (PPA) and far from (NPA) protected areas.

Most of the studies took place in the Cerrado (54 papers) and Atlantic Forest (45 papers), with a greater overlap in the Cerrado (indicated by the red points in **Figure 4**). On the other hand, the studies carried out in the Atlantic Forest are more spread out across the biome geographically. The Pampa has a great area covered by researchers with only 21 papers. Amazonia (09 papers), Caatinga (08 papers) and Pantanal (08 papers) have a smaller number of studies.

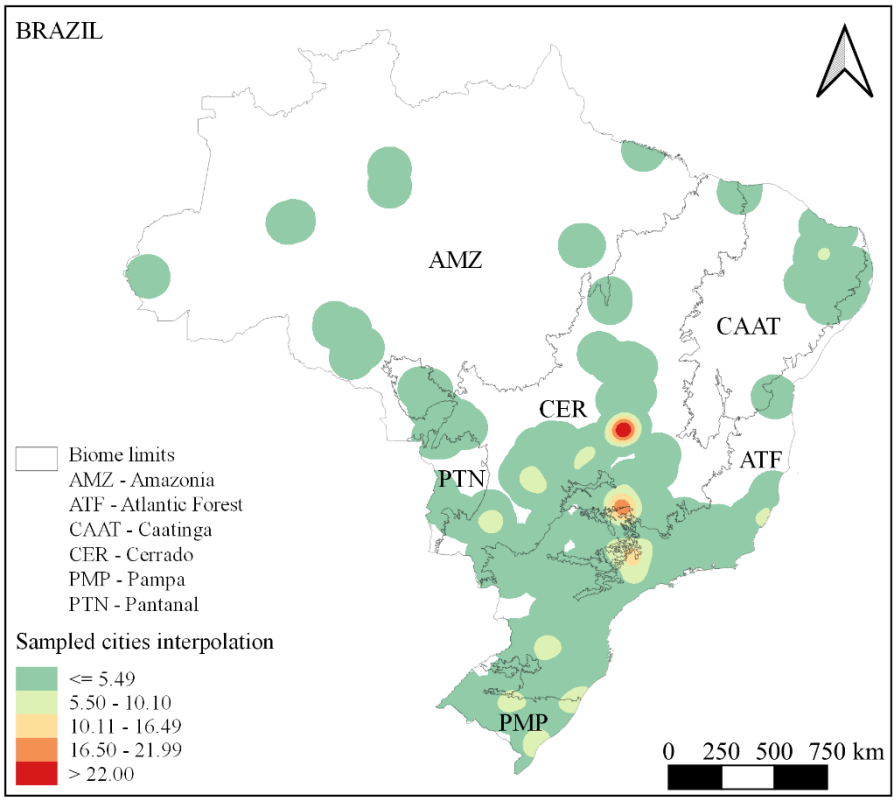

Figure 4. Interpolation of the starting and ending points of the routes where wildlife roadkill was surveyed up until 2021 in Brazil. Red regions indicate locations that have more published studies.

Although Amazonia has a high number of visible PAs on the map (**Figure 5A**), the Atlantic Forest has the greatest number of PAs (1183 PAs). The Cerrado is the region with the second most PAs (n = 358), followed by Amazonia (n = 301), Caatinga (n = 184), Pampa (n = 27), and Pantanal (n = 19). The Cerrado and Atlantic Forest also have a high density of roads (**Figure 5B**). Furthermore, the largest extension of surveyed roads is found in the Southeast of Brazil, between the Cerrado and Atlantic Forest, in the state of São Paulo (**Figure 5C** and **5D**).

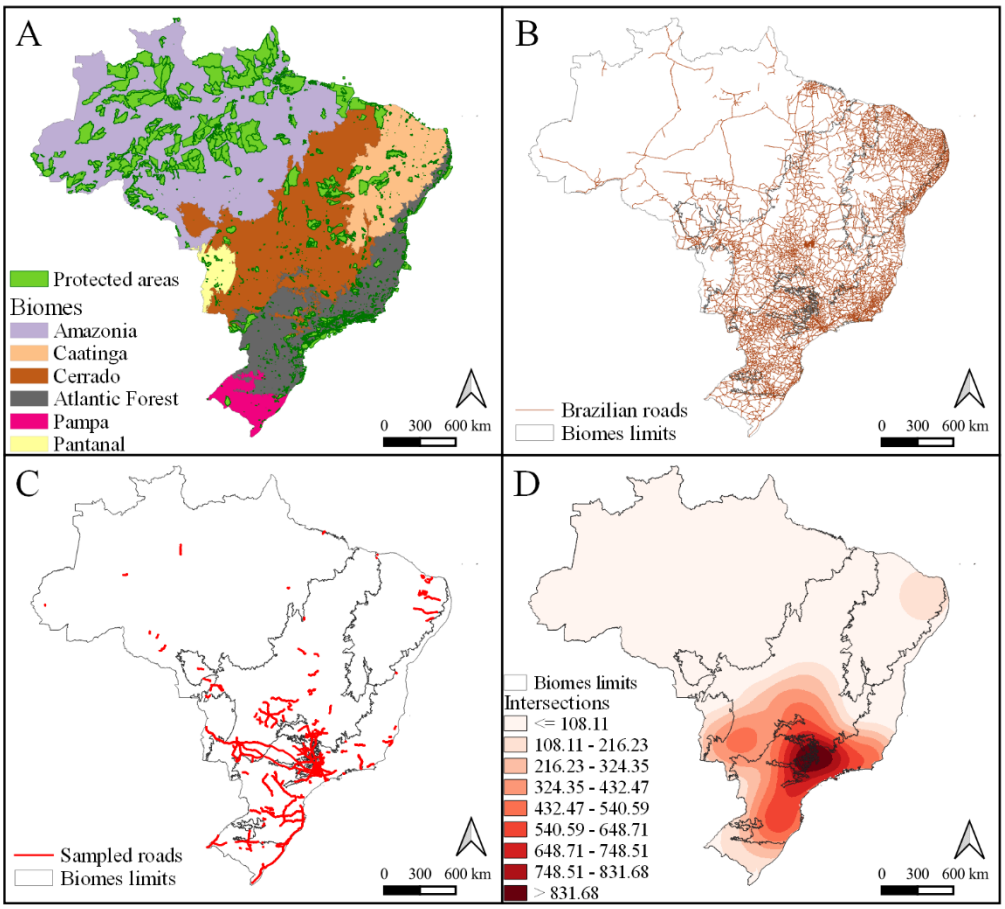

Figure 5. Roads surveyed in Brazil to 2021. A: Biomes and protected areas in Brazil. B: Roads in Brazil. C: Surveyed roads. D: Interpolation of the intersection between meeting points of roads in the country and roads surveyed to 2021. Biomes represented in colors that are easier to see for people with color vision deficiency (https://colorbrewer2.org/).

Amazonia, Caatinga and Pantanal make up a minority of studies, including a lower number of studies in PAs (**Figure 6A**). The Cerrado and Atlantic Forest hosted most of the studies, with 54 and 45 studies respectively (**Figure 6A**). These two biomes also have the most studies in Protected Areas (**Figure 6B**). When we separated the papers by biological groups we found the same result, with more studies in the Cerrado and Atlantic Forest in PAs for amphibians (**Figure 6C**), birds (**Figure 6D**), mammals (**Figure 6E**) and reptiles (**Figure 6F**). We observed that half of the papers about amphibians (**Figure 6C**) and birds (**Figure 6D**) are from the Cerrado.

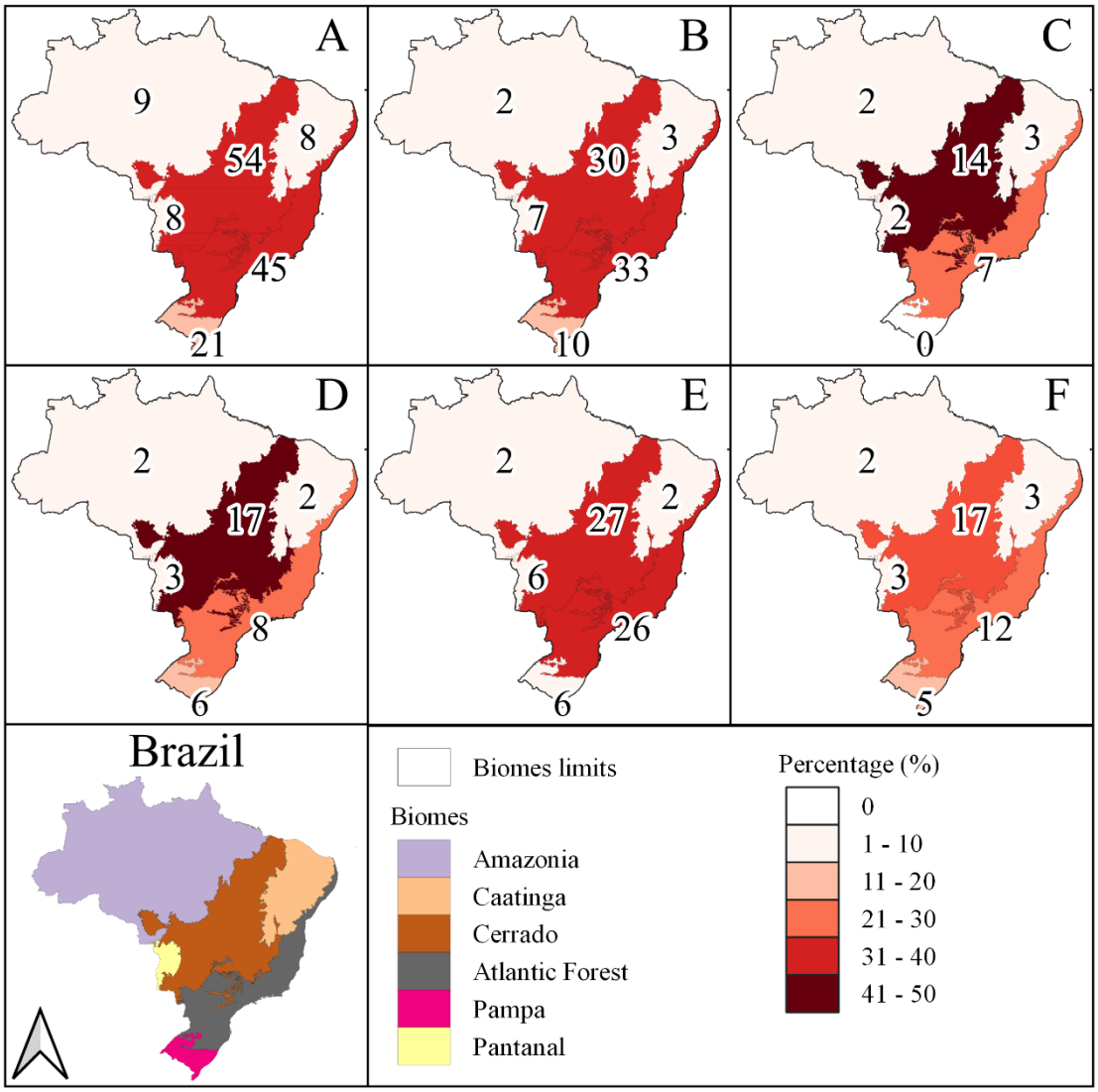

Figure 6. Number of studies (represented by the numbers on the maps) that collected wildlife roadkill data in Brazil and were published up until 2021, separated by biome, in which we have: total number of studies (A); studies that surveyed roads within a 1km radius of protected areas (B), with: amphibians (C), birds (D), mammals (E) and reptiles (F). Scales in percentage up to 50%, because this is the highest value. Biomes represented in colors that are easy to see for people with color vision deficiency (https://colorbrewer2.org/).

We found 1054 PAs within a 1 km radius of Brazilian roads. Of these PAs, 126 had nearby roads surveyed (**Supplementary Table S2**), 26 of which are municipal, 66 are state and 34 are federal PAs. Most of the PPA studies are located in the Atlantic Forest (n = 33) and Cerrado (n = 30) regions, with the highest number of PAs within the direct influence area (1 km radius) of surveyed roads (**Table 4**). We found 992 PAs directly affected by roads that have not yet been surveyed, most of which are in the Atlantic Forest and Cerrado. As such, the Atlantic Forest has the greatest number of PAs near to roads that have not yet been surveyed (**Supplementary Table S3**), representing 57% of its PAs, followed by the Caatinga with 49% of its PAs near to roads that have not been surveyed, Pampa (48%), Amazonia (29%), Cerrado (18%) and Pantanal (15%).

Table 4. Number of studies about wildlife roadkill in Brazil, classified according to the Biome and the presence of protected areas. PAs = Protected areas; PPA = Presence of Protected Area; NPA = No Protected Area.

Biomes	Number of papers			Number of PAs within a 1km radius of sampled roads*	Number of PAs	Number of PAs without papers**
	PPA	NPA	All			
Amazonia	2	7	9	3	301	87
Atlantic Forest	33	12	45	78	1183	566
Caatinga	3	5	8	5	184	90
Cerrado	30	24	54	38	358	180
Pampa	10	11	21	6	27	13
Pantanal	7	1	8	1	19	3

Legend: *As there are PAs that are in more than one biome, the sum will not be the same as the total number of PAs studied in the country. **Number of PAs taken from the shape used for the previous analyses.

Most PAs had their surrounding roads surveyed after their creation (average = 18 years later; sd = 12.6; minimum = 1 year later; maximum = 64 years later), although some were surveyed before (average = 5 years before; minimum = 2 years before; maximum = 8 years before) and only two were surveyed in the same year of creation. We observed that most PAs were surveyed 13 years after their creation and only 14 areas that are currently protected areas had nearby roads surveyed before they were established (**Figure 7**).

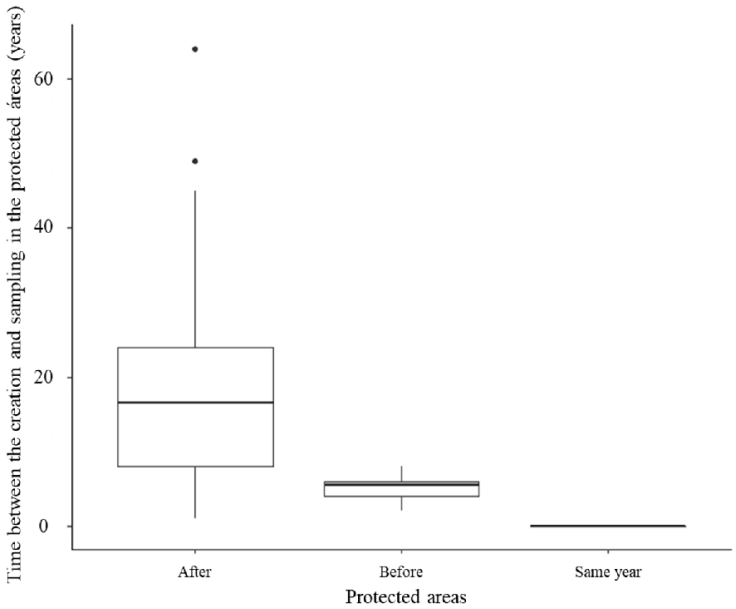

Figure 7. Difference between the first year of surveying for a study and the year of creation of the protected areas. Most roads were surveyed later (average = 18 years later; sd = 12.6; minimum = 1 year later; maximum = 64 years later), a few were surveyed before (average = 5 years before; sd = 1.8; minimum = 2 years before; maximum = 8 years before).

Of the 126 published papers, only 16 were co-authored by a government agency, of which 13 were near to PAs. In other words, approximately 18% of the PPA papers involved the participation of an employee of a government agency. The institutions mentioned are Instituto Brasília Ambiental (IBRAM - Brasília Environmental Institute) (n = 5), ICMBio (n = 3),

Municipal Departments (n = 2), State Departments (n = 2), IBAMA (n = 2), Polícia Rodoviária Federal (PRF - Federal Highway Police) (n = 1), and Instituto Nacional da Mata Atlântica (INMA – National Institute of the Atlantic Forest) (n = 1).
Only 18 (25.0%) of the PPA papers made specific suggestions, indicating the location or period and the mitigation measure that should be considered for the area (**Table 5**). However, 33 (45.8%) PPA papers made general suggestions, without discussing the specific problem, or only suggested further research in the area or topic. Unfortunately, 21 (29.2%) of PPA papers do not recommend or suggest mitigation measures.

Table 5. Suggestions for the conservation of species or for the mitigation of wildlife-vehicle collisions presented in the studies that surveyed roads close to PAs (PPA papers).

Suggestions in papers	Frequency in papers
Wildlife passage	25
Speed reduction	24
Road signs	19
Fences, like barriers to the animals	9
Environmental education	6
Environmental education programs for drivers in training	6
Improve the structures that exist on the highways (e.g., adaptation of culverts)	6
Monitor and supervise mitigating measures	5
Clear the road and prune the vegetation	3
Monitor the surrounding population	2
Reduce traffic on roads within the protected area	2
Create a program for continuous monitoring of roadkilled fauna	1
Study the habitats and land use in the surroundings	1
Install light bulbs that are less attractive to insects	1
Use occupancy detection models to install measures	1
Requiring the study of roadkills focused on bats in some projects	1
More research about the topic to indicate a point measure	8

Discussion

The number of wildlife roadkill studies in Brazil has increased. The majority of these studies have surveyed roads near to PAs, performed descriptive and temporal analysis, collected data systematically, and focused on mammals as the main studied group. Although there was no significant difference between the approaches carried out by the PPA and NPA studies, the PPA studies addressed a greater diversity of topics. Even though we have found a wider range of approaches in publications in recent years, descriptive and temporal analyses have always been present. The number of approaches used in a paper does not seem to make a difference to the impact factor of the journal in which it was published, but we observed that PPA papers collected data over a longer period of time, on average, and are published in more reputable journals, given that more than half of the NPA studies are published in journals with no impact factor.

The increase in publications that surveyed wildlife roadkill reflects the increased interest in understanding and resolving the problem in Brazil. There are three reviews that point to the growing trend of studies on road ecology and wildlife roadkill in Brazil over the last two decades (Bager et al. 2007; Bager and Fontoura 2012; Oliveira et al. 2020). Currently Brazil has more publications on the subject than any other country in Latin America (Pinto et al. 2020) and ranks third in the world for productions on road ecology (Oliveira et al. 2020). The greater number of

roads surveyed in the vicinity of PAs is a positive point for the country, coinciding with a need pointed out by Bager et al. (2016), i.e., to understand the impacts of road structures in areas that are essential for biodiversity conservation. Thus, more published papers implies not only that more areas are surveyed, but also that there is an increase in understanding of the real impact of road structures on Brazilian fauna, enabling us to establish recommendations for better procedures for mitigation of accidents.

Most papers only adopt a descriptive approach. These descriptive data can be of great importance for the area, especially in a country like Brazil that has a large land area. However, there is a need to understand the interactions between roads, animals and plants (Oliveira et al. 2020). Studies that use spatial analysis to identify roadkill hotspots, for example, despite being very important, should be seen as basic works to suggest where the parameters of influence of roadkill can be analyzed (Pagany 2020).

Other approaches, such as economics, are also important and have been little explored so far. As we found only one study that is related to economic losses, we believe that this is an area for future study. The lack of studies that assess economic losses is a gap that has been pointed out since 2009 (Dornas et al. 2012). Collisions with larger animals can cause major material damage (Abra et al. 2019) and thinking about the economic losses is fundamental to drawing the attention of the population and public authorities to the problem. Another necessary approach is to incorporate DNA analysis into research on wildlife roadkill. This encompasses the ecological discussion, especially if associated with landscape or functional attributes and used to support locally specific conservation measures (Rodríguez-Castro et al. 2017).

Research conducted near PAs has used a greater number of different approaches. In addition to the descriptive approach of describing which species were affected, these studies also collected data over a longer time period and are published in more reputable journals. As the practice of occasional wildlife roadkill data collection is recurrent (Dornas et al. 2012), it is possible that the PPA papers have more robust data, hence their published in better journals. Despite the problems of occasional data collection, we believe that these studies are still important to increase the knowledge base regarding wildlife roadkill, which until now has been concentrated in the Atlantic Forest and the Cerrado.

However, before entering into more complex analyses, we need to standardize the data collection. Although most of the papers present data collected systematically, there are still studies that collect data occasionally or do not even make it clear how they have performed the data collection. It is common for studies to monitor wildlife roadkill on roads that are routes already traveled by the authors, whether for work or leisure (Dornas et al. 2012). Just like Dornas et al. (2012), we believe that these studies may present a large sampling error and impair the comparison of data in future research, especially if the monitoring is performed at higher speeds. This is a common sampling design flaw; the design should be created primarily based on the species we wish to study, as a flawed sampling design can impact the spatiotemporal patterns observed (Silva et al. 2021b). Carcasses of larger animals persist for a long time on the road (Santos et al. 2011; Teixeira et al. 2013). Therefore detectability of carcasses is not the same for the researcher because large animals, e.g., some mammals, tend to be more easily spotted due to their greater body mass (Teixeira et al. 2013), therefore we need standardized data collection. In the case of amphibians, for example, monitoring on foot can be 25 times more efficient (Pereira et al. 2018). Driving at a higher speed can make it even more difficult to see smaller species (Dornas et al. 2012; Santos et al. 2016). So, perhaps it is because of the ease of spotting the carcasses that most studies have studied mammals, especially studies that involved travelling at the same time as data collection. In the other words, the large number of papers with mammals is a result of non-sampled works.

The majority of studies took place in the Atlantic Forest and Cerrado, both overall and by group (amphibians, birds, mammals and reptiles). The two regions not only have a greater extension of surveyed roads, but also more roads surveyed close to PAs (more than half of the

surveyed PAs are in the Atlantic Forest). Spatially, the Cerrado-based studies are more sporadically distributed, with a greater number of studies in the same area. The Atlantic Forest-based studies are better distributed spatially, with not only more publications but also more surveyed areas. Pinto et al. (2020), demonstrated that in addition to most studies being in these two areas, the Cerrado regions stand out in relation to publications on biodiversity and mortality. In addition to these regions being responsible for the highest number of bird and mammal deaths (Medrano-Vizcaíno et al. 2022), they are also among the regions in which protected areas suffer most from lack of funding (Silva et al. 2021a). These aspect may contribute to reducing the chances of conducting studies and the possibility of implementing mitigation measures. As these two biomes have the largest number of PAs, descriptive studies may be helpful at first to increase knowledge about the diversity of roadkill animals. However, we emphasize the need to be careful with the sample design and to increase studies in PAs in other Brazilian biomes.

We also need to sample more roads in the Caatinga, for three reasons. First, approximately half of the PAs near roads have not been surveyed, and we need more knowledge about the impact of roads on these PAs. Second, the Caatinga includes areas where roadkill has a major impact on birds and mammals (Medrano-Vizcaíno et al. 2022). Third, recently a portion of this biome was classified as a priority for research with birds (Medrano-Vizcaíno et al. 2023).

The roads in the vicinity of state-run PAs have been surveyed more. This may reflect the increase in state-run PAs and greater investment in these areas by the states, unlike what happens with federal and municipal PAs (Vieira et al. 2019). However, the participation of PA managers and other environmental agencies was low, indicating little involvement of scientists with the government's environmental area. It is likely that budget constraints in PA administration and growing political pressure, which are major disadvantages for managers (Marque and Peres 2014), contribute to the low participation of government officials in these research and conservation projects. Although one of the SNUC's objectives is "to provide means and incentives for scientific research activities, studies and environmental monitoring" (Brasil 2000), we note that there is not always integration between researchers from universities with managers of protected areas or that there is hardly any execution and publication of studies by managers of Brazilian PAs.

As most of the sampling took place after the creation of the PA, we infer that there was no analysis before the creation of these areas, which makes it impossible to compare the effects before and after the presence of the PA. The objective of PAs in Brazil is to intervene to prevent biodiversity loss, but currently they are not able to ensure protection for the various Brazilian habitats, and therefore legislation must be strengthened both for breeding (Vieira et al. 2019) and for encouraging research in these environments. In addition, long-term studies are important to identify trends in biodiversity and ecosystem functions that support Brazilian conservation (Marques et al. 2022).

Finally, most of the papers made only generalized recommendations for mitigating accidents with wildlife in their conclusions, such as installing signs and fauna passages, and did not make specific recommendations for the mitigation of collisions in the study area. Even so, at least there were a large number of papers that cited mitigation measures.

Conclusions

Through our results we conclude that it is necessary to increase surveying on roads surrounding protected areas in Brazil, so that more basic science can be carried out. Despite the importance of listing wildlife roadkill, it is important that the studies begin to adopt new approaches and analyses to complement the research already published. These other approaches include evaluation of the financial cost of collisions with wildlife, DNA analysis and biological aspects of the species, so that we can deepen our knowledge about wildlife roadkill, mainly in protected areas, which are so little surveyed.

We believe that it is essential for government agencies to have more involvement in research in Brazilian protected areas, with more interaction between managers and researchers. The interaction of managers and researchers is essential for the proposition, implementation and monitoring of mitigating measures on roads within and close to PAs.

Research that suggests mitigation measures around the world is focusing on underpasses for animals and fences for large mammals, reptiles and amphibians (Rytwinski et al. 2016). As this is somewhat different from what papers in Brazil are recommending for specific areas (speed reduction and road signs for drivers), we suggest that further research should focus on the efficiency of these measures here in Brazil and complement them with studies to indicate efficient and cost-effective technological alternatives, in view of the current budgetary reality of low incentives for research and conservation of the environment in the country.

Although we found numerous studies in the Atlantic Forest and in the Cerrado, we would encourage sampling of more areas of these biomes, as there are still many PAs without surveyed roads. We also highlight the need for more studies in the Caatinga, due to the priority in understanding the real impact of roads in this region, mainly in PAs.

Finally, we encourage projects aimed at smaller animals, such as frogs and small mammals, to be implemented. This will enable us to understand the real impact of the roads on these groups. Another suggestion is to create a systematic way of informing the government and agencies that work with roads in Brazil. This could facilitate the installation of mitigation measures.

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Data Availability

The data used to support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors have no conflicts of interest to declare.

Contribution Statement

All authors contributed to the study. JESM had the idea for the article, performed the literature search and data analysis, and AS drafted and/or critically revised the work.

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CAPÍTULO 2 – Ufa! Os *hotspots* de atropelamentos não estão relacionados com áreas protegidas

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Phew! Roadkill hotspots are not related to protected areas

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Abstract

Roadkill poses a critical threat to wildlife and can cause the extinction of local populations. In this context, analyzing roadkill patterns could provide valuable insight into the severity of the threat, particularly in protected areas. We collected roadkill data for 16 months around the Chapada Diamantina National Park (PNCD) in Bahia, Brazil, to study the spatiotemporal distribution of roadkill across different tourist and climatic seasons. Moreover, the influence of landscape and highway characteristics on roadkill hotspots was analyzed, as well as their association with the protected area. In all, 580 roadkill consisting of 182 amphibians (31.4%), 185 reptiles (32.0%), 143 birds (24.6%), and 70 mammals (12.0%) were recorded. Of the sample, five species of amphibians, 20 species of reptiles, 36 species of birds, and 14 species of mammals were identified. The abundance and richness of roadkill were not statistically different between seasons. However, only herpetofauna richness and abundance for the amphibians (richness: $p = 0.0053$; $W = 826$, abundance: $p = 0.000956$; $W = 754$) and reptiles (richness: $p = 0.0000259$; $W = 595$, abundance: $p = 0.00000165$; $W = 512$) were statistically different and greater in the rainy season. The aggregation and number of roadkill hotspots change for each taxonomic group, which reveals that different variables are influencing this process. Most roadkill hotspots were outside the PNCD, and less than 30% of all roadkill hotspots were inside the PNCD. We emphasize the importance of analyzing the taxonomic groups separately to obtain better estimates and results and better understand the influence of roadkill on protected areas.

Key-words: Caatinga; Conservation; Environmental impacts; Highways; Linear infrastructures.

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Competing Interests

The authors declare that there is no conflict of interest.

Author Contributions

JESM and AS contributed to the study's conception and design. JESM and ACA performed data collection and material preparation. JESM performed data analyses. JESM wrote the first draft of the manuscript. All authors read the manuscript and made suggestions at least twice and approved the final version.

Data Availability

The data is available on request to the corresponding author.

Introduction

Highways have a considerable impact on biodiversity (van der Ree et al. 2015) by contributing to landscape fragmentation, which creates barriers and filters for species (Forman and Alexander 1998; Coffin 2007). While some species avoid highways, leading to divided and isolated populations due to their inability to cross, other species are attracted to highways and are more frequently found as roadkill (Jaeger et al. 2005; Fahrig and Rytwinski 2009). Roadkill can be particularly dangerous for wildlife and potentially deplete populations (Barrientos et al. 2021; Grilo et al. 2021), thus increasing the risk of extinction for many species, such as *Chrysocyon brachyurus* and *Leopardus tigrinus* (Grilo et al. 2021).

To better understand roadkill patterns, researchers use roadkill hotspot analysis, a method that identifies the concentration of roadkill incidents on highways and enables more effective mitigation measures (Gutema et al. 2023; Miranda et al. 2020; Santos et al. 2022). Although some roadkill hotspots overlap between taxonomic groups (Rocha et al. 2022), hotspots can vary depending on the species involved, making them highly relevant for environmental management (Miranda et al. 2020; Filius et al. 2020). This variation is often explained by the landscape, which influences taxonomic groups in different ways (Santos et al. 2022; Medrano-Vizcaíno et al. 2023). While some groups have increased roadkill rates in forested areas, others have increased rates in areas dominated by herbaceous vegetation or human activity (Bueno et al. 2015; Medrano-Vizcaíno 2023). Additionally, road characteristics can also influence roadkill rates (Canal et al. 2018), with higher rates observed on highways with greater sinuosity (Laube et al. 2023).

Another common approach used to understand roadkill patterns is the analysis of temporal distribution. In general, factors such as rainfall, mist, and fog can increase roadkill incidents by reducing driver visibility (Oddone-Aquino and Nkomo 2021). Therefore, roadkill dynamics vary between taxonomic groups within the same region (Miranda et al. 2017; Ramos-Abrantes et al. 2018). For example, while some mammals exhibit high roadkill rates during cold seasons (Valerio et al. 2021), certain lizards and snakes are more frequently killed in the summer (Gonçalves et al. 2018). Amphibians and reptiles tend to be more abundant during rainy seasons, when many species become more active (Schalk and Saenz 2015; Montezol et al. 2018; Tenório et al. 2021; Rocha et al. 2022). Thus, analyzing the temporal distribution of roadkill is also crucial.

Considering the impact of roadkill on biodiversity, it is essential to understand and mitigate this issue in protected areas to prevent population declines (Collison et al. 2019). While protected areas play a key role in conservation, they often have high numbers of recorded roadkill incidents (Garriga et al. 2012). It is particularly

important to study protected areas such as national parks that are intersected by highways due to the severe consequences of roadkill in such regions (e.g., Braz and França 2016), especially in areas critical for conservation, as in the case of northern Brazil (Miranda and Schiavetti 2024).

In this study, we investigated the spatial and temporal distribution of roadkill in Chapada Diamantina National Park (PNCD) to understand how landscape and highway characteristics influence roadkill hotspots. We tested the spatiotemporal dynamics of roadkill for four taxonomic groups: amphibians, reptiles, birds, and mammals.

Methodology

Study area

Sampling was performed on highways around the *Parque Nacional da Chapada Diamantina* (PNCD - Chapada Diamantina National Park). The region is located within the *Espinhaço* orographic system, in the state of Bahia (Brasil 1994). The topography provides the region with a semi-humid tropical climate with a dry season (winter) from May to October and a rainy season (summer) from November to April (Brasil 2007). Thus, the region's climate is classified as *Cwb* according to the Köppen-Geiger climate classification (Alvares et al. 2013). The PNCD's vegetation is diverse, as the park is situated in a transition zone between the Atlantic Forest, Caatinga, and Cerrado biomes. Moreover, the region "comprises the following 9 basic vegetation types/landscapes: 1) rocky outcrop (63.4 % of the park area); 2) sandy sedge meadows (13.4%); 3) submontane to montane semi-deciduous seasonal to evergreen forests on litholic neosols (montane lithosolic forest); 4) sub-montane to montane evergreen riparian forests (3 and 4 together, 7.1%); 5) submontane to montane semi-deciduous seasonal forests on deep latosols (latosolic forests) (6%); 6) transition zones (7.3%); 7) wetlands (0.7%); 8) alluvial sands (0.5%), and; 9) anthropogenic landscapes (1.6%)" (Funch et al. 2009).

To the north of the PNCD lies a protected area called the *Área de Proteção Ambiental Marimbus-Iraquara* (APA Marimbus/Iraquara - Environmental Protection Area of Marimbus-Iraquara). An APA is defined as "a large area with human occupation that possesses abiotic, biotic, aesthetic, or cultural attributes of special importance for the quality of life and well-being of human populations. Its basic objectives are to protect biological diversity, regulate land use, and ensure the sustainable use of natural resources" (Brasil 2000).

We selected three highway sections for sampling: AND (70 km), MUC (50 km), and LEC (50 km):

- AND: Composed of the BA-142 (one lane, no shoulders), located between the BR-242 and BA-245 highways, AND is east of the PNCD. It is flatter and straighter than the other sample sections, with

fewer points of contact with the park. This is a two-lane highway without shoulders, spanning 70 km in total, 5.2 km of which border the PNCD.

- LEC: This section, located between the cities of Lençóis and Palmeiras, is composed of three highways: BA-849 (one lane, no shoulders), BA-850 (one lane, no shoulders), and BR-242 (one lane, with shoulders). The section covers a total of 50 km, with 28 km bordering the PNCD. Situated to the north of the park, LEC passes mostly within the park boundaries and experiences heavy traffic due to tourism in Lençóis and the transport of grains to Salvador via BR-242. This section is also near the APA Marimbus/Iraquara.
- MUC: This section of highway is the highest in altitude, with parts of the area dedicated to agribusiness (as indicated by circular formations visible in Figure 2). MUC is also located within the PNCD and features numerous tourist attractions. It comprises the BA-142 (one lane, no shoulders), located between the BA-245 and UVVA winery, with the city of Mucugê at its midpoint. MUC spans both the interior and western part of the PNCD, with a winding section between Mucugê and BA-245, and a flatter, straighter section between Mucugê and the UVVA winery.

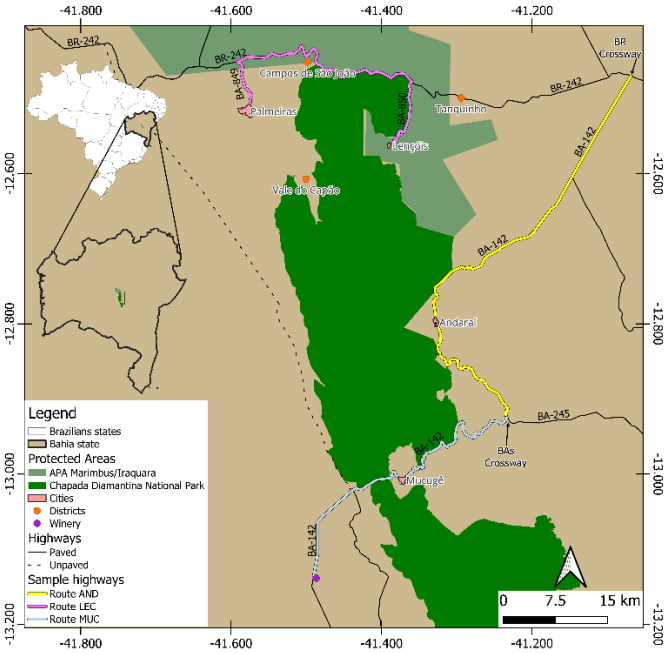

Fig. 1 Highways and sample highways around the Chapada Diamantina National Park (PNCD) and the Environmental Protection Area of Marimbus-Iraquara (APA Marimbus/Iraquara), Bahia, Brazil

Roadkill data

To collect roadkill data, we traveled along the sample highways biweekly between March 2022 and June 2023, totaling 32 campaigns. We used a car with two observers, driving between 40 and 50 km.h^{1}, starting at

sunrise. The sampling days were alternated to record the same number of days midweek and on weekends. We documented all carcasses with photos and geolocation. Carcasses were removed to prevent duplicate recordings. We also received some roadkill data from highway users and included these data in the species list but not in the analysis to avoid bias in the results.

Roadkill species

We analyzed the roadkill in terms of species richness and abundance by taxonomic group, creating a list of all species (across all taxonomic groups), both from systematic surveys and incidental observations. The species were categorized according to the IUCN Red List of Threatened Species (IUCN 2023) and the National List of Endangered Species from Brazil (Brasil 2022).

To assess sampling efficiency and compare the sections of highway, we generated rarefaction curves (Chao et al. 2014) for each section and for all sections combined, as well as for each taxonomic group and the total records for the study area. For this stage, we used the "iNEXT" package (Hsieh et al. 2024) and "ggplot2" (Wickham 2016) in R (R Core Team 2022).

Volume of vehicles

The number of vehicles in each section was recorded. During each roadkill data collection campaign, we stopped the car before, during, or after the transition on each section and counted the number of passing vehicles in 30 minutes. To estimate the number of daily vehicles per month in each section, each count was initially multiplied by two to obtain an hourly estimate, which was then multiplied by 10 to estimate the daytime traffic volume. Finally, the two monthly counts were combined to obtain the final monthly average for each section.

To validate the consistency of our vehicle count, we compared our data with vehicle volume data from the *Departamento Nacional de Infraestrutura de Transporte* – DNIT (National Department of Transport Infrastructure), which provided traffic volumes for the BR-242 highway. In this stage, DNIT's available data for 2022 (March, April, May, June, July, and December) was used, as no 2023 data was available at the time. The monthly average daily traffic from DNIT was calculated and compared with our data using the Kruskal-Wallis test (for non-normal data) and the Mann-Whitney test in R (R Core Team 2022).

After validating the vehicle count data, a Mann-Whitney test was performed to assess the difference in vehicle volume between high and low tourist seasons, using R (R Core Team 2022).

Precipitation

Precipitation data for the PNCD region was obtained from Hidroweb (ANA 2023) and the State Environmental Information System - SEIA (Bahia 2024). To assess differences in precipitation, average precipitation for the seven days prior to each roadkill data collection campaign was calculated. Each campaign was treated as a sampling unit, and a Mann-Whitney test was performed to compare the rainy and dry seasons in R (R Core Team 2022).

Temporal analysis

The temporal patterns in roadkill data were evaluated according to the categories “tourist season” and “climatic season”. Climatic seasons were defined as dry (May to October) and rainy (November to April), while tourist seasons were defined as high (January, February, March, June, July, and December) and low (April, May, August, September, October, November), based on the number of tourists in the region (Brasil 2007). Since the data did not meet normality assumptions, the Kruskal-Wallis test with a 95% confidence interval and Dunn’s test with Bonferroni correction were performed, using the "rstatix" package (Kassambara 2021).

Spatial analysis

To analyze the spatial distribution of carcasses along the sample sections, the modified Ripley's K test with two dimensions (Coelho et al. 2008, 2012) was conducted with SIRIEMA 2.0 software (Coelho et al. 2014). This test was performed for all individuals combined (Total) and for each biological group separately, namely amphibians, reptiles, birds, and mammals. The aim was to determine whether there were differences in spatial patterns among groups. The Ripley’s K test was performed with an initial radius of 500 m, an increment of 500 m, 1000 simulations, and a 95% confidence interval. A 2D Hotspot analysis for roadkill was also performed using the same parameters, except for reptiles on MUC, where we used a radius of 2000 m. The sections of highway were divided into sections of approximately 500 m (AND = 502 m, LEC = 501 m, MUC = 498 m). A 500 m radius was used in the Hotspot analysis, as this was the minimum scale with significant aggregation for all groups, except for reptiles on MUC, where the minimum scale was 2000 m (see Supplementary Material 3).

Landscape variables

After identifying the roadkill hotspots, we mapped road sections without roadkill occurrences. First, the Hotspot analysis graph was used to mark all segments without roadkill aggregation, represented as areas where the test line fell below the lower confidence limit (Coelho et al. 2014, see Supplementary Material 3). Next, these

locations were numbered, and a person uninvolved in the study randomly selected a number without knowledge of the order or corresponding locations. These areas were referred to as 'Coldspots' (areas without roadkill). Both Hotspots and Coldspots were subsequently used to analyze landscape variables.

The MapBiomas 2022 classification of landscapes with 30x30 m pixels, collection 8 (MapBiomas 2022), was applied to a clipped landscape within a 5000 m buffer around the sample highways. The classification was validated using photos taken during roadkill sampling and drone imagery to ensure accuracy. The drone captured photos at five altitudes (50 m, 100 m, 150 m, 200 m, and 250 m) at the Hotspots and Coldspots. These images were used to validate the MapBiomas classification with QGIS 3.16 (QGIS 2021). The following anthropic and natural land use classes were considered: Forest (natural class with arboreal vegetation with continuous canopy), Savanna (natural class with a predominance of herbaceous species and rocky savanna), Water, Farming (pasture and agriculture), and Urban areas (cities and small towns).

Highway variables

Slope. This variable was analyzed in sections of Hotspots and Coldspots to determine whether each section was inclined or flat. The altitude of each section's initial and final point was used, and the largest value was subtracted from the smallest value. The results indicate flatter (smallest values) or inclined (largest values) sections. Data were obtained from Google Earth.

Sinuosity: This variable was obtained for each Hotspot and Coldspot by dividing the actual length of the section (in meters) by the straight-line distance (in meters) between the first and last points. Values closer to 1 indicated a more linear section. Data were obtained from Google Earth.

Topographic Position Index (TPI). The relation between the road and lateral elevation was calculated using the Topographic Position Index (TPI). The TPI “identifies topographic slope positions as a basis of landform classifications” (Ghimire and Timalsina 2020) and point values to represent upper slope or ridge. This index was calculated with QGIS 3.16 (QGIS 2021). First, points were plotted every 100m along wall road segments (line shapes) with Hotspots and Coldspots. Second, TPI was calculated using the “Terrain Shading” and “Topographic Position Index” tools in QGIS 3.16 (QGIS 2021) for the eight pixels surrounding each point along the road line. Third, the values were extracted and the average TPI was calculated for the points in each Hotspot and Coldspot. The TPI was calculated using the SRTM image of the United States Geological Survey – USGS.

Predictive model for roadkill

Based on the literature (Benítez-López et al. 2010; Hamer et al. 2021; Gigeroff and Blouin-Demers 2023; Gonçalves et al. 2023), 5 km buffers were employed for mammals and 1 km buffers were employed for amphibians, reptiles, and birds. The variables influencing roadkill hotspots were analyzed using Generalized Linear Models (GLM) with highway variables (TPI, Sinuosity, and Slope) and landscape variables (Forest, Savanna, Urban area, Water, and Farming). A binomial distribution was applied, classifying Hotspots as 1 and Coldspots as 0. Collinearity between variables was removed using the Variance Inflation Factor (VIF < 3). The Akaike Information Criterion (AICc) was employed to select the best models, considering ΔAICc ΔAICc $\leq$ 2. The best models were used to construct the best-fitting model, and the importance of each variable was assessed based on wAICc (Burnham and Anderson 2002). This stage was performed with R (R Core Team 2022) and the "MuMIn" (Bartón 2022) and "car" (Fox and Weisberg 2019) packages.

Results

Sample highway characteristics

The selected sections of highway are located in mostly natural rather than anthropic areas (Figure 2). AND is most degraded at 5000m around the highway, with more Farming areas composed of small properties with cows, plantations of *Opuntia ficus-indica* Mill, regionally known as Palma, corn plantations, and some properties with pastures. LEC has mostly natural areas around the highway at 5km and is inserted in two protected areas. MUC has more natural areas and some areas with crops.

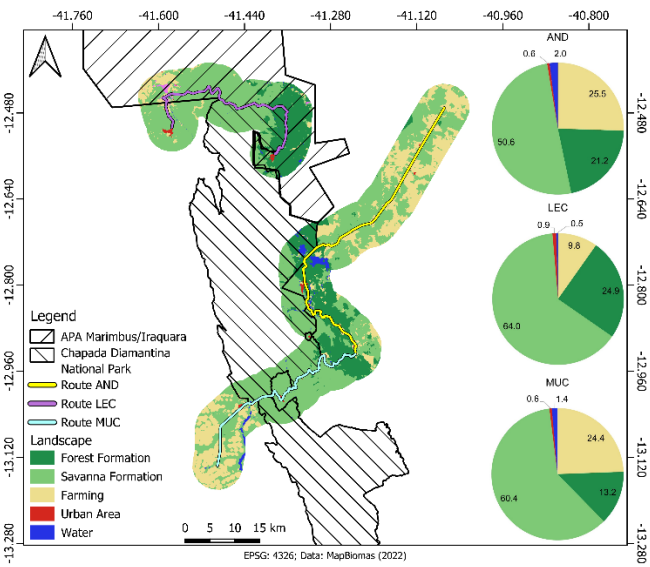

Fig. 2 Description of the landscape at 5km around the highways studied in the Chapada Diamantina National Park.

APA Marimbus/Iraquara: Environmental Protection Area of Marimbus/Iraquara

Roadkill animals

The roadkill animals totaled 580, consisting of 182 amphibians (31.4%), 185 reptiles (32.0%), 143 birds (24.6%), and 70 mammals (12.0%). The highest number was recorded for AND, with 310 roadkill, followed by MUC (n = 143) and LEC (n = 127). Moreover, amphibians, reptiles, and mammals were more abundant in AND, while birds were more abundant in MUC (Table 1).

Table 1. Abundance of roadkill in the sample highways around the Chapada Diamantina National Park (PNCD). AND: between BR-242 and BA-245, east of PNCD. LEC: between Palmeiras and Lençóis cities, north of PNCD. MUC: between BA-245 and UVVA winery, middle of PNCD.

Groups	AND section	LEC section	MUC section	Total
Amphibians	134	27	21	182
Reptiles	92	49	44	185
Birds	40	35	68	143
Mammals	44	16	10	70
Total	**310**	**127**	**143**	**580**

We identified six species of amphibians, 20 reptile species, 35 bird species, and 10) mammal species (Supplementary material S1). Some species could not be identified since some individuals were in advanced stages of decomposition. The most common species were *Rhinella* sp. (n = 65), *Rhinella diptycha* (n = 55), *Amphisbaena* sp. (n = 45), *Cerdocyon thous* (n = 28), *Coragyps atratus* (n = 19), and *Boa constrictor* (n = 18). Furthermore, the roadkill records included two threatened species according to the International Union for Conservation of Nature (IUCN) Red List (IUCN 2023), namely *Lycalopex vetulus* (n = 2; NT) and *Leopardus tigrinus* (n = 2; VU), and three species included in the Brazilian List of Endangered Species (Brasil 2022), namely *Lycalopex vetulus* (n = 2; VU), *Crypturellus zabele* (n = 1; VU), and *Leopardus tigrinus* (n = 2; EN).

Amphibians were richer in AND, with the asymptote both in AND and in the Total study area. Although the reptiles reached the asymptote for Total study area, this was not observed for the individual highways. Moreover, the highway with the highest species richness was AND. Birds were the richest group, especially in MUC, which is in the middle of the PNCD. The section of highway AND, west of PNCD (Figure 3) showed the lowest richness of bird species. The highest richness of mammals was observed in LEC, north of PNCD, although the asymptote was only reached for AND, which is west of PNCD and the most anthropic section.

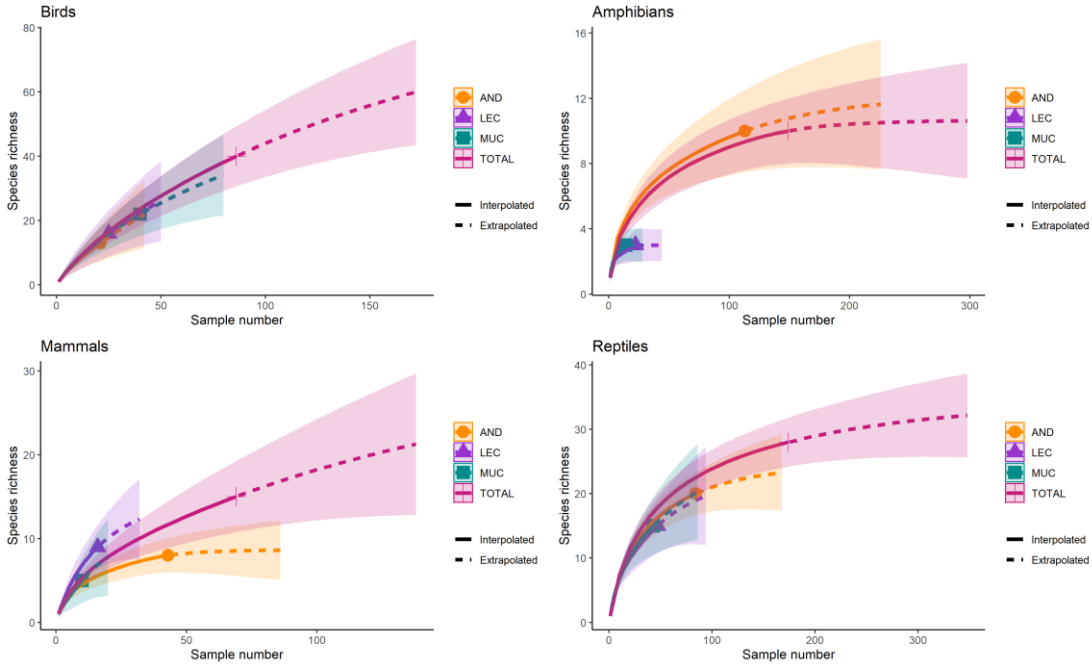

Fig. 3 Rarefaction curve with roadkill species around the Chapada Diamantina National Park, in three sections of highway: AND = BA-142 between BR-242 and BA-245; LEC = between the cities of Lençóis and Palmeiras; MUC = BA-142 between BA245 and UVVA winery

The Kruskal-Wallis test showed significant differences between amphibians richness for the three highways (p = 0.000011). Dunn's test indicated significant differences between AND and LEC (p = 0.000368) and between AND and MUC (p = 0.00000565). Similarly, for amphibians abundance (p = 0.000105), significant differences were observed in relation to AND and LEC (p = 0.000438), and between AND and MUC (p = 0.000108). Bird richness (p = 0.124) and abundance (p = 0.0807) between the highways did not show significant differences. In relation to reptiles, richness differed between the three highways (p = 0.0465), and the post-hoc test indicated significant difference between AND and LEC (p = 0.0271) and between AND and MUC (p = 0.0381). Similarly, reptile abundance (p = 0.0362) revealed a difference between AND and LEC (p = 0.050), and between AND and MUC (p = 0.0151). For mammals, richness differed for three highways (p = 0.0000494), with significant difference between AND and LEC (p = 0.00114) and between AND and MUC (p = 0.0000204). Lastly, for mammal abundance (p = 0.00000666), significant differences were observed between AND and LEC (p = 0.000249) and between AND and MUC (p = 0.00000371).

Temporal distribution

With regard to the tourist seasons, no differences were observed in richness for the groups: amphibians (p = 0.363; W = 1258); reptiles (p = 0.623; W = 1218); birds (p = 0.509; W = 1236), and mammals (p = 0.855, W = 1175). The same results were observed for abundance across the tourist seasons: amphibians (p = 0.258; W = 1288);

reptiles (p = 0.497; W = 1243); birds (p = 0.193; W = 1324), and mammals (p = 0.91, W = 1166). In terms of richness and abundance, no significant differences were observed in vehicle volume for the high and low seasons (p = 0.1272; W = 7012).

For climate variation, the number of amphibians (p = 0.0053; W = 826) and reptiles species (p = 0.0000259; W = 595) showed significant differences across the climatic seasons, with greater richness in the rainy season. However, this result was not observed for birds (p = 0.253; W = 1007) and mammals (p = 0.569, W = 1222). Regarding abundance, significant differences were also observed across the seasons for amphibians (p = 0.000956; W = 754) and reptiles (p = 0.00000165; W = 512), with greater abundance in the rainy season. This result was not observed for birds (p = 0.213; W = 988) or mammals (p = 0.55, W = 1226). Moreover, precipitation showed significant differences between rainy and dry seasons (p = 0.001081; W = 1597.5).

Roadkill hotspots and landscape

Our analyses identified seven roadkill hotspots for Total group in AND, six in LEC, and four in MUC (Figure 4). Moreover, 10 roadkill hotspots were identified for amphibians, six in AND, two in LEC. and two in MUC. For reptiles, five were observed in AND, zero in LEC, and three in MUC. On AND, three roadkill hotspots were clustered together near the middle of the section. For birds, five were identified in AND, four in LEC, and six in MUC. On LEC, three roadkill hotspots were clustered in the west. Mammals were observed in five roadkill hotspots, with three in AND, zero in LEC, and two in MUC.

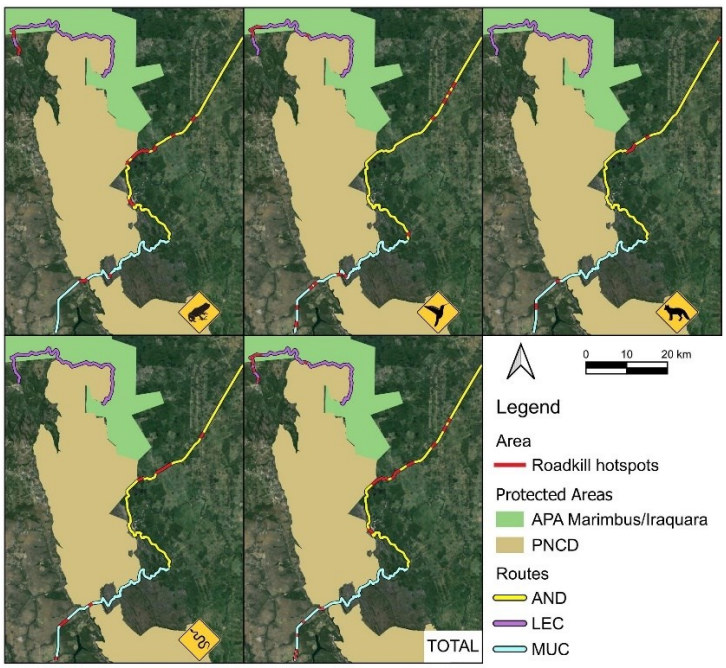

Fig. 4 Localization of roadkill hotspots around the Chapada Diamantina National Park and the Environmental Protection Area of Marimbus/Iraquara (APA Marimbus/Iraquara)

Most of the roadkill hotspots were located outside the PNCD or APA Marimbus/Iraquara. For Total, only five (29.4%) roadkill hotspots were within the limit of some protected areas. Amphibians, with the most hotspots in the protected areas, accounted for five (50%) roadkill hotspots in the limit of PCND or APA Marimbus/Iraquara. Birds had only three (20%) roadkill hotspots in the protected area, while mammals had one (20%) and reptiles had two (25%).

We found different influences of landscape classes for roadkill (Table 2). For amphibians, reptiles, and mammals, no statistically important variable was observed to predict roadkill hotspots. For birds, however, Farming (agriculture and pasture) was an important variable with significant statistical relevance. Urban area was the only landscape class found in all models, with negative estimates only for amphibians. The amphibians medium model had six variables, three of which were "Highway variables" and three "Landscape variables". The reptile medium model had five variables, with two "Highway variables". The birds medium model had six variables, but only two were "Highway variables". Mammals had the medium model with fewer variables, namely two "Landscape variables" and one "Highway variable".

Table 2. Results of Generalized Linear Models for roadkill, with variables according to Importance value for amphibians, birds, mammals, and reptiles in the Chapada Diamantina region, Bahia, Brazil. Variable nature (V.N.): Highway variable (H) or Landscape variable (L). *Statistically significant.

Dependent variables	Independent variables	V.N.	Estimate	Std. Error	Z value	P value	Importance
Amphibians	(Intercept)		-4.028	7.134	-0.564	0.572	
	Slope	H	-0.709	0.516	-1.372	0.169	0.59
	Sinuosity	H	7.029	7.909	0.888	0.374	0.29
	Farming	L	-0.008	0.033	-0.247	0.804	0.21
	TPI	H	0.020	0.275	0.075	0.939	0.2
	Urban area	L	-0.035	0.086	-0.410	0.681	0.2
	Water	L	-0.041	0.123	-0.331	0.740	0.19
Reptiles	(Intercept)		-45.884	33.270	-1.379	0.167	
	Sinuosity	H	47.669	33.810	1.409	0.158	0.79
	Forest	L	-0.002	0.044	-0.046	0.962	0.22
	Urban area	L	1.916	2.734	0.700	0.483	0.2
	TPI	H	-0.092	0.240	-0.384	0.700	0.19
	Farming	L	-0.018	0.037	-0.499	0.617	0.19
Birds	(Intercept)		-2.101	5.434	-0.386	0.698	
	Farming	L	0.053	0.025	2.078	0.037*	0.94
	Urban area	L	0.245	0.203	1.209	0.226	0.64
	Slope	H	-0.440	0.429	-1.025	0.305	0.39
	Forest	L	-0.034	0.035	-0.978	0.327	0.37
	Sinuosity	H	1.836	5.401	0.339	0.733	0.21
	Water	L	-0.047	0.909	-0.051	0.958	0.21
Mammals	(Intercept)		2.462	1.564	1.574	0.115	
	Forest	L	-0.092	0.066	-1.403	0.160	0.57
	Slope	H	-0.419	0.355	-1.177	0.238	0.3
	Urban area	L	1.010	3.763	0.268	0.788	0.12

Discussion

A large number of roadkill animals were recorded in the Chapada Diamantina region, with amphibians and reptiles being the most representative groups. In general, tourist seasons have no relevance in predicting roadkill incidents, while climatic seasons can predict roadkill incidents among amphibians and reptiles. Although roadkill can be clustered, this is not consistent across all sections, as we found hotspots in different areas depending on the taxonomic group. The results showed this divergence is a response to the landscape and highway variables since different variables can influence roadkill hotspots for each taxonomic group.

Roadkill animals

We believe the large number of amphibians and reptiles records reveals the efficiency of surveying, as these small-bodied groups are usually overlooked by researchers due to difficulties in spotting their carcasses on the road (Santos and Ascensão 2019; Teixeira et al. 2013). Other studies with roadkill surveying by car generally found more mammals or birds (Guinard et al. 2023; Santos et al. 2017). Moreover, body-size influences carcass persistence and the time variations a species remains on the road, with carcasses weighing more than 1kg persisting more days on the highway (Santos et al. 2011).

Although amphibians were the most abundant group, birds exhibited the greatest richness, followed by reptiles. This result was expected, as birds and reptiles account for the highest recorded roadkill richness in Latin America (Pinto et al. 2020). Species with higher population densities are more frequently roadkill, and roadkill records can reflect variation in local abundance (Medrano-Vizcaíno et al. 2022). The high diversity of birds at the PNCD, with threatened and endemic species (Parrini et al. 1999; Goes-Coelho et al. 2008; Anjos et al. 2019), explains the high richness of birds among the roadkill and revealed the importance of studying and understanding the effect of roadkill on birds. For reptiles, the high number of roadkill species could be associated with the use of highways for thermoregulation, wherein individuals of this group are attracted to the road and are roadkilled (McCardle and Fontenot 2016), and with the local abundance, as mentioned previously (Medrano-Vizcaíno et al. 2022).

Although mammals were the least abundant among the roadkill groups, they included the highest number of threatened species. Since roadkill reflects local abundance (Medrano-Vizcaíno et al. 2022), we believe that mammals are less abundant than other groups across the PNCD. However, further studies on species occurrence are needed in landscapes surrounding regional highways for validation. The occurrence of threatened species among the roadkill highlights the importance of understanding this issue and the effects of highways on these populations in the

PNCD and surrounding area, especially given its status as a protected area with intense tourist activity (Miranda and Schiavetti 2024).

The divergence between the richness and abundance of amphibians, reptiles, and mammals from AND in relation to other sections can be result of landscape variety. AND is more distant from the PNCD and has more heterogenous habitats such as pasture, agriculture, and natural patches. The other routes, however, are merged with the PNCD and have more continuous natural vegetation surrounding the highway. In this regard, birds were the only group with no differences in richness and abundance between the sections of highway. Therefore, we believe that flight capacity plays a critical role in enabling species to move and utilize the space in and around the PNCD.

Temporal distribution

The effects of tourism on roadkill were not identified. Although some studies indicate changes in roadkill rates due to tourist activities and the increased road traffic (Rendall et al. 2021), these changes were not observed in the Chapada Diamantina region. Our results show no relation between traffic volume between high and low seasons, although more studies seem necessary to properly understand the relation. Furthermore, roadkill rates can be more influenced by specific events or dates, such as festivities in the cities around the PNCD. To validate this assumption, however, it would be necessary to evaluate roadkill occurrences with systematic surveys before and after these dates.

Amphibians and reptiles were the only groups with significant differences in richness and abundance between dry and rainy seasons, with greater richness and abundance in the rainy season. This result was expected, as this pattern was also observed in other regions (Tenório et al. 2021; Rocha et al. 2022). Species such as *Rhinella* sp. are most active in rainy periods (Montezol et al. 2018) since many amphibians depend on water for reproduction (Schalk and Saenz 2015). Consequently, the number of amphibians moving across the highways can increase in rainy seasons, resulting in higher roadkill rates in these periods. The same occurs for some reptile species, such as Amphisbaenians, which reproduce in hot and rainy seasons (Andrade et al. 2006).

Roadkill hotspots and landscape

Some roadkill hotspots overlapped in Total analysis but differed and were further apart when analyzed separately. This highlights the importance of understanding spatial distribution for each taxonomic group. It has been demonstrated that highways in the same region have different distributions of roadkill hotspots. Total analysis is often influenced by the most frequently recorded groups, while groups such as birds and mammals can overlap on one highway but be distant on another (Miranda et al. 2020). The divergence between roadkill hotspots in each

taxonomic group was expected (Santos et al. 2022; Rocha et al. 2022), as each taxonomic group responds differently to the landscape around the highways (Santos et al. 2022). In this regard, the use of general protective measures based only on overall analyses can be dangerous for animals and vehicles (Miranda et al. 2020). Moreover, mitigation measures can be installed in inefficient locations for a given taxonomic group. In contrast, overlapping points indicate the ideal locations to install general protective measures such as speed bumps. In this study, one roadkill hotspot overlapped for mammals and reptiles on AND, one roadkill hotspot overlapped for amphibians, birds, and mammals on MUC, and one overlapped for amphibians and birds on LEC (see Figure 6). In this case, the installation of speed bumps at these spots could reduce the roadkill.

Most of the roadkill hotspots were located outside the PNCD. We believe this result indicates that animals in protected areas avoid using highways or do not need to cross highways to find resources, such as food or partners. Our results support this idea, as the GLM indicates that more anthropic variables (such as Urban area and Farming) are more closely related to roadkill hotspots than natural variables (Forest and Savanna) in the best-fitting model. The roadkill may be more related to the matrix (Bueno et al. 2015), indicating the need to analyze habitats surrounding the highways with more detail.

Four landscape variables are important to predict roadkill hotspots: Farming, Forest, Urban area, and Water. Farming was observed for amphibians, reptiles, and birds, with a positive association with birds and a negative association with amphibians and reptiles. Generally, landscape changes are associated negatively with amphibians and reptiles since deforestation alters the structure and functions of forest, resulting in less species of these two groups (Cordier et al. 2021). Fragmentation negatively affects amphibians and reptiles (Teixido et al. 2021), and landscapes changes reduce amphibians diversity (Doherty et al. 2020; Oro et al. 2024). This may explain the decrease in roadkill for these groups in sections with more Farming. In contrast, for birds, the most common roadkill hotspots were in unprotected and Farming areas. This can be explained by the greater number of opportunistic species (Fraga et al. 2022), such as *Coragyps atratus* and *Caracara plancus*, which were frequently found in our study. Furthermore, birds are often attracted to cereals lost during transportation and may use this opportunity to forage, which can result in roadkill incidents (Husby 2017; Morelli et al. 2020).

For the Forest variable, a negative relation was observed with birds, mammals, and reptiles. This result is expected for birds since roadkill hotspots of this group are associated with Farming areas. Therefore, the number of roadkill animals increases in Farming areas and decreases in Forest areas. Mammals and reptiles can be associated with Forest areas (Santos et al. 2022), indicating that negative relation with Forest for mammals and reptiles can also reveal the importance of the matrix, with species using more open areas with herbaceous vegetation (Bueno et al.

2015). Therefore, we believe that other landscape characteristics can be more important, such as number of fragments, and should be investigated.

The Urban area was identified in all models, with a negative relation with amphibians and a positive relation with the other three groups. This is expected for amphibians because the group commonly reduces with landscape change (Doherty et al. 2020; Oro et al. 2024). Since birds, mammals, and reptiles are not associated with Forest areas, according to our results, it is necessary to understand how cities can influence roadkill. This investigation could be conducted with demographic analysis (Araújo et al. 2019) or with the functional groups approach (Filius et al. 2020).

The Water class was negatively related to amphibians and birds. Although amphibians are associated with water (Santos et al. 2022), a different result was observed in this study. Since amphibians are associated with water to reproduce (Schalk and Saenz 2015), we believe they move more in sections of highway far from water and remain more immobile in sections with water surrounding the highway. Another possibility is that the region's anurans cross the highways by passing under bridges or through pipes, thus explaining the absence of association with the amount of water near the hotspots. In the case of birds, the group is found farther from water as they are closer to Farming and Urban areas, where they forage.

The highway variables adopted in the models were Sinuosity, Slope, and TPI. Positive sinuosity was observed in the models for amphibians, reptiles, and birds. Therefore, more roadkill was observed in sections with more curves. This occurs because the drivers and animals have more difficulty seeing and recognizing potential hazards in curved highways than in straight highways (Laube et al. 2023).

Slope class was negative for amphibians, birds, and mammals, indicating a greater number of roadkill incidents in flatter sections for these groups. In most flat sections, vehicle speed is greater, and drivers have less time to react when they see animals. Moreover, drivers may increase the speed in sections with more visibility (Valero et al. 2015), such as areas with less slope.

The TPI showed a positive association with amphibians and a negative association with reptiles. This suggests that amphibians roadkill hotspots tend to be located in higher areas compared to the surrounding landscape, while reptile roadkill hotspots are more likely to occur in lower areas ("sunken") relative to the highway. Few studies have investigated the influence of topography on roadkill, but the existing literature indicates that high slopes and rugged terrain are important factors in explaining roadkill patterns (Pagany 2020). However, Pagany (2020) did not specifically analyze these variables for amphibians and reptiles due to the scarcity of data on these

groups in the literature. Most roadkill occurs in areas at the same level as the surrounding terrain (Borkovcová et al. 2012). Considering the barrier effect of topography, it is expected that fewer roadkill incidents would occur on sections of road at the same level as the surrounding terrain, as animals can more easily cross these sections (Delgado et al. 2019). For instance, if we consider a snake crossing two sections of road with similar traffic intensity, with one section being "flat" and the other "sunken", the likelihood of the snake escaping would be higher in the flat section, especially because many highways in the study area lack shoulders. In this regard, two possibilities are considered: for amphibians, the roadkill hotspots are located in areas with surrounding water (river, flooded) and the animals cross the highways looking for partners in the reproductive period; for reptiles, which were mostly snakes in this study, the roadkill hotspots can occur in areas lower than the highway because they move down to the road, but the barrier posed by traffic makes it difficult for them to escape. Therefore, amphibians and reptiles respond differently to TPI, suggesting the need for further studies about the movement and behavior of these groups around the highways.

Conclusion

Although seasonal distribution may be important for certain groups, tourist seasons do not currently appear to have a significant effect on roadkill patterns. Therefore, we suggest that future studies focus on better understanding the frequency of tourists in protected areas and how traffic volumes fluctuate at specific times and locations.

Regarding roadkill hotspots, we conclude that there are areas where hotspots of different taxonomic groups overlap. Consequently, these regions may be more suitable for implementing general mitigation measures, such as speed bumps. Such measures could be crucial not only for species protection but also for tourist safety. However, the management of PNCD (Chapada Diamantina National Park) must carefully evaluate these hotspot areas to make decisions, as the analysis serves as a guiding tool rather than a definitive solution. In this regard, it is important to evaluate structures and habitats in each roadkill hotspot to make better decisions.

The influence of landscape composition on roadkill varies between taxonomic groups, highlighting the need to better understand the role of the surrounding matrix. Future research should focus on the landscape structure, including the number of patches and how different groups interact with the landscape around highways in protected areas. We emphasize the importance of analyzing taxonomic groups separately to obtain more accurate estimates and results.

We conclude that most roadkill occurs far from the protected area, suggesting the need to study and understand the occurrence of fauna around the highways. We consider two possibilities: 1. The protected areas are effective in protecting and maintaining the fauna and the animals do not use the highways frequently around protected areas; 2. Other impacts influence the PNCD, and less biodiversity exists in the PNCD than expected. Despite the high number of studies on protected areas in Brazil, more approaches are required (Miranda and Schiavetti 2024). Moreover, the spatial distribution of roadkill around protected areas must be better understood to enable more effective long-term management.

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CAPÍTULO 3 – Compreendendo os fatores que influenciam a ocorrência de espécies no entorno das rodovias

O presente capítulo será submetido com o título **"Understanding the factors that influence species occurrence alongside roads",** na revista **Environmental Management**. A formatação segue as normas da revista. Endereço eletrônico da revista: https://link.springer.com/journal/267

The animals aren't alright: understanding the factors that influence species occurrence alongside highways

ABSTRACT

Although the most visible impact of highways is the roadkills, highways can influence the occurrence of species in their surroundings. Thus, we aimed to analyze the factors that influence animals in areas around the highways. With this, we collected data on roadkill and about birds and mammals near highways in Chapada Diamantina National Park (PNCD). First, we surveyed roadkill animals, then identified the points with high roadkill occurrence (roadkill hotspots) and point without roadkill (roadkill coldspots), and then defined areas to analyze the fauna near highways. We found that only 16% of the birds that occur near highways are roadkill, while 50% of the mammals near highways are roadkill. Furthermore, we found that the effects of highways on the fauna can vary according to the functional group and only for carnivorous birds is the distance from the highway important. As the distance from the highway increases, more carnivorous birds are found. Coldspots demonstrated more mammals near the highway than hotspots, so we encourage more studies to understand this effect. We reinforce the importance of analyzing impacts separately for functional groups and better understanding the resources in the environment surrounding highways, and analyzing local aspects together with the composition of the landscape.

Keywords: Biodiversity; Road Ecology; Roadkill; Protected Areas.

INTRODUCTION

Highways impact biodiversity in different ways, directly or indirectly. Although the most seen impact is animal roadkill, highways are also responsible for habitat loss, population subdivision and inaccessibility, because some species are attracted to the road and are roadkill and other species avoid the road and populations are divided (Jaeger et al. 2005; van der Ree et al. 2015). Furthermore, areas with higher road density can increase the risk to biodiversity, and the continuous roadkill events can extinct some threatened species (González-Suárez et al. 2018; Grilo et al. 2021). Increase of linear structures offer high risk to species and threats many populations persistence (Grilo et al. 2020). A large highway networking could be a risk to many species, mainly for more sensitive species that cannot adapt to changes (Kent et al. 2021). This can occur because noise avoidance effect inhibits species more sensitive to noise, light or pollutants on the highways (Jaeger et al. 2005).

The avoidance effect changes behavior and force species use more unappropriated habitats (Barrientos et al. 2021), because some species can be sensible to vehicle avoidance and move to habitats distant to the highway (Husby, Husby 2014). But the effect of the infrastructure zone changes between the vertebrate groups, and can vary according to habitat, diet and distance to the highway (de Jonge et al. 2022). To birds the most impacted zone around the highway is 1km, and for mammals the zone is 5km, demonstrating different behavior to each group and the impact of the highways (Benítez-López et al. 2010).

In addition to distance from the highway, other factors may be important in predicting roadkills, such as land use classes (Cirino et al. 2022; Medrano-Vizcaíno et al. 2023). For some mammal species, landscape is important to predict roadkill, and the effect change with the proportion of matrix and natural areas (Cirino et al. 2022). The effect of landscape is taxa-specific, and the same land cover can influence different taxonomic groups (Medrano-Vizcaíno et al. 2023). With this, it is necessary studies to understand diversity near highways in all ecosystems (Pinto et al. 2020).

Considering the low number of studies with avoidance behavior (Jaeger et al. 2005), is necessary understand the road effect on biodiversity near highways (Pinto et al. 2020), and fill the spatial sampling gaps, as northeast of Brazil (Medrano-Vizcaíno et al. 2022; Miranda and Schiavetti 2024). Additionally, a few studies near protected area reinforce the urgence to understand the effect of highways near protected areas on Brazil (Miranda and Schiavetti 2024). So, in this study we aimed to understand if distance from highway is important to predict the occurrence of birds and mammals. So, we question if the landscapes variables are better than the distance to predict birds and mammals around the highways.

METHODS

Study area

We collected the data on *Chapada Diamantina*, a region of *Espinhaço* orographic system, in Bahia state (Brasil 1994), and have a semi-humid tropical climate, with a summer season, the rainy period between November and April, and a winter season, the dry period between May and October (Brasil 2007). The region can be classified as Cwb according to the Köppen-Geiger climate classification (Alvares et al. 2013). We sampled roadkill rates in three routes around the *Parque Nacional da Chapada Diamantina* - PNCD (Chapada Diamantina National Park), and the areas around these highways.

The three routes were distributed north, east and middle of PNCD, called here: AND, LEC and MUC (Figure 1). The AND route is formed by 70km of BA-142, localized east of PNCD, with Andaraí city centered the route. The LEC route is formed by 50km of three highways north of PNCD, BA-849, BA-850 and BR-424, between Palmeiras and Lençóis cities. MUC route is formed by 50km of BA-142, localized in the middle to west of PNCD, with Mucugê city in the center of the route.

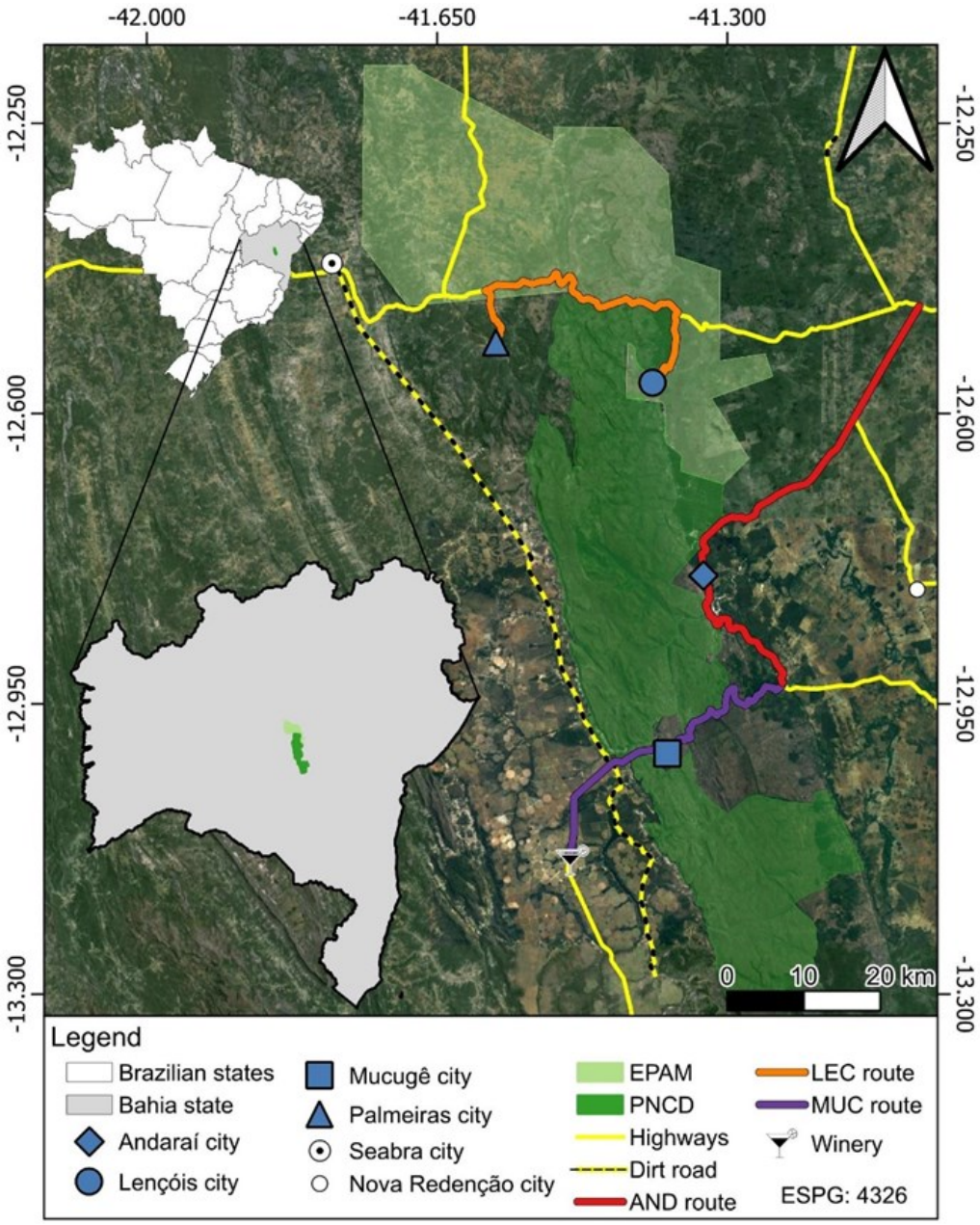

Figure 1. Chapada Diamantina National Park (PNCD) and Environmental Protected Area Marimbus/Iraquara (EPAM) with sampled highways around them.

Roadkill data

We collected data about roadkill travelling the routes between March/2022 and June/2023. We travelled each route one time each 15 days, and we used a car with two observers (including the driver), with average speed between 40-50 km.h^{-1}. We begin the route sampling in the sunrise. We alternated the sampling days to record once mid-week and once weekend per month. We recorded all carcasses with photos and geolocation, and take photo around the carcasses.

Data collection: animals around the highways

First, we analyzed the spatial distribution of roadkills with 2D Ripley's K test and "Hotspots analysis", both using SIRIEMA 2.0 (Coelho et al. 2008; Coelho et al. 2012; Coelho et al., 2014). We carried out this analyze separately for birds and mammals using one year of roadkill data collected (March/2022 to February/2023). To 2D Ripley's K test we use a initial radius of 500 m, an increment radius of 500 m, 1000 simulations and a 95% confidence limit. After this test we realize "Hotspots analysis" using radius of 500m (the minimum scale with significance aggregation for the two groups in the 2D Ripley's K test), 1000 simulations and 95% confidence limit. We divide the routes in sections with approximately 500m (AND = 502 m; LEC = 501m; MUC = 498m).

After the "Hotspots analysis" we obtained the graph indicating areas with significant roadkill aggregation (roadkill hotspots) and areas without roadkill (roadkill coldspots). We found 10 hotspots to birds, wherein two were around PNCD. For mammals, we found six hotspots, wherein one was around PNCD and one near to the PNCD. So, we chose to sample these two hotspots around and near to the PNCD and we selected two hotspots outside of PNCD. To select the areas to sample around the highways we numbered all Hotspots (except the four selected hotspots into PNCD) and all coldspots, and after this we request that one person outside of the work chooses the numbers without knowing the locations. We expected with this reduced bias in the next analysis. At the end of selected the areas we obtained four hotspots to each group, with two into the PNCD and two outside PNCD, and the same number to coldspots.

To collect birds data, we use a transect with 1km and five-point counts. The first point was on the highway, the second 250m from highway, third 500m from highway, fourth 750m from highway and fifth point at 1000m from highway. We use the 1km of transect because this distance is most dangerous to bird populations around the highways (Benítez-López et al. 2010). We started sampling at the sunrise, staying 10min each point. We sampled each transect once month (March to June, 2023) and alternated the starting point (once started to the first point, and the next month started to the fifth point).

To collect mammals data, we use a transect with 2.5km with three sampling points. The first point was 0.5km from highway, the second 1.5km from highway and third point 2.5km from highway. The maximum effect of the roads on mammal population occurs at 5km (Benítez-López et al. 2010), therefore we consider analyzing the effects to the middle of the maximum impacted radius. Each point was installed a camera-trap, without food or other substances to attract animals, stayed on for four months (between March and December, 2023).

Landscape variables

We use the MapBiomas classification (MapBiomas 2023) with manual correction. We downloaded the classification for the year 2023 and validated it using our knowledge about the area and photos taken with a drone. We made the classification according to MapBiomas classification, and we considered six classes: Grassland (natural areas with herbaceous predominant and with rocky Cerrado), Farming (anthropic areas with pasture and crops, as plantations of *Opuntia ficus-indica* Mill, corn, potato and tomato), Forest (natural areas with arboreal vegetation predominant), Savanna (natural areas with herbaceous vegetation predominant, with some trees, as Cerrado), Urban area (anthropic areas with cities or other human agglomeration as villages), Water (natural or anthropic areas with water, for example, rivers or lakes). To work with this data, we use QGIS (Qgis 2021).

To select the adequate buffer to analyze the landscape around sampling points we use the coefficient of determination (R^2) between all classes of birds and mammals. For birds, we constructed five buffers with the maximum distance equal to the minimum distance between sampling point count: 50m, 100m, 150m, 200m, and 250m. For mammals, we constructed seven buffers, with the maximum distance equal to the minimum distance between the cameras-trap: 50m, 100m, 175m, 250m, 500m, 750m, 1000m. With this, we chose the scale with the landscape variables that showed better results to R^2: 250m for birds and 1000m for mammals. We realized the test with R (R Core Team 2022).

Data Analysis

We did the Wilcoxon test to verify the abundance and richness differences between hotspots and coldspots areas, with 95% confidence limits. We constructed boxplot graphs with "ggplot2" package (Wickham 2016) to R (R Core Team 2022).

To evaluate the sampling efficiency, we carried out a rarefaction curve (Chao et al. 2014), for each transect of birds and mammals, and we considered the sampling unit as the sampling point per month. For this, we use the "iNEXT" package (Hsieh et al. 2024) and "ggplot2" (Wickham 2016), with the R (R Core Team 2022).

To understand the variables that influence animals around the highways we carried out a Generalized Linear Mixed Model (GLMM) test for birds and mammals using trait data. Birds and mammals were separated as "carnivore", "herbivore", and "omnivore", like proposed by González-Suárez et al. (2018). We analyze the presence of landscapes classes around all sampling points and to simplify the model we exclude all classes present in less than 25% of the sampling points, for birds and mammals separately. With this, we exclude Water and Urban Area to birds and mammals tests, because these two classes were present in less than 25% of the sampling points to the two biological groups.

To GLMM we used Poisson distribution with abundance as response variable, the sampling points as random effect, and predict variables: Forest, Savanna, Grassland, Farming and Distance (the distance of the sampling point to the highway). We removed the collinearity with Variance Influence Factor (VIF < 3), and we used Delta Akaike Information Criterion (ΔAICc < 2) to select the best model in the R with (R Core Team 2022) with packages "MuMIn" (Bartón 2022) and "car" (Fox and Weisberg 2019). The GLMM test was carried out for each carnivore, herbivore and omnivore, to birds and mammals.

RESULTS

Points description

All birds hotspots have some type of natural class. Although Savanna is present in all hotspots, Grassland and Forest are not present in all points (Figure 2). Farming is on all hotspots, but Urban area exist only two areas (hotspot 2 and 3). Savanna is present on all coldspots too, but Forest is only one hotspot (coldspot 2). The mammal's hotspots have more natural vegetation than anthropic areas, wherein Savanna is predominant. Only one mammal's hotspot (hotspot 3) have Water and Urban area on the buffer (Figure 3).

Figure 2. Percentage of landscape classes at each bird sampling point around highways in the Chapada Diamantina National Park region.

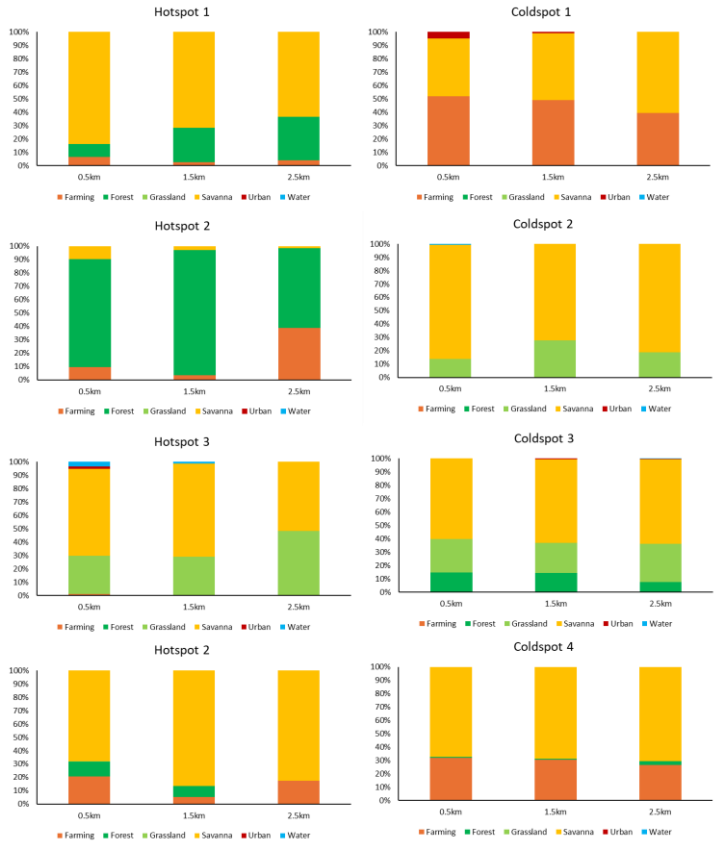

Figure 3. Percentage of landscape classes at each mammal sampling point around highways in the Chapada Diamantina National Park region.

Road effect

We recorded 213 roadkill animals (birds = 143; mammals = 70) and 50 species (birds = 40; mammals = 10). Near highways we recorded 4004 birds and 193 mammals, of which 168 bird (Appendix 1 – Birds species list) species and 18 mammal species (Appendix 2 – Mammals species list). Only 16% (n = 28) of the bird species recorded in the surrounding area were roadkill, on the other hand 50% (n = 9) of the mammal species recorded in the surrounding area were roadkill. Only *Callithrix penicillata* was recorded only roadkill, and although we not recorded on camera-trap, the species was recorded crossing the highways.

Seven bird species recorded around the highways are on the Brazilian National List of Endangered Species (Brasil 2022): *Augastes lumachella* (EN), *Colibri delphinae* (EN), *Crypturellus zabele* (VU), *Formicivora grantsaui* (EN), *Spinus yarrellii* (VU), *Stigmatura napensis* (VU), *Thamnophilus caerulescens* (VU). Four mammal species are on the Brazilian National List of Endagered Species (Brasil 2022): *Lycalopex vetulus* (VU), *Herpailurus yagouaroundi* (VU), *Kerodon rupestris* (VU).

The rarefaction test showed that birds richness stabilized in majority sampled areas (Figure 4), but some areas are more richness and abundant (Table 2), with "Hot1" the most abundant and rich area. Mammals' richness stabilized in many areas, except for Hot1 and Hot2 (Table 2), wherein the Cold2 is the most abundant and Hot2 is the richest (Figure 2).

Table 2. Abundance and species richness in the transects sampled around highways in Chapada Diamantina National Park. Transect: transect name; Type: if the transect is a roadkill aggregation (Hotspots) or dispersion (Coldspot); Park: if the transect is insert on Chapada Diamantina National Park (Inside) or not (Outside).

			BIRDS	
Transect	Type	Park	Abundance	Richness
Hot1	Hotspot	Outside	941	108
Hot2	Hotspot	Inside	442	76
Hot3	Hotspot	Inside	263	37
Hot4	Hotspot	Outside	484	72
Cold1	Coldspot	Outside	786	90
Cold2	Coldspot	Inside	250	34
Cold3	Coldspot	Inside	359	50
Cold4	Coldspot	Outside	479	64
			MAMMALS	
Hot1	Hotspot	Outside	7	6
Hot2	Hotspot	Inside	44	10
Hot3	Hotspot	Inside	19	8
Hot4	Hotspot	Outside	1	1
Cold1	Coldspot	Outside	21	7
Cold2	Coldspot	Inside	54	8
Cold3	Coldspot	Inside	21	4
Cold4	Coldspot	Outside	26	6

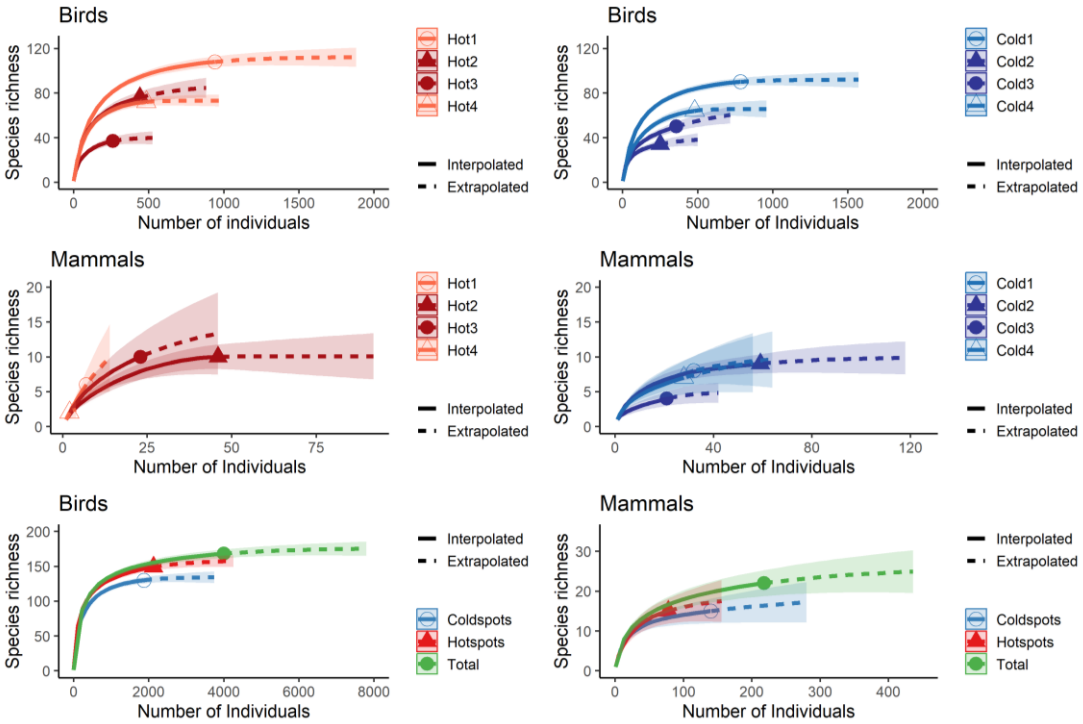

Figure 4. Rarefaction curve for mammals and birds records around highways at Chapada Diamantina National Park (PNCD), demonstrating roadkill hotspots and coldspots. Colors: red and dark blue: transects inside PNCD; orange and light blue: transects outside PNCD.

In general, the rarefaction curve for hotspots and coldspots demonstrated that the areas were efficiently sampled. Birds showed greater abundance (W = 3400, p-value = 0.4958) and richness (W = 3687, p-value = 0.09641) in the areas surrounding hotspots, but it was not significant. For mammals, we recorded more species in coldspots areas, without significant difference (W = 936, p-value = 0.09557), and we found significant differences between the abundance of hotspots and coldspots areas (W = 890.5, p-value = 0.04664), with more records for coldspots (Figure 5).

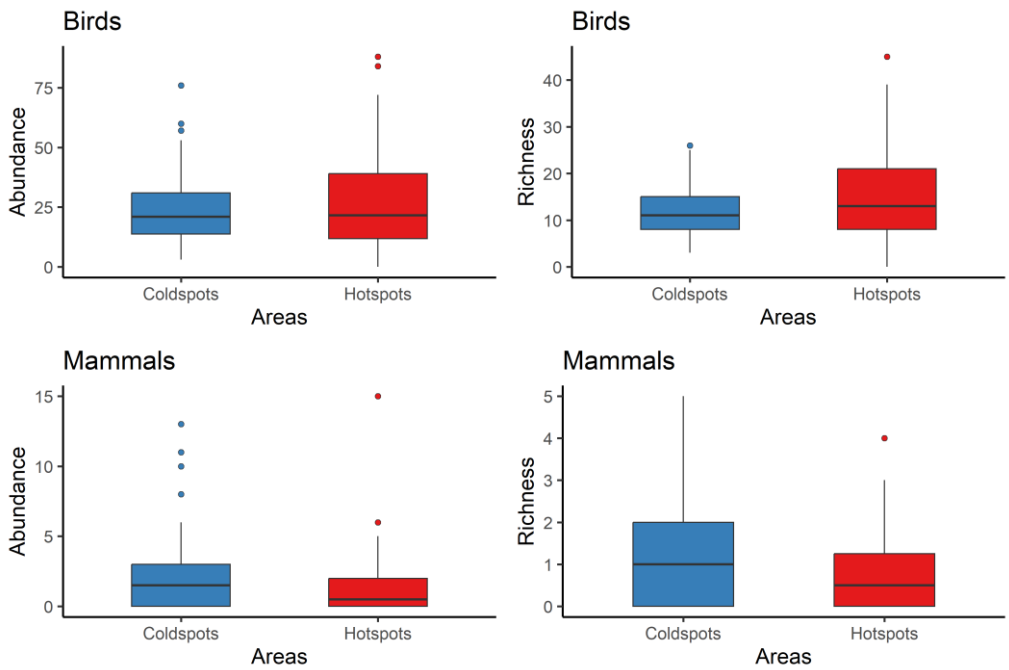

Figure 5. Difference for abundance and species richness between hotspots and coldspots roadkill areas around highways on the Chapada Diamantina National Park.

All the best models from bird trophic levels showed Farming. The carnivore birds best model has positive relation with Distance and Farming, and negative influence of Grassland, all variables are significative. The herbivore birds has only Farming in the best model, with positive and significative relation. Omnivore birds have Faming and Forest with positive relation, and significant influence of Forest. Mammals, we obtained different variables in the best models. Carnivore mammals has significative differences between Groups (Hotspots: min. = 0.00; mean = 0.37; max. = 3.00; Coldspots: min. = 0.00; Mean = 1.12; max. = 8.00), showing more omnivores individuals in coldspots, and includes Savanna, with negative relation. To herbivores mammals only Farming is present in the best model, with significative and negative relation. Omnivores mammals has only Savanna in the best model, with negative and significative relation.

Table 3. Best models about the influence of landscape and distance to birds and mammals around the highways at Chapada Diamantina National Park. SE: Standard Error. GroupHot: Variable hotspots and coldspots, wherein the GLMM considered coldspots as reference.

Group	Trophic level	Variables	Estimate	SE	z value	p value
Birds	Carnivore	(Intercept)	1.54713	0.17371	8.906	< 0.000005
		Distance	0.51847	0.22065	2.35	0.018786
		Grassland	-0.09824	0.02576	-3.814	0.000137
		Farming	0.06104	0.01284	4.755	< 0.000005
	Herbivore	(Intercept)	0.94081	0.10571	8.9	< 0.000005
		Farming	0.06712	0.01351	4.968	< 0.000005
	Omnivore	(Intercept)	2.13	0.07892	26.991	< 0.000005
		Forest	0.03285	0.02103	1.563	0.118
		Farming	0.05968	0.00961	6.211	< 0.000005
Mammals	Carnivore	(Intercept)	0.9535	0.65567	1.454	0.14588
		GroupHot	-1.46518	0.46965	-3.12	0.00181
		Savanna	-0.00511	0.00296	-1.722	0.08499
	Herbivore	(Intercept)	-0.57725	0.41236	-1.4	0.1615
		Farming	-0.01388	0.00653	-2.127	0.0334
	Omnivore	(Intercept)	0.16383	0.98625	0.166	0.86806
		Savanna	-0.01417	0.0053	-2.676	0.00745

DISCUSSION

Roadkill affects less than a third of bird species but affects half of the mammal species that occur around PNCD highways. The rarefaction curve indicates that bird and mammal roadkill hotspots have greater species richness than coldspots. However, the greater abundance of mammals in coldspots is significant. Contrary to what was expected, only carnivorous birds are influenced by the distance from the highway. For the other groups of birds and mammals, the characteristics of the landscape are more important.

The great number of bird species near highways can be explained to the bird diversity in the Chapada Diamantina region. Was expected record a great number of bird species around the highways because the region has a great number of bird species and is a good region to birdwatch (Parrini et al. 1999; Goes-Coelho et al. 2008; Anjos et al. 2019). Furthermore, the low record of species roadkill compared to occurrences around the highways can be explained by the noise avoidance effect. Noise avoidance is the effect of animals avoiding roads because of noise, light or pollutants, and species with high noise avoidance will avoid highways and stay more distant to the highway (Jaeger et al. 2005).

The richness of roadkill mammals and near highways is similar. Probably this occurs because it is common mammals use the roads (Hill et al. 2021). For medium and large mammals, the roads are not a great obstacle to be overcome (Saklaurs and Baltmanis 2014). Some factors influencing mammals to use roads, as deposition of anthropogenic food by the traffic, facility to foraging, roadkill can provide food to many species, facility to travel because are less obstacles, and others (Hill et al. 2021). Species with grater home-ranges, as medium and large mammals, have more chance to cross highways more times and this increases the risk to roadkill (Peter et al. 2013).

For both birds and mammals, the roadkill hotspots are more richness. This result was expected because the roadkill hotspots are areas with high roadkill index, while roadkill coldspots are areas without roadkill. So, the points with more roadkill have more chance to be more richness than points without roadkill.

Although the richness was greater on hotspots, the abundance of mammals around the highway is higher on coldspots areas. This result was not expected because commonly species with large populations around the highways have more chance to be roadkill (Medrano-Vizcaíno et al. 2022). With this, probably the mammal coldspots has more resources to mammals, which contributes to support more animals, and in this way fewer animals try cross the highway looking for food or other resource. Therefore, more research it is necessary to available environments around hotspots and coldspots, looking for food availability or hiding place.

Bird groups showed different variables influencing the species around the highways, but Farming is present in all bird models, and Distance is present only to carnivorous birds. To carnivorous birds, the greater distance to the highway, more Farming and less Grassland, increase the abundance. May be this occur because carnivores need more open areas, as Farming, to see they prey. Furthermore, Farming area can be more heterogenous, with crops and grasses, and can attract more preys. Additionally, birds can adjust their vehicle avoidance according to speed limit, and fly away from the highway (Husby and Husby 2014), and the road noise can influence the reduction of birds around the highways because affected negatively the communication network, and reduce biodiversity near highways (Grade and Sieving 2016), and this reduce the number of prays to carnivores.

Although herbivorous and omnivorous birds are most associated with collisions (Grilo et al. 2020), we do not find relationship between these groups with highway distance. Herbivore birds are related only to Farming class, and this can be explained because these areas are composed by pasture and many crops. As environmental heterogeneity can increase the richness (Stein et al. 2014), we believe that herbivore birds are more related to Farming because these areas have more food diversity, and birds access these resources easily.

Omnivore birds are associated with Forest and significantly associated to Farming. The increase of habitat heterogeneity can increase the richness (Stein et al. 2014), and can be good to generalist animals, as omnivores. As omnivorous birds consume a greater variety of food, this result demonstrates that the environment is more important than the distance of the highway. Omnivorous birds are more recorded in transition areas between forest and other habitats, because the group is less sensitive to forest fragmentation (Betiol et al. 2023), and these omnivorous birds are associated with Forest and Farming.

In general, mammals are not influenced by the distance of highway. Carnivorous and omnivorous mammals are negatively associated with Savanna, and herbivorous mammals are negatively associated to Farming. The absence of Distance from highway was expected because mammals commonly use roads to move (Hill et al. 2021).

The negative association between herbivorous mammals and anthropogenic areas, as Farming, was expected. Pasture areas had the lowest mammal's richness, wherein demonstrates the importance to maintenance native forests (Dotta and Verdade 2011). Thus, the negative association with Farming, can demonstrate the importance to preserve natural fragments as corridor for mammals (Bovo et al. 2018). Therefore, a landscape more heterogeneity with natural patches can be more important to support high mammalian biodiversity (Piña et al. 2019).

The negative relation between carnivorous and omnivorous mammals with Savanna can be related to structural variables and dietary preference. Sometimes mammals can be more abundant in homogeneous areas, with fewer transitions between landscape classes (Piña et al. 2019). Some species use open and anthropic areas because it is easier to move (Dickie et al. 2019), and possibly mammals are using more dirt road than natural areas to move. Carnivorous mammals persist in small forest remnants, where they find more small-sized vertebrates to consumption (Magioli et al. 2021).

CONCLUSION

Although the roadkill rates can reflect the species surrounding area (Konzen et al. 2024), this can be different for taxonomic groups. Mammals, commonly use roads to move and the species richness roadkill and surrounding highways were similar, but this do not occur to birds. This reinforces the necessity to study and understand the highway impacts separately for each taxonomic group.

Since mammal coldspots have significantly more animals than hotspots, it is suggested that these environments be evaluated on a microscale. It is necessary to analyze more than landscape classes and understand what resources are found in these environments. Perhaps the availability of shelter, variety of food, and ease of movement are more important than the landscape class.

The distance from the highways is not important for all groups. Thus, reinforce the necessity to understand the highways impacts for taxonomic groups and for detailed for functional groups. The use of highways and surrounding areas can change with habits, such as diet.

We indicate that the future works understand the environment around the highways, because this can explain more about the impact of the highways on species. Furthermore, we emphasize the need to study the impacts of highways separately for functional groups, considering the characteristics of the species of each group.

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CONCLUSÕES GERAIS

Considerando a grande quantidade de Unidades de Conservação (UCs) na área de influência direta das rodovias e a ausência de trabalhos em diversas dessas UCs, torna-se urgente a ampliação de estudos que foquem no efeito das rodovias em UCs. No entanto, é preciso ir além do efeito direto do atropelamento de animais silvestres e utilizar outras abordagens, como a avaliação custo de colisões, o uso de DNA, a influência na fauna que vive no entorno das rodovias, entre outras. Além disso, é preciso que os gestores de UCs tenham mais envolvimento com esses trabalhos, pois assim poderão pensar medidas mitigadoras eficientes para cada área.

Ao observar os atropelamentos no entorno do Parque Nacional da Chapada Diamantina, uma UCs de grande relevância para a conservação da biodiversidade, reafirmamos que embora existam padrões temporais e espaciais, eles podem variar entre os grupos taxonômicos. Apesar da distribuição temporal ser importante para anfíbios e répteis, aumentando a riqueza e abundância dos atropelamentos em período chuvoso, o mesmo não acontece para aves e mamíferos. O turismo não se mostrou relevante na distribuição temporal quando analisamos as estações de alta e baixa temporada. Por isso, acreditamos que análises mais refinadas, focando nas datas dos eventos regionais fornecer uma melhor perspectiva do impacto das rodovias em relação à movimentação turística da região.

Quanto aos *hotspots* de atropelamentos, encontramos o mesmo que outros trabalhos: a distribuição espacial varia conforme o grupo taxonômico. No entanto, há *hotspots* de atropelamentos que coincidem entre alguns grupos. Assim, é preciso que a análise espacial seja refinada para cada grupo taxonômico, além de observar a área e o comportamento de cada grupo para tomar decisões. Em áreas com sobreposição de *hotspots* de atropelamentos pode-se estudar a viabilidade de instalação de medidas generalistas que atendam mais de um grupo. Descobrimos também que a maioria desse *hotspots* de atropelamentos estão fora da área do PNCD, o que acreditamos ser um bom indicativo da eficiência da UC em manter a fauna na área de proteção. Nesse sentido, a análise do uso do solo pode ajudar a compreender melhor esse efeito na fauna atropelada e no entorno das rodovias.

Embora a paisagem possa ser de grande importância para compreender os padrões de distribuição espacial, a distância das rodovias também deve ser utilizada para estudar a fauna que ocorre no entorno das rodovias. A análise dos grupos funcionais, demonstrou que mesmo dentro de um grupo taxonômico pode ocorrer variação de variáveis que influenciam a ocorrência de espécies no entorno das rodovias. Também verificamos que nem sempre a distância da rodovia é uma variável decisiva. Aqui encontramos influência da distância apenas para as aves carnívoras,

enquanto a paisagem foi mais importante para outros grupos de aves e mamíferos. Com isso, reforçamos não somente a necessidade de compreender a influência da paisagem e da distância da rodovia, mas também do habitat local. Acreditamos que analisar os recursos fornecidos pelas áreas no entorno das rodovias possa auxiliar na compreensão da influência das rodovias na fauna.

Por fim, sugerimos que os trabalhos em UCs sejam incentivados para mitigar os problemas nessas áreas que são de grande relevância para a proteção da fauna brasileira. Reforçamos os cuidados ao definir *hotspots* de atropelamentos e incentivamos que novos trabalhos realizem essas análises considerando traços funcionais relevantes para cada área de estudo. Além disso, enfatizamos que os gestores de UCs devem se envolver mais nas pesquisas, pois acreditamos que esse é um fator crucial para a mitigação dos atropelamentos nessas áreas.

Quanto à gestão do PNCD, sugerimos que se atentem aos resultados de modo que possam utilizá-lo para elaborar medidas de mitigação no entorno da UC. Os resultados da tese podem servir como ponto de partida para indicar áreas de instalação de medidas e, se possível, o monitoramento da eficiência das medidas selecionadas para cada grupo taxonômico. Ainda, podem usar as áreas de *hotstpots* para estudos de influência das rodovias no PNCD, bem como utilizar os dados de amostragem realizados por outros pesquisadores sobre cada grupo taxonômico dentro do PNCD para comparar com os atropelamentos, por exemplo.

MATERIAL DE DIVULGAÇÃO

A seguir os materiais criados para divulgação dos resultados da tese. Eles foram apoiados por empresas e órgãos da região da Chapada Diamantina e distribuído aos moradores, guias e turistas. Ressaltamos a importância da produção desse material, pois permitem que a sociedade seja informada das pesquisas realizadas na região, além de terem conhecimento sobre os diferentes problemas ambientais que possam ocorrer no parque e no entorno. Encorajamos que essas atividades sejam realizadas por futuros pesquisadores, pois poderá aproximar a sociedade da academia.

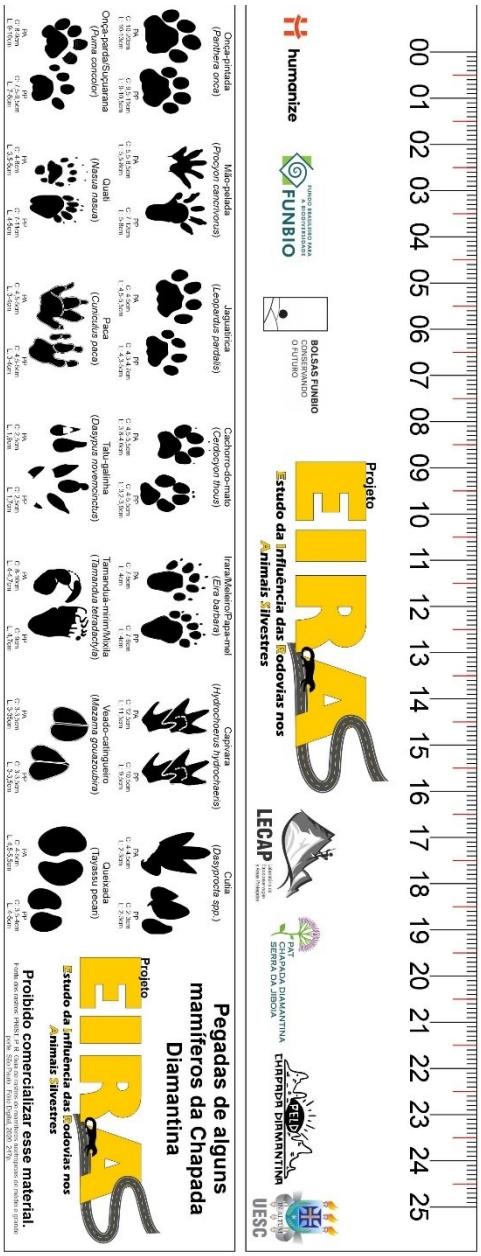
Criamos o material descrito na seguinte lista:

1. Régua com pegadas de espécies registradas na região: Material 1.

2. Panfleto sobre fauna atropelada: Material 2 e Material 3.
   2.1. Link de acesso para o modelo digital:
   https://drive.google.com/file/d/1NVmx7Q7AZ4OQYnIXLCorJqrcD0gXrCTD/view?usp=sharing
   2.2. Link de acesso para o modelo impresso:
   https://drive.google.com/file/d/16OY-FgBItpQR8p7s5f9PHKECJHJqp1U0/view?usp=sharing

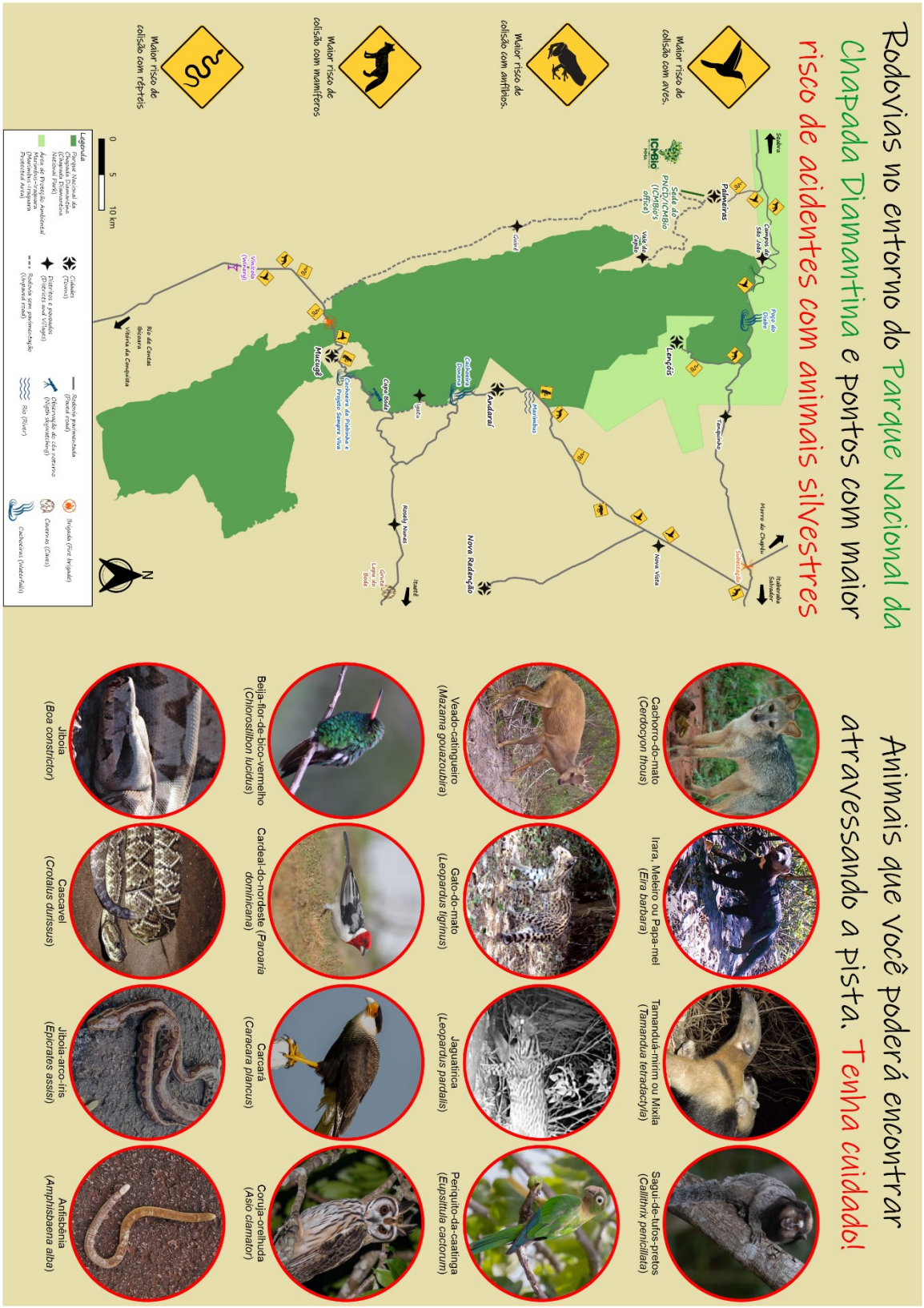
3. Panfleto sobre aves da Chapada Diamantina: Material 4 e Material 5.
   3.1. Link de acesso ao panfleto digitalizado:
   https://drive.google.com/file/d/1Jj0cXM3Cy6Yo41u54fbD3shf3hd3hMzN/view?usp=drive_link

4. Panfleto sobre mamíferos da Chapada Diamantina: Material 6 e Material 7.
   4.1. Link de acesso ao panfleto digitalizado:
   https://drive.google.com/file/d/1sl6mvkW8V1S9lQF9kyuRoDXpOVaIg-TX/view?usp=drive_link



Material 1. Régua com pegadas de espécies registradas na região. Esse material foi distribuído para guias de Andaraí, Lençóis e Mucugê.

Material 2. Parte externa do panfleto sobre fauna atropelada distribuído na região da Chapada Diamantina. Material teve apoio oficial da gestão do Parque Nacional da Chapada Diamantina.



Material 3. Parte interna do panfleto sobre fauna atropelada distribuído na região da Chapada Diamantina. Material teve apoio oficial da gestão do Parque Nacional da Chapada Diamantina.

As informações aqui apresentadas são parte dos resultados de pesquisas em andamento na Chapada Diamantina, por meio de um Programa de Pesquisas Ecológicas de Longa Duração (PELD) realizado por universidades públicas da Bahia. Aqui, são destacadas algumas espécies de aves encontradas no Parque Nacional da Chapada Diamantina (PNCD) e no seu entorno.

Entre 2022 e 2023, foi realizado um levantamento dos animais atropelados nas estradas, assim como de aves presentes nas proximidades dessas rodovias, culminando neste material. Neste panfleto, os leitores terão a oportunidade de conhecer um pouco mais sobre algumas espécies de aves que podem ser avistadas tanto em trilhas quanto nas rodovias circundantes ao PNCD.

No folheto, são destacadas 48 espécies de aves, mas registramos mais de 160 espécies durante a pesquisa. Contudo, vale mencionar que outras espécies relevantes e que não foram ilustradas nesse material também foram identificadas, como *Mimus saturninus* (sabiá-do-campo), *Passer domesticus* (pardal), *Asio clamator* (coruja-orelhuda), *Sicalis flaveola* (canário-da-terra). Os leitores conhecerão o estado de conservação das espécies, o sexo do indivíduo fotografado, se a espécie é endêmica da Chapada Diamantina (ou seja, se ocorre apenas aqui) e a ocorrência por bioma (sendo que a ocorrência no bioma não indica que a ave ocorra em todo aquele bioma marcado).

'The information presented here is part of the results of research in Chapada Diamantina, through a Long-Term Ecological Research Program (PELD) carried out by public universities in Bahia. Here some species of birds found in the Chapada Diamantina National Park (PNCD) and its surroundings are highlighted.

Between 2022 and 2023, a survey of animals run over on roads was carried out, as well as birds present in the vicinity of these highways, culminating in this material. In this pamphlet, readers will have the opportunity to learn a little more about some birds that can be seen on trails or highways surrounding the PNCD.

The leaflet highlights 48 species of birds, but more than 160 species were recorded during the research. However, it is worth mentioning that other relevant species that were not illustrated in this material were also identified, such as Mimus saturninus (Chalk-browed Mockingbird), Passer domesticus (House Sparrow), Asio clamator (Striped Owl), Sicalis flaveola (Saffron Finch). Readers will learn about the conservation status of the species, the sex of the individual photographed, whether the species is endemic to Chapada Diamantina (i.e., whether it only occurs here) and the occurrence by biome (whereas the occurrence in the biome does not indicate that the bird occurs throughout that marked biome).'

Não percorra trilhas sozinho! Sempre busque o apoio de um condutor local. Há dois condutores que participaram da produção desse material e poderão te ajudar.

Do not walk the trails alone and always seek the support of a local guide. There are two guides who participated in the production of this material and will be able to help you.

Contato/Contact: @luciocvmoraes / @r_thalison

Como ler e interpretar o material

Estado de conservação no Brasil (Conservation status in Brazil)

EW: Extinta na natureza (Extinct in the wild)
CR: Criticamente ameaçada (Critically Endangered);
EN: Em perigo (Endangered)
VU: Vulnerável (Vulnerable);
NT: Quase ameaçada (Near threatened);
LC: Pouco preocupante (Least concern);
NE: Não está ameaçada (Not threatened).

Mapa de ocorrência por bioma (Biome occurrence map)

- Amazônia (Amazon Forest)
- Caatinga (Caatinga)
- Pantanal (Wetland)
- Cerrado (Brazilian Savannah)
- Pampa (Pampa)
- Mata Atlântica (Atlantic Forest)

Ocorre apenas na Chapada Diamantina
(Only occurs in Chapada Diamantina)

Sexo (Sex)

Macho (Male): ♂ Fêmea (Female): ♀

Macho e fêmea são iguais (Male and Female are equal): ♂♀

Mais informações (more information): Wiki Aves.
https://www.wikiaves.com.br/wiki/areas:pn_da_chapada_diamantina:inicio

Veja também os App's(See too the Apps): 'Merlin'; 'iNaturalist'.

Veja Lista Nacional de Espécies Ameaçadas aqui (See National List of Threatened Species): Portaria MMA Nº 148, de 7 de Junho de 2022.

APOIO

LECAP · UESC · PPG Ecologia & Conservação (Universidade Estadual de Santa Cruz) · LEBI Laboratório de Evolução e Biogeografia · Fazenda Marimbus · humanize · BOLSAS FUNBIO CONSERVANDO O FUTURO · FUNDO BRASILEIRO PARA A BIODIVERSIDADE FUNBIO · Prefeitura LENÇÓIS · ANDARAÍ · Pousada Casa da Geleia · PAT CHAPADA DIAMANTINA SERRA DA JIBOIA

Aves da Chapada Diamantina, Bahia

(Birds from Chapada Diamantina, Bahia)

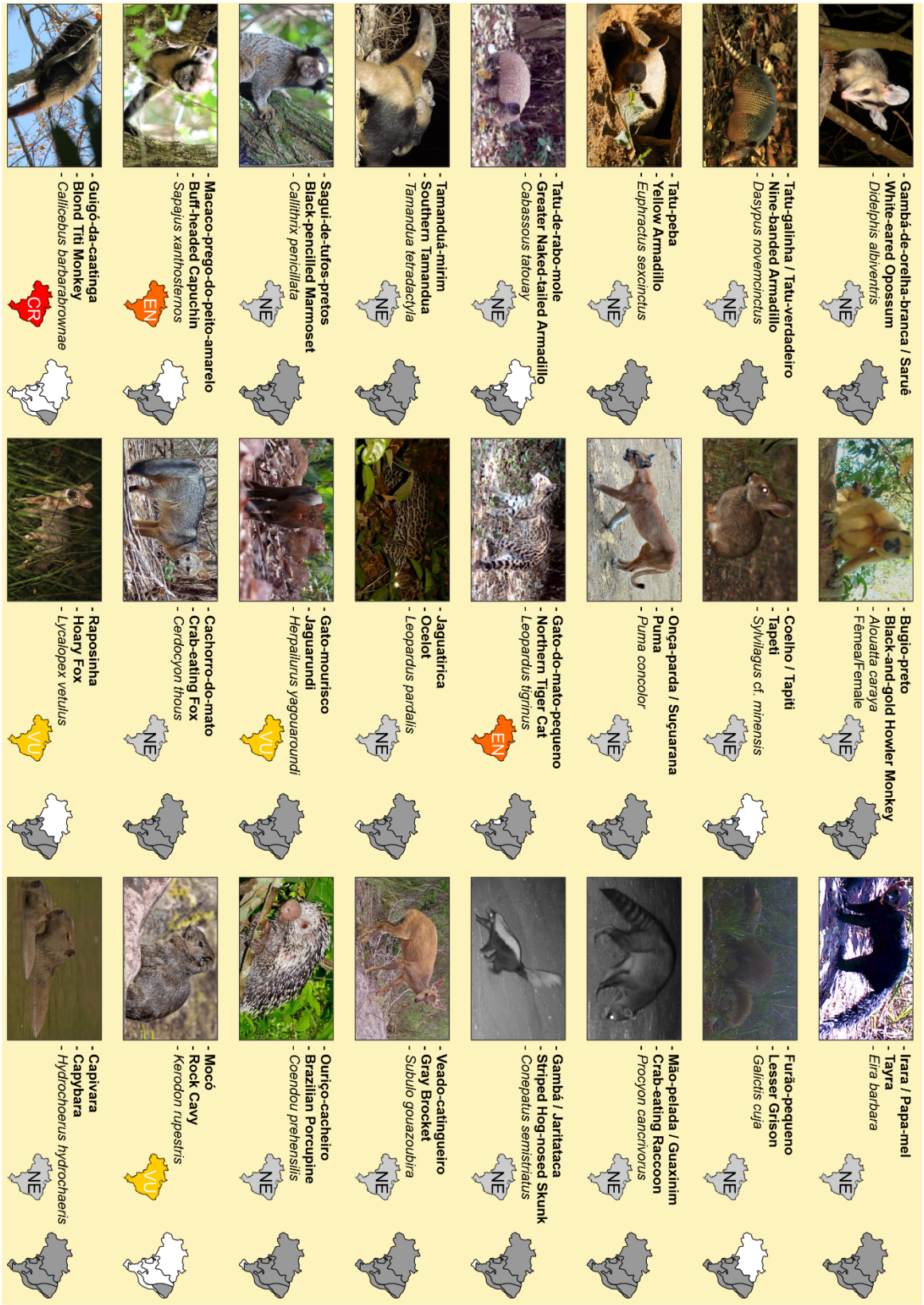
Foto: Thalison Ribeiro (@r_thalison)

Organização
Jefferson Eduardo Silveira Miranda (UESC)
Sidnei Sampaio dos Santos (UFBA)
Thiago Nascimento Zanetti (UFBA)
Henrique Batalha Filho (UFBA)
Maisa Alves (UFBA)
Marcel Silva Lemos (UFRB)
Lúcio Costa Vieira de Moraes (Condutor/Lençóis)
Thalison da Silva Ribeiro (Condutor/Mucugê)
Alexandre Schiavetti (UESC)

Projeto EIRAS – Estudo da Influência das Rodovias nos Animais Silvestres · PELD Chapada Diamantina

Material 4. Parte externa do panfleto sobre avifauna na região da Chapada Diamantina.

Material 5. Parte interna do panfleto sobre avifauna na região da Chapada Diamantina**.**



Material 6. Parte interna do panfleto sobre mastofauna na região da Chapada Diamantina**.**

As informações aqui apresentadas são parte dos resultados de pesquisas em andamento na Chapada Diamantina, por meio de um Programa de Pesquisas Ecológicas de Longa Duração (PELD) realizado por universidades públicas da Bahia. Aqui, são destacadas algumas espécies de mamíferos encontradas no Parque Nacional da Chapada Diamantina (PNCD) e no seu entorno.

Entre 2022 e 2023, foi realizado um levantamento dos animais atropelados nas estradas, assim como dos mamíferos de médio e grande porte presentes nas proximidades dessas rodovias, culminando neste material. Neste panfleto, os leitores terão a oportunidade de conhecer um pouco mais sobre algumas espécies de mamíferos que podem ser avistadas tanto em trilhas quanto nas rodovias circundantes ao PNCD.

No folheto, são destacadas 24 espécies de mamíferos de médio e grande porte registradas durante o monitoramento. Contudo, vale mencionar que outras espécies relevantes e que não foram ilustradas nesse material também foram identificadas, como *Cuniculus paca* (paca), *Dasyprocta prymnolopha* (cutia) e *Tayassu pecari* (queixada). Os leitores poderão conhecer o status de conservação das espécies apresentadas, assim como à sua distribuição por bioma.

The information presented here is part of the results of research carried out in Chapada Diamantina, through a Long-Term Ecological Research Program (PELD) carried out by public universities in Bahia. Here, some species of mammals found in the Chapada Diamantina National Park (PNCD) and its surroundings are highlighted.

Between 2022 and 2023, a survey was carried out of animals run over on roads, as well as medium and large mammals present in the vicinity of these highways, culminating in this material. In this pamphlet, readers will have the opportunity to learn a little more about some species of mammals that can be seen both on trails and on highways surrounding the PNCD.

This pamphlet highlights 24 species of medium and large mammals recorded during monitoring. However, it is worth mentioning that other relevant species that were not illustrated in this material were also identified, such as Cuniculus paca (paca), Dasyprocta prymnolopha (agouti) and Tayassu pecari (peckerel). Readers will be able to learn about the conservation status of the species presented, as well as their distribution by biome.

Como ler e interpretar o guia

Nomes comuns
Common name
Nome científico (Scientific name)

Estado de conservação no Brasil (Conservation status in Brazil)

EW: Extinta na natureza (*Extinct in the wild*)
CR: Criticamente ameaçada (*Critically Endangered*);
EN: Em perigo (*Endangered*)
VU: Vulnerável (*Vulnerable*);
NT: Quase ameaçada (*Near threatened*);
LC: Pouco preocupante (*Least concern*);
NE: Não está ameaçada (*Not threatened*).

Mapa de ocorrência por bioma (*Biome occurrence map*)

Amazônia (*Amazon Forest*)
Caatinga (*Caatinga*)
Pantanal (*Wetland*)
Cerrado (*Brazilian Savannah*)
Pampa (*Pampa*)
Mata Atlântica (*Atlantic Forest*)

Áreas cinzas indicam a ocorrência da espécie em alguma parte daquele bioma e não em todo o bioma. Ex.: (*Gray areas indicate the occurrence of the species in some part of the biome. Ex.:*)

Mamíferos da Chapada Diamantina

(Mammals from Chapada Diamantina)

Foto: Jefferson E. S. Miranda

Organização
Jefferson Eduardo Silveira Miranda (UESC)
Sidnei Sampaio dos Santos (UFBA)
Luciano Fires Guedes Pereira (Condutor/Mucugê)
Thalison da Silva Ribeiro (Condutor/Mucugê)
Francielly Reis (Bióloga)
Thiago Barbosa da Silveira (Biólogo)
Igor Pfeifer Coelho (Biólogo)
Alexandre Schiavetti (UESC)

APOIO

Projeto EIRAS — Estudo da influência das rodovias nos Animais Silvestres

PELD CHAPADA DIAMANTINA

Material 7. Parte interna do panfleto sobre mastofauna na região da Chapada Diamantina

APÊNDICE

APÊNDICE I - MATERIAL SUPLEMENTAR DO CAPÍTULO 1

Table S1. 126 studies that surveyed wildlife roadkill in Brazil, organized per year of publication. Citation = Citation of the paper. Title = Title of paper. Year = year of publication of the paper. Group = group studied in the paper. Biome = Biome of the study. PAs = PAs within 1 km radius of the surveyed roads. Journal = Journal where the research was published.

Citation	Year	Title	Group	Biome	PAs	Journal
Novelli et al. (1988)	1988	Estudo das aves mortas por atropelamento em um trecho da rodovia BR-471, entre os distritos da Quinta e Taim, Rio Grande do Sul, Brasil	Birds	Pampa	1	Revista Brasileira de Zoologia
Rosa and Maush (2004)	2004	Atropelamento de animais na rodovia RS-40	All groups	Pampa	0	Caderno de Pesquisa - Série Biologia
Pereira et al. (2006)	2006	Dois anos de monitoramento dos atropelamentos de mamíferos na rodovia PA-458, Bragança, Pará	Mammals	Amazonia	0	Bol. Mus. Para. Emílio Goeldi
Prado et al. (2006)	2006	Efeito da implantação de rodovias no cerrado sobre a fauna de vertebrados	All groups	Cerrado	1	Acta Scientiarum - Biological Sciences
Mili and Passamani (2006)	2006	Impacto da Rodovia Josil Espíndula Agostini (ES-259) sobre a mortalidade de animais silvestres (Vertebrata) por atropelamento	All groups	Atlantic Forest	1	Natureza online
Tumeleiro et al. (2006)	2006	Notas sobre mamíferos da região de Uruguaiana: estudo de indivíduos atropelados com informações sobre a dieta e conservação	Mammals	Pampa	1	Biodiversidade Pampeana
Melo and Santos-Filho (2007)	2007	Efeitos da BR-070 na Província Serrana de Cáceres, Mato Grosso, sobre a comunidade de vertebrados silvestres	All groups	Cerrado	0	Revista Brasileira de Zoociências
Cherem et al. (2007)	2007	Mamíferos de médio e grande porte atropelados em rodovias do Estado de Santa Catarina, sul do Brasil	Mammals	Atlantic Forest	2	Biotemas
Silva et al. (2007)	2007	Road kills impact over the herpetofauna of Atlantic Forest	Amphibians	Atlantic	1	Acta Biológica

		(PR-340, Antonina, Paraná)	and reptiles	Forest		Paranaense
Miranda et al. (2008)	2008	Contribuição ao conhecimento dos mamíferos dos Campos de Palmas, Paraná, Brasil	Mammals	Pampa	0	Biotemas
Hengemühle and Cademartori (2008)	2008	Levantamento de mortes de vertebrados silvestres devido a atropelamento em um trecho da estrada do mar (RS-389)	All groups	Pampa	0	Biodiversidade Pampeana
Coelho et al. (2008)	2008	Roadkills of vertebrate species on two highways through the Atlantic Forest Biosphere Reserve, southern Brazil	Except amphibian	Atlantic Forest	2	European Journal of Wildlife Research
Gumier-Costa and Sperber (2009)	2009	Atropelamentos de vertebrados na Floresta Nacional de Carajás, Pará, Brasil	All groups	Amazonia	1	Acta Amazonica
Zaleski et al. (2009)	2009	Run-over of wild mammals in the area of Telêmaco Borba, Paraná, Brazil	Mammals	Atlantic Forest	0	Natureza & Conservação
Kunz and Ghizoni (2009)	2009	Serpentes encontradas mortas em rodovias do estado de Santa Catarina, Brasil	Snakes	Atlantic Forest	1	Biotemas
Turci and Bernarde (2009)	2009	Vertebrados atropelados na rodovia estadual 383 em Rondônia, Brasil	All groups	Amazonia	0	Biotemas
Meneguetti et al. (2010)	2010	Georreferenciamento e avaliação da mortalidade por atropelamento de animais silvestres na linha 200 entre os municipios de Ouro Preto do Oeste e Vale do Paraíso – RO.	All groups	Amazonia	0	Revista Científica FAEMA
Cáceres et al. (2010)	2010	Mammal occurrence and roadkill in two adjacent ecoregions (Atlantic Forest and Cerrado) in South-Western Brazil"	Mammals	Cerrado, Pantanal, Atlantic forest	2	Zoologia (Curitiba)
Bager and Rosa (2010)	2010	Priority ranking of road sites for mitigating wildlife roadkill	Except amphibian	Pampa	0	Biota Neotropica
Cunha et al. (2010)	2010	Roadkill of wild vertebrates along the GO-060 road between Goiânia and Iporá, Goiás State,	All groups	Cerrado	1	Acta Scientiarum - Biological Sciences

		Brazil				
Bueno and Almeida (2010)	2010	Sazonalidade de atropelamentos e os padrões de movimentos em mamíferos na BR-040 (Rio de Janeiro-Juiz de Fora)	Mammals	Atlantic Forest	5	Revista Brasileira de Zoociências
Ramos et al. (2011)	2011	A biologia e a ecologia das aves é um fator importante para explicar a frequência de atropelamentos?	Birds	Atlantic Forest	1	Neotropical Biology and Conservation
Cáceres (2011)	2011	Biological characteristics influence mammal road kill in an Atlantic Forest–Cerrado interface in south-western Brazil	Mammals	Cerrado, Pantanal, Atlantic forest	2	Italian Journal of Zoology
Freitas and Araujo (2011)	2011	Ecological data on road killed Amphisbaena alba linnaeus, 1758 (Squamata, Amphisbaenidae) in southeast Brazil	Specific species	Cerrado	1	The Herpetological Bulletin
Bager and Rosa (2011)	2011	Influence of sampling effort on the estimated richness of road-killed vertebrate wildlife	Except amphibian	Pampa	1	Environmental Management
Costa (2011)	2011	Levantamento de mamíferos silvestres de pequeno e médio porte atropelados na BR 101, entre os municípios de Joinville e Piçarras, Santa Catarina	Mammals	Atlantic Forest	0	Bioscience Journal
Hartmann et al. (2011)	2011	Snake road mortality in a protected area in the Atlantic Forest of southeastern Brazil	Snakes	Atlantic Forest	3	South American Journal of Herpetology
Silva et al. (2011)	2011	O impacto das rodovias sobre a fauna de vertebrados silvestres no Cerrado mineiro	All groups	Cerrado	1	Enciclopédia Biosfera
Coelho et al. (2012)	2012	Anuran road-kills neighboring a peri-urban reserve in the Atlantic Forest, Brazil	Anurans	Atlantic Forest	1	Journal of Environmental Management
Paes and Povaluk (2012)	2012	Atropelamento de animais silvestres na rodovia federal BR-116, trecho administrado pela concessionária autopista planalto sul	All groups	Atlantic Forest	1	Saúde e meio ambiente: revista interdisciplinar

Omena Jr. et al. (2012)	2012	Caracterização da fauna de vertebrados atropelada na rodovia BR 174, Amazonas, Brasil	All groups	Amazonia	2	Revista Colombiana de Ciência Animal
Rosa and Bager (2012)	2012	Seasonality and habitat types affect roadkill of neotropical birds	Birds	Pampa	1	Journal of Environmental Management
Santana (2012)	2012	Fatores influentes sobre atropelamentos de vertebrados na região central do Rio Grande do Sul, Brasil	All groups	Atlantic Forest	0	Neotropical Biology and Conservation
Bager and Rosa (2012)	2012	Impacto da rodovia BR-392 sobre comunidades de aves no extremo sul do Brasil	Birds	Pampa	1	Revista Brasileira de Ornitologia
Düpont and Lobo (2012)	2012	Levantamento da fauna silvestre atropelada na Avenida Felisberto Bandeira de Moraes, Santa Cruz do Sul, RS, Brasil	All groups	Pampa	0	Caderno de Pesquisa - Série Biologia
Hegel et al. (2012)	2012	Mamíferos silvestres atropelados na rodovia RS-135 e entorno	Mammals	Atlantic Forest	1	Biotemas
Ferreira and Silva-Soares (2012)	2012	Road mortality of snakes at the Parque Estadual da Fonte Grande, an urban Forest of Southeastern Brazil	Reptiles	Atlantic Forest	3	Boletim do Museu de Biologia Mello Leitão
Caceres et al. (2012)	2012	Variação espacial e sazonal de atropelamentos de mamíferos no bioma cerrado, rodovia BR 262, Sudoeste do Brasil	Mammals	Cerrado	1	Mastozoología neotropical
Santos et al. (2012)	2012	Variação sazonal da fauna selvagem atropelada na rodovia MG 354, Sul de Minas Gerais – Brasil	All groups	Cerrado, Atlantic forest	0	Biotemas
Oliveira and Silva (2012)	2012	Vertebrados silvestres atropelados na BR 158, RS, Brasil	All groups	Atlantic forest, Pampa	0	Biotemas
Teixeira et al. (2013)	2013	Are road-kill hotspots coincident among different vertebrates groups?	Except amphibian	Atlantic Forest	5	Oecologia Australis
Bager and Fontoura	2013	Evaluation of the effectiveness of a wildlife roadkill mitigation	Except	Pampa	1	Ecological

(2013)		system in wetland habitat	amphibian			Engineering
Bueno et al. (2013)	2013	Influence of landscape characteristic on capybara road-kill on highway BR-040, southeastern Brazil.	Specific species	Atlantic Forest	8	Oecologia Australis
Sássi et al. (2013)	2013	Levantamento de animais silvestres atropelados em trecho da rodovia BR482	All groups	Cerrado	0	Arquivo Brasileiro de Medicina Veterinária e Zootecnia
Weiss and Vianna (2013)	2013	Levantamento do impacto das rodovias BR-376, BR-373 e BR-277, trecho de Apucarana a Curitiba, Paraná, no atropelamento de animais silvestres	All groups	Atlantic Forest	3	Publicatio UEPG: Ciências Biológicas e da Saúde
Silva et al. (2013)	2013	Monitoramento de vertebrados atropelados em dois trechos de rodovias na região central do Rio Grande do Sul-Brasil	All groups	Pampa	0	Revista de Ciências Ambientais - RCA
Gomes et al. (2013)	2013	Registro de atropelamento de animais silvestres entre as cidades de Palmeiras de Goiás e Edealina–GO	All groups	Cerrado	0	Interdisciplinar: Revista Eletrônica da Univar
Figueiredo et al. (2013)	2013	Variação da taxa de atropelamento de animais entre rodovias com diferentes tipos de pavimentação e número de pistas.	All groups	Cerrado	10	Revista Heringeriana
Pinheiro and Turci (2013)	2013	Vertebrados atropelados na estrada da Variante (BR-307) , Cruzeiro do Sul, Acre, Brasil	All groups	Amazonia	0	Natureza online
Carvalho et al. (2014)	2014	Fast and furious: a look at the death of animals on the highway MS-080, Southwestern Brazil	All groups	Cerrado	0	Iheringia - Serie Zoologia
Belão et al. (2014)	2014	Incidentes de mamíferos na rodovia BR-277, Paraná – Brasil	Mammals	Atlantic Forest	4	Publicatio UEPG: Ciências Biológicas e da Saúde
Costa and Dias (2013)	2013	Mortalidade de Vertebrados por Atropelamento em um Trecho	Except amphibian	Cerrado	0	Revista de Biotecnologia &

		da GO-164, no Sudoeste Goiano				Ciência
Ferreira et al. (2014)	2014	Variação espacial de atropelamentos de mamíferos em área de restinga no estado do Espírito Santo, Brasil	Mammals	Atlantic Forest	4	Neotropical Biology and Conservation
Cunha et al. (2015)	2015	Atropelamentos de vertebrados em uma área de Pampa no sul do Brasil	All groups	Pampa	0	Revista Ambiência
Preuss (2015)	2015	Composição e caracterização da fauna de mamíferos de médio e grande porte atropelados em trecho da BR-282, oeste do Estado de Santa Catarina	Mammals	Atlantic Forest	0	Unoesc & Ciência - ACBS
Silva-Neto et al. (2015)	2015	Fauna atropelada nas estradas do município de Chapadão do Céu (Goiás, Brasil)	All groups	Cerrado	1	Revista Percurso - NEMO
Bueno et al. (2015)	2015	Habitat or matrix: which is more relevant to predict road-kill of vertebrates?	Except amphibian	Atlantic Forest	7	Brazilian Journal of Biology
Freitas et al. (2015)	2015	How landscape patterns influence road-kill of three species of mammals in the Brazilian Savanna?	Mammals	Cerrado	2	Oecologia Australis
Orlandin et al. (2015)	2015	Mamíferos de médio e grande porte atropelados no Oeste de Santa Catarina, Brasil	Mammals	Atlantic Forest	0	Biota Amazônia
Cherem and Althoff (2015)	2015	Mamíferos de uma área de estepe ombrófila nos estados do Paraná e Santa Catarina, sul do Brasil	Mammals	Atlantic Forest	1	Boletim da Sociedade Brasileira de Mastozoologia
Costa et al. (2015)	2015	Mixed sampling protocols improve the cost-effectiveness of roadkill surveys	Except amphibian	Pampa	1	Biodiversity and Conservation
Souza et al. (2015)	2015	Road mortality of the herpetofauna in a Cerrado ecosystem, central Brazil	Amphibians and reptiles	Cerrado	0	The Herpetological Journal
Machado et al. (2015)	2015	Roadkill on vertebrates in Brazil: seasonal variation and road type comparison	All groups	Cerrado, Atlantic forest	0	North-Western Journal of Zoology

De Freitas et al. (2015)	2015	Road-kills of the giant anteater in south-eastern Brazil: 10 years monitoring spatial and temporal determinants	Specific species	Cerrado, Atlantic forest	3	Wildlife Research
De Souza et al. (2015)	2015	Spatiotemporal variation in human-wildlife conflicts along highway BR-262 in the Brazilian Pantanal	All groups	Pantanal, Cerrado	1	Wetlands Ecology and Management
Carvalho et al. (2015)	2015	Wild vertebrates roadkill aggregations on the BR-050 highway, state of Minas Gerais, Brazil	Except amphibian	Cerrado	0	Bioscience Journal
De Almeida et al. (2016)	2016	Anfíbios & "répteis" atropelados em um trecho da BR-232, no Estado de Pernambuco	Amphibians and reptiles	Caatinga, Atlantic forest	1	Revista Ibero-Americana de Ciências Ambientais
Santos et al. (2016)	2016	Carcass persistence and detectability: reducing the uncertainty surrounding wildlife-vehicle collision surveys	All groups	Cerrado	10	PLoS ONE
Deffaci et al. (2016)	2016	Diversidade de aves, mamíferos e répteis atropelados em região de floresta subtropical no sul do Brasil	Except amphibian	Atlantic Forest	0	Ciência e Natura
Grilo et al. (2016)	2016	Do the size and shape of spatial units jeopardize the road mortality-risk factors estimates?	Specific species	Pampa	1	Perspectives in Ecology and Conservation
Steil et al. (2016)	2016	Levantamento da fauna silvestre atropelada na BR-290 (km 210 a 214), município de Pantano Grande, RS, Brasil	All groups	Pampa	0	Caderno de Pesquisa - Série Biologia
Veras et al. (2016)	2016	Levantamento da fauna silvestre atropelada nas rodovias BR-343 (Município de buriti Dos Lopes) E BR-402 (Município de Parnaíba), Piauí, Brasil	All groups	Caatinga	1	Revista Espacios
Almeida and Cardoso (2016)	2016	Registros de atropelamentos de animais silvestres na Rodovia Civinal Antônio Joaquim de Moura Andrade entre os municípios de Mogi Guaçu-SP e	All groups	Atlantic Forest	0	FOCO: Caderno de Estudos e Pesquisas

		Itapira-SP				
Saranholi et al. (2016)	2016	Roadkill hotspots in a protected area of Cerrado in Brazil: planning actions to conservation	All groups	Cerrado	3	Revista MVZ Cordoba
Maschio et al. (2016)	2016	Road-kills of snakes in a tropical rainforest in the Central Amazon Basin, Brazil	Snakes	Amazonia	0	Journal of Herpetology
Braz and França (2016)	2016	Wild vertebrate roadkill in the Chapada dos Veadeiros National Park, Central Brazil	All groups	Cerrado	2	Biota Neotropica
De Souza et al. (2017)	2017	Animais atropelados em um trecho da rodovia BR-158, região central do Rio Grande do Sul	All groups	Pampa	0	Disciplinarum Scientia. Série: Naturais e Tecnológicas
Santos et al. (2017)	2017	Assessing the consistency of hotspot and hot-moment patterns of wildlife road mortality over time	All groups	Cerrado	10	Perspectives in Ecology and Conservation
Brum et al. (2017)	2017	Effects of roads on the vertebrates diversity of the Indigenous Territory Paresi and its surrounding	All groups	Cerrado	0	Brazilian Journal of Biology
Ciocheti et al. (2017)	2017	Highway widening and underpass effects on vertebrate road mortality	Mammals	Cerrado	2	Biotropica
Carvalho et al. (2017)	2017	Influence of climate variables on roadkill rates of wild vertebrates in the cerrado biome, Brazil	All groups	Cerrado	0	Bioscience Journal
De Oliveira et al. (2017)	2017	Levantamento de Animais Vertebrados Vítimas de Atropelamentos em Trechos das Rodovias MG-223, MG-190 e BR-352	Except amphibian	Cerrado	0	Revista GeTeC
Laurindo et al. (2017)	2017	Mammals in forest remnants of an ecotonal Atlantic Forest-Cerrado area from southeastern Brazil	Mammals	Cerrado, Atlantic forest	0	Neotropical Biology and Conservation
Secco et al. (2017)	2017	Road and landscape features that affect bat roadkills in	Bats	Atlantic	4	Oecologia

		southeastern Brazil		Forest		Australis
Miranda et al. (2017)a	2017	Roadkill in the Brazilian cerrado savanna: Comparing five highways in southwestern Goiás	All groups	Cerrado	0	Oecologia Australis
Ascensão et al. (2017)	2017	Spatial patterns of road mortality of medium–large mammals in Mato Grosso do Sul, Brazil	Mammals	Pantanal, Cerrado	3	Wildlife Research
Rodríguez-Castro et al. (2017)	2017	Using DNA barcode to relate landscape attributes to small vertebrate roadkill	All groups	Cerrado	0	Biodiversity and Conservation
Corrêa et al. (2017)	2017	Vertebrate road kill survey on a highway in southern Brazil	All groups	Pampa	0	Acta Scientiarum - Biological Sciences
Pereira Viturino et al. (2017)	2017	Trilha da Vida Silvestre: um jogo a partir do monitoramento de atropelamento de animais em trecho da Rodovia MS 162	All groups	Cerrado	0	Multitemas
Miranda et al. (2017)b	2017	Levantamento Indireto da fauna por animais atropelados na rodovia MG181: uma proposta de educação ambiental	Except amphibian	Cerrado	0	Humanidades e Tecnologia em Revista
Valadão et al. (2018)	2018	Atropelamentos de vertebrados silvestres em quatro rodovias no Cerrado, Mato Grosso, Brasil	All groups	Cerrado	2	Multi-Science Journal
Guimarães et al. (2018)	2018	Atropelamentos e influência da paisagem na sobrevivência de mamíferos silvestres de médio e grande porte	Mammals	Cerrado	0	Revista Ibero-Americana de Ciências Ambientais
Pereira et al. (2018)	2018	Less impacted or simply neglected? Anuran mortality on roads in the Brazilian semiarid zone	Anurans	Caatinga	0	Journal of Arid Environments
Santos et al. (2018)	2018	Predicting wildlife road-crossing probability from roadkill data using occupancy-detection models	Specific species	Cerrado	10	Science of the Total Environment
Gonçalves et al. (2018)	2018	Reptile road-kills in Southern Brazil: composition, hot moments and hotspots	Reptiles	Pampa	1	Science of The Total Environment

Fischer et al. (2018)	2018	Roadkill records of reptiles and birds in Cerrado and Pantanal landscapes	Birds and reptiles	Pantanal, Cerrado	1	Check List
Zanzini et al. (2018)	2018	Roadkills of medium and large-sized mammals on highway BR-242, Midwest Brazil: a proposal of new indexes for evaluating animal roadkill rates	Mammals	Cerrado	1	Oecologia Australis
Bastos et al. (2018)	2018	Seasonal and spatial variation of road-killed vertebrates on BR-330, Southwest Bahia, Brazil	All groups	Atlantic forest, Caatinga	0	Oecologia Australis
Ramos-Abrantes et al. (2018)	2018	Vertebrados silvestres atropelados na rodovia BR-230, Paraíba, Brasil	All groups	Caatinga	0	PubVet
Calabuig et al. (2019)	2019	Assessment of Rabies and Canine Distemper Viruses in Road-Killed Wildlife Mammals From the Semiarid Region of Northeastern Brazil	All groups	Caatinga	3	Tropical Conservation Science
de Araújo et al. (2019)	2019	Can human demographic or biological factors influence mammal roadkill? A case study in the GO-060 highway	Mammals	Cerrado	1	Oecologia Australis
Carvalho-Roel et al. (2019)	2019	Do roadkill aggregations of wild and domestic mammals overlap?	Mammals	Cerrado	0	Revista de Biologia Tropical
Monteiro-Alves et al. (2019)	2019	Occupancy, detectability, and density of crab-eating fox (Cerdocyon thous) in two protected areas of restinga habitats in Brazil	Specific species	Atlantic Forest	3	Canadian Journal of Zoology
Ascensão et al. (2019)	2019	Predicting spatiotemporal patterns of road mortality for medium-large mammals	Mammals	Pantanal, Cerrado	3	Journal of Environmental Management
Santos and Calvo (2019)	2019	Traffic mammals attraction of the highway MT-358	Mammals	Amazonia	0	Scientific Electronic Archives
Silveira Miranda et al. (2020)	2020	Are roadkill hotspots in the Cerrado equal among groups of vertebrates?	All groups	Cerrado	0	Environmental Management

Araujo et al. (2020)	2020	Efeito da paisagem sobre os atropelamentos de mamíferos de médio e grande porte no sul de Goiás, Brasil	Mammals	Cerrado	0	Oecologia Australis
Soares and Dias (2020)	2020	Look both ways: factors affecting roadkill probability in Blue-black Grassquits (Volatinia jacarina)	Specific species	Cerrado	10	Canadian Journal of Zoology
Paraguassu-Chaves et al. (2020)	2020	Monitoring of Wildlife Mortality on a State Road in Rondônia, Western Amazon	All groups	Amazonia	0	International Journal of Advanced Engineering Research and Science
Ferreguetti et al. (2020)	2020	Roadkill of medium to large mammals along a Brazilian road (BR-262) in Southeastern Brazil: spatial distribution and seasonal variation	Mammals	Atlantic Forest	2	Studies on Neotropical Fauna and Environment
Markwith et al. (2020)	2020	Scale, rank and model selection in evaluations of land cover influence on wildlife–vehicle collisions	Specific species	Pantanal, Cerrado	0	Wildlife Research
Castro et al. (2020)	2020	Atropelamentos de vertebrados em uma área de mata atlântica na rodovia MG-260 em Cláudio, Minas Gerais, Brasil	All groups	Cerrado	1	Revista NBC - Belo Horizonte
Abra et al. (2021)	2021	An estimate of wild mammal roadkill in São Paulo state, Brazil	Mammals	Cerrado, Atlantic forest	35	Heliyon
Miranda et al. (2021)	2021	Atropelamento de animais silvestres na rodovia GO-060 entre Iporá e Arenópolis, estado de Goiás.	All groups	Cerrado	0	Brazilian Journal of Development
Vasconcelos et al. (2021)	2021	Avaliação dos atropelamentos de animais silvestres na BR-153, trecho Guaraí-Tabocão	All groups	Cerrado	0	Research, Society and Development
Damásio et al. (2021)	2021	Diversity and Abundance of Roadkilled Bats in the Brazilian Atlantic Forest	Bats	Atlantic Forest	1	Diversity
Pereira et al. (2021)	2021	Don’t speed up speed kills:	Mammals	Atlantic	1	Oecologia

		Mammal roadkills on highway sections of pr-445 in the south of Brazil		Forest		Australis
Tenório et al. (2021)	2021	Efeitos do clima e sazonalidade nos atropelamentos de *Rhinella Jimi*, em duas rodovias do Agreste de Pernambuco	Specific species	Caatinga	0	Revista Ibero-americana de Ciências Ambientais
De Figueiredo Ramalho et al. (2021)	2021	Factors influencing bat road casualties in a Neotropical savanna	Bats	Cerrado	10	Perspectives in Ecology and Conservation
Cezar et al. (2021)	2021	Mamíferos silvestres atropelados em estradas da Paraíba, Nordeste do Brasil	Mammals	Caatinga	0	Brazilian Journal of Development
Franceschi et al. (2021)	2021	Mammalian fatalities on roads: how sampling errors affect road prioritization and dominant species influence spatiotemporal patterns	Mammals	Atlantic forest, Pampa	4	European Journal of Wildlife Research
Vela-Ulian et al. (2021)	2021	New records of bats (Chiroptera) in the Atlantic Forest of Espírito Santo, southeastern Brazil	Bats	Atlantic Forest	1	Mammalia
Alves et al. (2021)	2021	Overview of roadkills in the Serra da Macaca Park Road (SP-139), state of São Paulo, Brazil	All groups	Atlantic Forest	2	Iheringia - Serie Zoologia
Ascensão et al. (2021)	2021	Preventing wildlife roadkill can offset mitigation investments in short-medium term	All groups	Pantanal, Cerrado	4	Biological Conservation
Banhos et al. (2021)	2021	Roadkills of Lowland Tapir Tapirus terrestris (Mammalia: Perissodactyla: Tapiridae) in one of its last refuges in the Atlantic Forest	Specific species	Atlantic Forest	1	Journal of Threatened Taxa
Carvalho-Roel et al. (2021)	2021	Wildlife roadkill in the surroundings of Emas National Park, Cerrado Biome, Brazil	Except amphibian	Cerrado	1	Oecologia Australis

Table S2. Protected areas with surveyed road, category (Federal, State or Municipal), Year of PA creation (Year), Biomes, Group studied in each PA separated by papers, Papers near to PAs (Citation) and Linear distance of PAs and surveyed roads in kilometers (LD).

Protected areas	Category	Year	Biome	Groups	Citation (see Appendix I)	LD
Área de Proteção Ambiental Bacia do Paraíba do Sul	Federal	1982	Atlantic Forest	Mammals	Abra et al. (2021)	0
Área de Proteção Ambiental Cabreuva	State	1984	Atlantic Forest	Mammals	Abra et al. (2021)	0
Área de Proteção Ambiental Cajamar	State	1984	Atlantic Forest	Mammals	Abra et al. (2021)	0
Área de Proteção Ambiental Corumbataí, Botucatu e Tejupá Perímetro Botucatu	State	1983	Atlantic Forest and Cerrado	Mammals	Abra et al. (2021)	0
Área de Proteção Ambiental Corumbataí, Botucatu e Tejupá Perímetro Corumbataí	State	1983	Cerrado	Mammals	Freitas et al. (2015)	0
				All groups	Saranholi et al. (2016)	0
				Mammals	Ciocheti et al. (2017)	0
				Mammals	Abra et al. (2021)	0
Área de Proteção Ambiental da Bacia do Rio Descoberto	Federal	1983	Cerrado	All groups	Figueiredo et al. (2013)	0
				All groups	Santos et al. (2016)	0
				All groups	Santos et al. (2017)	0
				Specific species	Santos et al. (2018)	0
				Specific species	Soares and Dias (2020)	0
				Bats	De Figueiredo Ramalho et al. (2021)	0
Área de Proteção Ambiental da Bacia do Rio São Bartolomeu	Federal	1983	Cerrado	All groups	Figueiredo et al. (2013)	0.1
				All groups	Santos et al. (2016)	0.1
				All groups	Santos et al. (2017)	0.1
				Specific species	Santos et al. (2018)	0.1

				Specific species	Soares and Dias (2020)	0.1
				Bats	De Figueiredo Ramalho et al. (2021)	0.1
Área de Proteção Ambiental da Bacia do Rio São João - Mico Leão	Federal	2002	Atlantic Forest	Bats	Secco et al. (2017)	0
Área de Proteção Ambiental da Bacia dos Ribeirões do Gama e Cabeça de Veado	State	1986	Cerrado	All groups	Figueiredo et al. (2013)	0.2
				All groups	Santos et al. (2016)	0.2
				All groups	Santos et al. (2017)	0.2
				Specific species	Santos et al. (2018)	0.2
				Specific species	Soares and Dias (2020)	0.2
				Bats	De Figueiredo Ramalho et al. (2021)	0.2
Área de Proteção Ambiental da Bacia Hidrográfica do Rio Uberaba	State	1999	Cerrado	All groups	Silva et al. (2011)	0
		1999	Cerrado	Specific species	De Freitas et al. (2015)	0
Área de Proteção Ambiental da Baleia Franca	Federal	2000	Atlantic Forest	Except amphibians	Teixeira et al. (2013)	0
Área de Proteção Ambiental da Lagoa Grande	Municipal	2006	Atlantic Forest	Mammals	Ferreira et al. (2014)	0
				Specific species	Monteiro-Alves et al. (2019)	1
Área de Proteção Ambiental da Lagoa Verde	Municipal	2005	Pampa	Birds	Bager and Rosa (2012)	0
Área de Proteção Ambiental da Sub-bacia do Rio Pardo	Municipal	2010	Cerrado	All groups	Ascensão et al. (2021)	0
Área de Proteção Ambiental de Cafuringa	State	1988	Cerrado	All groups	Figueiredo et al. (2013)	0
				All groups	Santos et al. (2016)	0
				All groups	Santos et al. (2017)	0

				Specific species	Santos et al. (2018)	0
				Specific species	Soares and Dias (2020)	0
				Bats	De Figueiredo Ramalho et al. (2021)	0
Área de Proteção Ambiental de Cairuçu	Federal	1983	Atlantic Forest	Snakes	Hartmann et al. (2011)	0
Área de Proteção Ambiental de Campinas	Municipal	2001	Atlantic Forest	Mammals	Abra et al. (2021)	0
Área de Proteção Ambiental de Guaraqueçaba	Federal	1985	Atlantic Forest	Amphibians and reptiles	Silva et al. (2007)	0
Área de Proteção Ambiental de Petrópolis	Federal	1982	Atlantic Forest	Mammals	Bueno and Almeida (2010)	0
				Specific species	Bueno et al. (2013)	0
				Except amphibians	Bueno et al. (2015)	0
Área de Proteção Ambiental de Presidente Figueiredo - Caverna do Moroaga	State	1990	Amazonia	All groups	Omena Jr. et al. (2012)	0
Área de Proteção Ambiental de São Bento	Municipal	1997	Atlantic Forest	Mammals	Bueno and Almeida (2010)	0
				Specific species	Bueno et al. (2013)	0
				Except amphibians	Bueno et al. (2015)	0
Área de Proteção Ambiental de Setiba	State	1994	Atlantic Forest	Mammals	Ferreira et al. (2014)	0
				Specific species	Monteiro-Alves et al. (2019)	0
Área de Proteção Ambiental do Banhado Grande	State	1998	Atlantic Forest and Pampa	Mammals	Franceschi et al. (2021)	0

Área de Proteção Ambiental do Campo Grande	Municipal	2011	Atlantic Forest	Mammals	Abra et al. (2021)	0
Área de Proteção Ambiental do Entorno Costeiro	State	2009	Atlantic Forest	Except amphibians	Teixeira et al. (2013)	0
Área de Proteção Ambiental do Iguaçú	Municipal	1991	Atlantic Forest	All groups	Paes and Povaluk (2012)	0
Área de Proteção Ambiental do Lago Paranoá	State	1989	Cerrado	All groups	Figueiredo et al. (2013)	0.1
				All groups	Santos et al. (2016)	0.1
				All groups	Santos et al. (2017)	0.1
				Specific species	Santos et al. (2018)	0.1
				Specific species	Soares and Dias (2020)	0.1
				Bats	De Figueiredo Ramalho et al. (2021)	0.1
Área de Proteção Ambiental do Passauna	State	1991	Atlantic Forest	All groups	Weiss and Vianna (2013)	0
Área de Proteção Ambiental do Pequeno	State	1996	Atlantic Forest	Mammals	Belão et al. (2014)	0
Área de Proteção Ambiental do Pico do Goiapaba-Açu	State	1994	Atlantic Forest	All groups	Mili and Passamani (2006)	0
Área de Proteção Ambiental do Planalto Central	Federal	2002	Cerrado	All groups	Figueiredo et al. (2013)	0
				All groups	Santos et al. (2016)	0
				All groups	Santos et al. (2017)	0
				Specific species	Santos et al. (2018)	0
				Specific species	Soares and Dias (2020)	0
				Bats	De Figueiredo Ramalho et al. (2021)	0

Área de Proteção Ambiental Estadual da Escarpa Devoniana	State	1992	Atlantic Forest	All groups	Weiss and Vianna (2013)	0
Área de Proteção Ambiental Estadual de Guaratuba	State	1992	Atlantic Forest	Mammals	Belão et al. (2014)	0
Área de Proteção Ambiental Estadual do Piraquara	State	1996	Atlantic Forest	Mammals	Belão et al. (2014)	0.5
Área de Proteção Ambiental Estrada Parque de Piraputanga	State	2000	Cerrado	Mammals	Cáceres et al. (2010)	0
				Mammals	Cáceres et al. (2011)	0
				Mammals	Caceres et al. (2012)	0
				Mammals	Ascensão et al. (2017)	0
				Birds and Reptiles	Fischer et al. (2018)	0
				Mammals	Ascensão et al. (2019)	0
				All groups	Ascensão et al. (2021)	0
Área de Proteção Ambiental Foz do Rio Santa Tereza	State	1997	Cerrado	Mammals	Zanzini et al. (2018)	0
Área de Proteção Ambiental Itupararanga	State	1998	Atlantic Forest	Mammals	Abra et al. (2021)	0
Área de Proteção Ambiental Jundiaí	State	1984	Atlantic Forest	Mammals	Abra et al. (2021)	0
Área de Proteção Ambiental Margem Esquerda do Rio Negro-Setor Aturiá-Apuauzinho	State	1995	Amazonia	All groups	Omena Jr. et al. (2012)	0
Área de Proteção Ambiental Morro de Osório	Municipal	1994	Atlantic Forest	Except amphibians	Coelho et al. (2008)	0
				Except amphibians	Teixeira et al. (2013)	0
				Mammals	Franceschi et al. (2021)	0
Área de Proteção	Municipal	2010	Atlantic	Bats	Secco et al. (2017)	1

Ambiental Municipal Serra do Sambê			Forest			
Área de Proteção Ambiental Pedregulho	Municipal	2013	Atlantic Forest	Mammals	Abra et al. (2021)	0
Área de Proteção Ambiental Piracicaba Juqueri Mirim Área I	State	1991	Cerrado	Mammals	Freitas et al. (2015)	0.7
				All groups	Saranholi et al. (2016)	0.7
				Mammals	Ciocheti et al. (2017)	0.7
				Mammals	Abra et al. (2021)	0
Área de Proteção Ambiental Piracicaba Juqueri Mirim Área II	State	1991	Atlantic Forest and Cerrado	Mammals	Abra et al. (2021)	0
Área de Proteção Ambiental Pouso Alto	State	2001	Cerrado	All groups	Braz and França (2016)	0
Área de Proteção Ambiental Represa Bairro da Usina	State	1986	Atlantic Forest	Mammals	Abra et al. (2021)	0
Área de Proteção Ambiental Retiro	Municipal	2004	Atlantic Forest	Specific species	Bueno et al. (2013)	0.8
				Except amphibians	Bueno et al. (2015)	0.8
Área de Proteção Ambiental Rio Batalha	State	2001	Atlantic Forest and Cerrado	Mammals	Abra et al. (2021)	0
Área de Proteção Ambiental Serra da Ibiapaba	Federal	1996	Caatinga	All groups	Veras et al. (2016)	0
Área de Proteção Ambiental Serra da Jibóia	State	2000	Cerrado	All groups	Cunha et al. (2010)	0
				Mammals	de Araújo et al. (2019)	0
Área de Proteção Ambiental Serra do Mar	State	1984	Atlantic Forest	All groups	Alves et al. (2021)	0
Área de Proteção Ambiental Sistema	State	1998	Atlantic Forest	Mammals	Abra et al. (2021)	0

Cantareira						
Área de Proteção Ambiental Tietê	State	1983	Atlantic Forest	Mammals	Abra et al. (2021)	0
Área de Proteção Ambiental Várzea do Rio Tietê	State	1987	Atlantic Forest	Mammals	Abra et al. (2021)	0
Área de Relevante Interesse Ecológica Mata de Santa Genebra	Federal	1985	Atlantic Forest	Mammals	Abra et al. (2021)	0.4
Área e Proteção Ambiental Ilhas e Várzeas do Rio Paraná	Federal	1997	Atlantic Forest	Mammals	Cáceres et al. (2010)	0
				Mammals	Cáceres et al. (2011)	0
Estação Ecológica da Serra das Araras	Federal	1982	Cerrado	All groups	Valadão et al. (2018)	0
Estação Ecológica de Áreas Emendadas	State	1968	Cerrado	All groups	Figueiredo et al. (2013)	0.7
				All groups	Santos et al. (2016)	0.7
				All groups	Santos et al. (2017)	0.7
				Specific species	Santos et al. (2018)	0.7
				Specific species	Soares and Dias (2020)	0.7
				Bats	De Figueiredo Ramalho et al. (2021)	0.7
Estação Ecológica de Itapeva	State	1985	Cerrado	Mammals	Abra et al. (2021)	0
Estação Ecológica de Itirapina	State	1984	Cerrado	All groups	Saranholi et al. (2016)	1
Estação Ecológica de Ribeirão Preto	State	1982	Cerrado	Mammals	Abra et al. (2021)	0
Estação Ecológica de Santa Bárbara	State	1984	Cerrado	Mammals	Abra et al. (2021)	0
Estação Ecológica do Jardim Botânico	State	1992	Cerrado	All groups	Figueiredo et al. (2013)	0
				All groups	Santos et al. (2016)	0
				All groups	Santos et al. (2017)	0

				Specific species	Santos et al. (2018)	0
				Specific species	Soares and Dias (2020)	0
				Bats	De Figueiredo Ramalho et al. (2021)	0
Estação Ecológica do Seridó	Federal	1982	Caatinga	All groups	Calabuig et al. (2019)	0
Estação Ecológica do Taim	Federal	1975	Pampa	Birds	Novelli et al. (1988)	0
				Except amphibians	Bager and Rosa (2011)	0
				Birds	Rosa and Bager (2012)	0
				Except amphibians	Bager and Fontoura (2013)	0
				Except amphibians	Costa et al. (2015)	0
				Specific species	Grilo et al. (2016)	0
Estação Ecológica Valinhos	State	1966	Atlantic Forest	Mammals	Abra et al. (2021)	0.8
Floresta Estadua Serra Dágua	State	2010	Atlantic Forest	Mammals	Abra et al. (2021)	0.5
Floresta Estadual Córrego da Biquinha	State	1994	Atlantic Forest	All groups	Weiss and Vianna (2013)	0
Floresta Estadual de Assis	State	2002	Cerrado	Mammals	Abra et al. (2021)	0.7
Floresta Estadual Pederneiras	State	2002	Cerrado	Mammals	Abra et al. (2021)	0
Floresta Nacional de Açu	Federal	1950	Caatinga	All groups	Calabuig et al. (2019)	0
Floresta Nacional de Brasíia	Federal	1999	Cerrado	All groups	Figueiredo et al. (2013)	0.1
				All groups	Santos et al. (2016)	0.1
				All groups	Santos et al. (2017)	0.1
				Specific species	Santos et al. (2018)	0.1

				Specific species	Soares and Dias (2020)	0.1
				Bats	De Figueiredo Ramalho et al. (2021)	0.1
Floresta Nacional de Capão Bonito	Federal	1968	Atlantic Forest and Cerrado	Mammals	Abra et al. (2021)	0
Floresta Nacional de Carajás	Federal	1998	Amazonia	All groups	Gumier-Costa and Sperber (2009)	0
Monumento Natural Municipal do Encontro dos Três Rios	Municipal	2010	Atlantic Forest	Specific species	Bueno et al. (2013)	0.2
Parque Estadual Altamiro de Moura Pacheco	State	1993	Cerrado	All groups	Prado et al. (2006)	0
Parque Estadual Carlos Botelho	State	1982	Atlantic Forest	All groups	Alves et al. (2021)	0
Parque Estadual da Ara	State	1969	Atlantic Forest	Mammals	Abra et al. (2021)	0.9
Parque Estadual da Fonte Grande	Municipal	1986	Atlantic Forest	Reptiles	Ferreira and Silva-Soares (2012)	0
Parque Estadual da Serra do Mar	State	1977	Atlantic Forest	Snakes	Hartmann et al. (2011)	0
				Mammals	Abra et al. (2021)	0
Parque Estadual da Serra do Tabuleiro	State	1975	Atlantic Forest	Mammals	Cherem et al. (2007)	0.6
				Except amphibians	Teixeira et al. (2013)	0
Parque Estadual das Fontes do Ipiranga	State	1969	Atlantic Forest	Mammals	Abra et al. (2021)	0.6
Parque Estadual das Furnas do Bom Jesus	State	1989	Cerrado	Specific species	Freitas and Araujo (2011)	0
				Specific species	De Freitas et al. (2015)	0
Parque Estadual de Itapeva	State	2002	Atlantic Forest	Except amphibians	Coelho et al. (2008)	0
				Anurans	Coelho et al. (2012)	0

Parque Estadual de Porto Ferreira	State	1962	Atlantic Forest	Mammals	Abra et al. (2021)	0
Parque Estadual de Vassununga	State	1970	Cerrado	Mammals	Abra et al. (2021)	0
Parque Estadual do Espinilho	State	1975	Pampa	Mammals	Tumeleiro et al. (2006)	0
Parque Estadual do Jaraguá	State	1961	Atlantic Forest	Mammals	Abra et al. (2021)	0
Parque Estadual do Prosa	State	2002	Cerrado	Mammals	Ascensão et al. (2017)	0.5
				Mammals	Ascensão et al. (2019)	0.5
				All groups	Ascensão et al. (2021)	0.5
Parque Estadual Mãe Bonifácia	State	2000	Cerrado	All groups	Valadão et al. (2018)	0.6
Parque Estadual Paulo César Vinha	State	1990	Atlantic Forest	Mammals	Ferreira et al. (2014)	0
				Specific species	Monteiro-Alves et al. (2019)	0
Parque Estadual Serra do Tabuleiro	State	1975	Atlantic Forest	Snakes	Kunz and Ghizoni (2009)	0.6
Parque Estadual Xixová-Japuí	State	1993	Atlantic Forest	Mammals	Abra et al. (2021)	0.5
Parque Nacional da Chapada dos Veadeiros	Federal	1961	Cerrado	All groups	Braz and França (2016)	0
Parque Nacional da Lagoa do Peixe	Federal	1986	Pampa	Reptiles	Gonçalves et al. (2018)	0
Parque Nacional da Serra da Bocaina	Federal	1971	Atlantic Forest	Snakes	Hartmann et al. (2011)	0
Parque Nacional das Emas	Federal	1961	Cerrado	All groups	Silva-Neto et al. (2015)	0
				Except amphibians	Carvalho-Roel et al. (2021)	0
Parque Nacional de Brasília	Federal	1961	Cerrado	All groups	Figueiredo et al. (2013)	0
				All groups	Santos et al. (2016)	0
				All groups	Santos et al. (2017)	0
				Specific species	Santos et al. (2018)	0

				Specific species	Soares and Dias (2020)	0
				Bats	De Figueiredo Ramalho et al. (2021)	0
Parque Nacional de Furna Feia	Federal	2012	Caatinga	All groups	Calabuig et al. (2019)	0
Parque Nacional de Saint-Hilaire/Lage	Federal	2001	Atlantic Forest	Mammals	Belão et al. (2014)	0
Parque Nacional do Catimbau	Federal	2002	Caatinga	Amphibians and reptiles	De Almeida et al. (2016)	0.6
Parque Natural Municipal da Caixa d'Água	Municipal	2008	Atlantic Forest	Mammals	Bueno and Almeida (2010)	0.9
				Specific species	Bueno et al. (2013)	0.8
				Except amphibians	Bueno et al. (2015)	0.8
Parque Natural Municipal das Araucárias	Municipal	1991	Atlantic Forest	Birds	Ramos et al. (2011)	1
Parque Natural Municipal de Jacarenema	Municipal	2003	Atlantic Forest	Mammals	Ferreira et al. (2014)	0
Parque Natural Municipal de Sertão	Municipal	1998	Atlantic Forest	Mammals	Hegel et al. (2012)	0
Parque Natural Municipal do Campo Grande	Municipal	2011	Atlantic Forest	Mammals	Abra et al. (2021)	0
Parque Natural Municipal Manuel de Barros Pereira	Municipal	2006	Atlantic Forest	Mammals	Franceschi et al. (2021)	0
Parque Natural Municipal Pedra dos Olhos	Municipal	2003	Atlantic Forest	Reptiles	Ferreira and Silva-Soares (2012)	0.6
Parque Natural Municipal Peroba Rosa	Municipal	1995	Atlantic Forest	Mammals	Pereira et al. (2021)	0.2
Parque Natural Municipal Raimundo Gonçalez	Municipal	1993	Atlantic Forest	Mammals	Cherem et al. (2007)	0.7

Malta						
Parque Natural Municipal Rota das Garças	Municipal	2002	Atlantic Forest	Mammals	Ferreguetti et al. (2020)	0.1
Parque Natural Municipal Saint Hilaire	Municipal	2015	Pampa	Mammals	Franceschi et al. (2021)	0
Parque Natural Municipal Vale Mulembá	Municipal	2002	Atlantic Forest	Reptiles	Ferreira and Silva-Soares (2012)	0.8
Refúgio de Vida Silvestre dos Campos de Palmas	Federal	2006	Atlantic Forest	Mammals	Cherem and Althoff (2015)	0
Reserva Biológica de Araras	State	1977	Atlantic Forest	Specific species	Bueno et al. (2013)	0.4
				Except amphibians	Bueno et al. (2015)	0.4
Reserva Biológica de Poços das Antas	Federal	1974	Atlantic Forest	Bats	Secco et al. (2017)	0
Reserva Biológica de Sooretama	Federal	1982	Atlantic Forest	Specific species	Banhos et al. (2021)	0
				Bats	Damásio et al. (2021)	0
				Bats	Vela-Ulian et al. (2021)	0
Reserva Biológica do Tinguá	Federal	1989	Atlantic Forest	Mammals	Bueno and Almeida (2010)	0
				Specific species	Bueno et al. (2013)	0
				Except amphibians	Bueno et al. (2015)	0
Reserva Biológica União	Federal	1998	Atlantic Forest	Bats	Secco et al. (2017)	0
Reserva Particular do Patrimônio Natural Canoa Vale dos Ipês	State	2013	Cerrado	All groups	Castro et al. (2020)	1
Reserva Particular do Patrimônio Natural Ecocerrado	State	2009	Cerrado	Specific species	De Freitas et al. (2015)	0.3

Brasil						
Reserva Particular do Patrimônio Natural Graziela Maciel Barroso	Federal	2005	Atlantic Forest	Mammals	Bueno and Almeida (2010)	0.5
				Specific species	Bueno et al. (2013)	0.5
				Except amphibians	Bueno et al. (2015)	0.5
Reserva Particular do Patrimônio Natural Koehler	State	2015	Atlantic Forest	Mammals	Ferreguetti et al. (2020)	0.2
Reserva Particular do Patrimônio Natural Mata do Professor Baptista	Federal	2009	Atlantic Forest	Except amphibians	Teixeira et al. (2013)	0.3
Reserva Particular do Patrimônio Natural Mutinga	Municipal	2011	Atlantic Forest	Mammals	Abra et al. (2021)	0.3
Reserva Particular do Patrimônio Natural Portal do Pantanal I	State	2001	Pantanal	All groups	De Souza et al. (2015)	0
				Mammals	Ascensão et al. (2017)	0
				Mammals	Ascensão et al. (2019)	0
				All groups	Ascensão et al. (2021)	0

Table S3. Protected areas without surveyed road, category of PA described (Federal, State or Municipal), Year of PA creation (Year) and Biomes. Conservation unit types (with Portuguese acronyms) - APA: Environmental Protection Area; ARIE: Area of Relevant Ecological Interest; ESEC: Ecological Station; RDS: Sustainable Development Reserve; REVIS: Wildlife Refuge; REBIO: Biological Reserve; RESEX: Extractive Reserve; RPPN: Private Natural Heritage Reserve.

Name of Protected Areas (PAs)	**Category**	**Year**	**Biome**
APA Água Santa De Minas	Municipal	2003	Atlantic Forest
APA Águas Claras	Municipal	2021	Cerrado
APA Águas Vertentes	State	1998	Atlantic Forest
APA Aldeia-beberibe	State	2010	Atlantic Forest
APA Alto Taboão	Municipal	1998	Atlantic Forest
APA Bacia Do Cobre / São Bartolomeu	State	2001	Atlantic Forest
APA Bacia Do Paraíba Do Sul	Federal	1982	Atlantic Forest
APA Bacia Do Rio De Janeiro	State	1993	Cerrado
APA Bacia Do Rio Pandeiros	State	1995	Cerrado
APA Baía Das Tartarugas	Municipal	2018	Atlantic Forest
APA Baía De Camamu	State	2002	Atlantic Forest
APA Baía De Todos Os Santos	State	1999	Atlantic Forest
APA Baía Negra	Municipal	2010	Pantanal
APA Baleia Sahy	Municipal	2013	Atlantic Forest
APA Barra Do Rio Mamanguape	Federal	1993	Atlantic Forest and Caatinga
APA Barreiro Rico	State	2018	Atlantic Forest and Cerrado
APA Bemposta	Municipal	2012	Atlantic Forest
APA Bonfim/guaraíra	State	1999	Atlantic Forest and Caatinga
APA Bororé-colônia	Municipal	2006	Atlantic Forest
APA Cabreuva	State	1984	Atlantic Forest
APA Cachoeira Das Andorinhas	State	1989	Atlantic Forest
APA Cajamar	State	1984	Atlantic Forest
APA Cajati	State	2008	Atlantic Forest

APA Caminhos Ecológicos Da Boa Esperança	State	2003	Atlantic Forest
APA Campos Do Jordão	State	1984	Atlantic Forest
APA Canal Campos Macaé	Municipal	2019	Atlantic Forest
APA Carapiá	Municipal	2013	Atlantic Forest
APA Carste Da Lagoa Santa	Federal	1990	Cerrado
APA Castelandia	Municipal	2021	Cerrado
APA Cavernas Do Peruaçu	Federal	1989	Caatinga
APA Caxangá	Municipal	1996	Atlantic Forest
APA Chapada Do Araripe	Federal	1997	Caatinga
APA Conceição Da Barra	State	2007	Atlantic Forest
APA Corredeiras	Municipal	2001	Atlantic Forest
APA Corredores De Biodiversidade De Canela	Municipal	2021	Atlantic Forest
APA Corrego Da Mata	Municipal	2002	Atlantic Forest
APA Córrego Da Moranga	Municipal	2021	Cerrado
APA Corumbataí Botucatu Tejupa Perimetro Botucatu	State	1983	Atlantic Forest and Cerrado
APA Corumbataí Botucatu Tejupá Perimetro Tejupá	State	1983	Atlantic Forest
APA Corumbataí, Botucatu E Tejupá Perimetro Corumbataí	State	1983	Atlantic Forest and Cerrado
APA Costa Das Algas	Federal	2010	Atlantic Forest
APA Costa De Itacaré/ Serra Grande	State	1993	Atlantic Forest
APA Costa Dos Corais	Federal	1997	Atlantic Forest
APA Da Ararinha Azul	Federal	2018	Caatinga
APA Da Bacia Do Córrego Capão Grande	Municipal	2018	Cerrado
APA Da Bacia Do Iguatemi No Município De Amambai	Municipal	2003	Atlantic Forest and Cerrado
APA Da Bacia Do Rio Descoberto	Federal	1983	Cerrado
APA Da Bacia Do Rio Dos Frades	State	1990	Atlantic Forest
APA Da Bacia Do Rio Iguatemi	Municipal	2003	Atlantic Forest
APA Da Bacia Do Rio Iguatemi Do Município De Mundo Novo	Municipal	2003	Atlantic Forest

APA Da Bacia Do Rio Iguatemi Do Município De Tacuru	Municipal	2003	Atlantic Forest and Cerrado
APA Da Bacia Do Rio Iguatemi No Município De Iguatemi	Municipal	2003	Atlantic Forest and Cerrado
APA Da Bacia Do Rio Iguatemi No Município De Paranhos	Municipal	2003	Atlantic Forest and Cerrado
APA Da Bacia Do Rio Macacu	State	2002	Atlantic Forest
APA Da Bacia Do Rio São Bartolomeu	Federal	1983	Cerrado
APA Da Bacia Do Rio São João - Mico Leão	Federal	2002	Atlantic Forest
APA Da Bacia Dos Ribeirões Do Gama E Cabeça De Veado	State	1986	Cerrado
APA Da Bacia Hidrográfica Do Rio Machado	State	1999	Atlantic Forest
APA Da Baía De Paraty	Municipal	1984	Atlantic Forest
APA Da Baixada Maranhense	State	1991	Amazonia
APA Da Baleia Franca	Federal	2000	Atlantic Forest
APA Da Bica Do Ipú	State	1999	Caatinga
APA Da Carapeba Boa	Municipal	2018	Atlantic Forest
APA Da Cehab	Municipal	2021	Atlantic Forest
APA Da Chapada Dos Guimarães	State	1995	Cerrado
APA Da Foz Do Rio Das Preguiças - Pequenos Lençóis - Região Lagunar Adjacente	State	1991	Cerrado
APA Da Lagoa Da Jijoca	State	2000	Caatinga
APA Da Lagoa Da Maraponga	Municipal	1991	Caatinga
APA Da Lagoa Do Iriry	Municipal	2003	Atlantic Forest
APA Da Lagoa Do Uruaú	State	1999	Caatinga
APA Da Lagoa Grande	Municipal	2006	Atlantic Forest
APA Da Lagoa Guanandy	State	1994	Atlantic Forest
APA Da Lagoa Verde	Municipal	2005	Pampa
APA Da Marituba Do Peixe	State	1988	Atlantic Forest
APA Da Orla Marítima	Municipal	1988	Atlantic Forest
APA Da Orla Marítima Da Baía De Sepetiba	Municipal	1988	Atlantic Forest
APA Da Pedra Branca	Municipal	1988	Atlantic Forest

APA Da Pedra Lisa	Municipal	2009	Atlantic Forest
APA Da Perdição	Municipal	2013	Atlantic Forest
APA Da Região Do Maracanã	State	1991	Amazonia
APA Da Região Metrolpolitana De Belém	State	1993	Amazonia
APA Da Represa Alto Rio Preto	Municipal	1998	Atlantic Forest
APA Da Serra Da Aratanha	State	1998	Caatinga
APA Da Serra Da Bolívia	Municipal	2013	Atlantic Forest
APA Da Serra Da Cambraia	Municipal	2015	Atlantic Forest
APA Da Serra Das Galés E Da Portaria	State	2002	Cerrado
APA Da Serra De Baturité	State	1990	Caatinga
APA Da Serra De Sapiatiba	State	1990	Atlantic Forest
APA Da Serra Dos Pretos Forros	Municipal	2000	Atlantic Forest
APA Da Serra Dourada	State	1998	Cerrado
APA Da Sub Bacia Do Rio Pardo	Municipal	2010	Atlantic Forest
APA Das Cabeceiras Do Rio Cuiabá	State	1998	Cerrado
APA Das Dunas Do Litoral Oeste	State	1998	Caatinga
APA Das Estâncias De Pendotiba	Municipal	2018	Atlantic Forest
APA Das Nascentes De Araguaina	State	1999	Cerrado
APA Das Nascentes Do Rio Vermelho	Federal	2001	Cerrado
APA Das Onças	State	2002	Caatinga
APA Das Reentrâncias Maranhenses	State	1991	Amazonia
APA Das Tabebuias	Municipal	1999	Atlantic Forest
APA De Algodoal-maiandeua	State	1990	Amazonia
APA De Alter Do Chão	Municipal	2003	Amazonia
APA De Cafuringa	State	1988	Cerrado
APA De Cairuçu	Federal	1983	Atlantic Forest
APA De Campinas	Municipal	2001	Atlantic Forest
APA De Cananéia-iguapé-peruíbe	Federal	1984	Atlantic Forest
APA De Costa Dourada	Municipal	1999	Atlantic Forest
APA De Engenheiro Passos Apaep	Municipal	1997	Atlantic Forest

APA De Gericinó/mendanha	State	2005	Atlantic Forest
APA De Guadalupe	State	1997	Atlantic Forest
APA De Guapi-mirim	Federal	1984	Atlantic Forest
APA De Guaraqueçaba	Federal	1985	Atlantic Forest
APA De Itaoca	Municipal	2018	Atlantic Forest
APA De Jenipabu	State	1995	Atlantic Forest
APA De Macaé De Cima	State	2001	Atlantic Forest
APA De Mangaratiba	State	1987	Atlantic Forest
APA De Maricá	State	1984	Atlantic Forest
APA De Massambaba	State	1986	Atlantic Forest
APA De Muricí	State	1997	Atlantic Forest
APA De Palmares	Municipal	2004	Atlantic Forest
APA De Petrópolis	Federal	1982	Atlantic Forest
APA De Piaçabuçu	Federal	1983	Atlantic Forest
APA De Praia Mole	State	1994	Atlantic Forest
APA De Presidente Figueiredo - Caverna Do Moroaga	State	1990	Amazonia
APA De Santa Cruz	State	2008	Atlantic Forest
APA De Santa Rita	State	1984	Atlantic Forest
APA De São Bento	Municipal	1997	Atlantic Forest
APA De São Desidério	State	2006	Cerrado
APA De Setiba	State	1994	Atlantic Forest
APA De Sirinhaém	State	1998	Atlantic Forest
APA De Tambaba	State	2002	Atlantic Forest
APA De Tamoios	State	1986	Atlantic Forest
APA De Tinguá	Municipal	2004	Atlantic Forest
APA De Upaon-açu / Miritiba / Alto Preguiças	State	1992	Amazonia and Cerrado
APA De Uso Sustentável, Sucupira	Municipal	2017	Cerrado
APA Delta Do Parnaiba	Federal	1996	Caatinga and Cerrado

APA Do Alto Do Gaia	Municipal	2018	Atlantic Forest
APA Do Alto Do Mucuri	State	2011	Atlantic Forest
APA Do Alto Iguaçu	State	2013	Atlantic Forest
APA Do Arquipélago Do Marajó	State	1989	Amazonia
APA Do Bairro Da Freguesia	Municipal	1992	Atlantic Forest
APA Do Banhado	State	2002	Atlantic Forest
APA Do Banhado Grande	State	1998	Atlantic Forest and Pampa
APA Do Cabuçu Tanque Grande	Municipal	2010	Atlantic Forest
APA Do Cariri	State	2004	Caatinga
APA Do Catolé E Fernão Velho	State	1992	Atlantic Forest
APA Do Córrego Da Lagoa	Municipal	2017	Cerrado
APA Do Engenho Pequeno	Municipal	1991	Atlantic Forest
APA Do Entorno Costeiro	State	2009	Atlantic Forest
APA Do Estuário Do Rio Ceará - Rio Maranguapinho	State	1999	Caatinga
APA Do Estuário Do Rio Mundaú	State	1999	Caatinga
APA Do Iguaçú	Municipal	1991	Atlantic Forest
APA Do Iraí	State	1996	Atlantic Forest
APA Do Itapiracó	State	1997	Amazonia
APA Do Lagamar Do Cauipe	State	1998	Caatinga
APA Do Lago De Tucurui	State	2002	Amazonia
APA Do Lago Paranoá	State	1989	Cerrado
APA Do Limoeiro	Municipal	2017	Cerrado
APA Do Maciço Central	Municipal	1992	Atlantic Forest
APA Do Manguezal Da Barra Grande	Municipal	2000	Caatinga
APA Do Morro Da Saudade	Municipal	1992	Atlantic Forest
APA Do Morro Dos Cabritos	Municipal	1992	Atlantic Forest
APA Do Parque Municipal Ecológico De Marapendi	Municipal	1991	Atlantic Forest
APA Do Passauna	State	1991	Atlantic Forest
APA Do Pau Brasil	State	2002	Atlantic Forest

APA Do Planalto Central	Federal	2002	Cerrado
APA Do Rio Amambai	Municipal	2006	Atlantic Forest and Cerrado
APA Do Rio Curiaú	State	1998	Amazonia
APA Do Rio Dos Bugres	Municipal	1998	Atlantic Forest
APA Do Rio Guandu	State	2007	Atlantic Forest
APA Do Rio Madeira	State	1991	Amazonia
APA Do Rio Maranguapinho	State	2021	Caatinga
APA Do Rio Pacoti	State	2000	Caatinga
APA Do Rio Preto	State	2006	Caatinga and Cerrado
APA Do Rio Verde	State	2000	Atlantic Forest
APA Do Rio Vermelho	Municipal	1998	Atlantic Forest
APA Do Saco De Coroa Grande	Municipal	2013	Atlantic Forest
APA Do Sacopã	Municipal	1986	Atlantic Forest
APA Do Salto Magessi	State	2002	Cerrado
APA Do Sertão Carioca	Municipal	2021	Atlantic Forest
APA Do Tapajós	Federal	2006	Amazonia
APA Do Várzea Country Club	Municipal	1991	Atlantic Forest
APA Dos Morros Garapenses	State	2010	Cerrado
APA Dos Pireneus	State	2000	Cerrado
APA Dos Recifes De Corais	State	2001	Atlantic Forest
APA Dunas Do Rosado	State	2018	Caatinga
APA Dunas E Veredas Do Baixo Médio São Francisco	State	1997	Caatinga
APA Estadual Da Escarpa Devoniana	State	1992	Atlantic Forest and Cerrado
APA Estadual Da Serra Da Esperança	State	1992	Atlantic Forest
APA Estadual De Guaratuba	State	1992	Atlantic Forest
APA Estadual Delta Do Jacuí	State	2005	Pampa
APA Estadual Mestre Álvaro	Municipal	1991	Atlantic Forest
APA Estrada Parque De Piraputanga	State	2000	Cerrado

APA Fazenda Nova	Municipal	2018	Cerrado
APA Fazenda Primavera	Municipal	2018	Cerrado
APA Fernão Dias	State	1997	Atlantic Forest
APA Guandú-açu	Municipal	2004	Atlantic Forest
APA Ibirapuitã	Federal	1992	Pampa
APA Ibitinga	State	1987	Atlantic Forest and Cerrado
APA Igarapé São Francisco	State	2005	Amazonia
APA Ilha Comprida	State	1987	Atlantic Forest
APA Ilha Do Bananal/cantão	State	1997	Cerrado
APA Ilhas E Várzeas Do Rio Paraná	Federal	1997	Atlantic Forest and Cerrado
APA Inaciolândia	Municipal	2018	Cerrado
APA Itaguaí Itingussú Espigão Taquara	Municipal	2012	Atlantic Forest
APA Itupararanga	State	1998	Atlantic Forest
APA Jaceruba	Municipal	2004	Atlantic Forest
APA Jalapão	State	2000	Cerrado
APA João Leite	State	2002	Cerrado
APA Jundiaí	State	1984	Atlantic Forest
APA Jupiá	Municipal	2009	Atlantic Forest and Cerrado
APA Lago De Palmas	State	1999	Cerrado
APA Lago De Peixe/angical	State	2002	Cerrado
APA Lago De Santa Isabel	State	2002	Amazonia
APA Lago De Sobradinho	State	2006	Caatinga
APA Lagoa De Itaparica	State	1997	Caatinga
APA Lagoa Encantada	State	1993	Atlantic Forest
APA Lagoas De Guarajuba	State	1991	Atlantic Forest
APA Lagoas E Dunas Do Abaeté	State	1987	Atlantic Forest
APA Litoral Norte	State	1992	Atlantic Forest
APA Marimbus / Iraquara	State	1993	Caatinga

APA Marinha Do Litoral Centro	State	2008	Atlantic Forest
APA Marinha Do Litoral Norte	State	2008	Atlantic Forest
APA Marinha Recifes Serrambi	State	2018	Atlantic Forest
APA Mata Da Biquinha	Municipal	2020	Atlantic Forest
APA Meandros Do Araguaia	Federal	1998	Cerrado
APA Minaçu	Municipal	2018	Cerrado
APA Miracema	Municipal	2010	Atlantic Forest
APA Monte Urubu	Municipal	2013	Atlantic Forest
APA Morro Agudo	Municipal	2004	Atlantic Forest
APA Morro Da Pedreira	Federal	1990	Atlantic Forest and Cerrado
APA Morro De Osório	Municipal	1994	Atlantic Forest and Pampa
APA Morro De São Bento	State	1988	Atlantic Forest
APA Municipal Da Lagoa Jacuném	Municipal	1998	Atlantic Forest
APA Municipal Da Serra Do Guararu	Municipal	2012	Atlantic Forest
APA Municipal Das Serras De Maricá	Municipal	2011	Atlantic Forest
APA Municipal Do Aricá-açu	Municipal	1999	Cerrado
APA Municipal Do Morro Do Vilante	Municipal	1999	Atlantic Forest
APA Municípal Manguezal Sul Da Serra	Municipal	2012	Atlantic Forest
APA Municipal Piracanjubinha	Municipal	2018	Cerrado
APA Municipal Serra Do Sambê	Municipal	2010	Atlantic Forest
APA Municipal Tartarugas	Municipal	2011	Atlantic Forest
APA Nascentes Do Rio Paraguai	State	2006	Cerrado
APA Novo Brasil	Municipal	2021	Cerrado
APA Palmelo	Municipal	2018	Cerrado
APA Panamá	Municipal	2018	Cerrado
APA Parque Municipal Da Estância Ecológica Do Cruzeiro	Municipal	2005	Atlantic Forest
APA Paytuna	State	2001	Amazonia
APA Pedregulho	Municipal	2013	Atlantic Forest

APA Piquiri-una	State	1990	Atlantic Forest and Caatinga
APA Piracicaba	Municipal	2004	Atlantic Forest and Cerrado
APA Piracicaba Juqueri Mirim Área I	State	1991	Atlantic Forest and Cerrado
APA Piracicaba Juquerí-mirim Area Ii	State	1991	Atlantic Forest
APA Planalto Do Turvo	State	2008	Atlantic Forest
APA Plataforma Continental Do Litoral Norte	State	2003	Atlantic Forest
APA Ponta Da Baleia / Abrolhos	State	1993	Atlantic Forest
APA Posse/guarita	Municipal	2012	Atlantic Forest
APA Pouso Alto	State	2001	Cerrado
APA Quilombos Do Médio Ribeira	State	2008	Atlantic Forest
APA Raposo	Municipal	2014	Atlantic Forest
APA Reserva Ecológica Vau Açu	Municipal	1999	Atlantic Forest
APA Retiro	Municipal	2004	Atlantic Forest
APA Rio Batalha	State	2001	Atlantic Forest and Cerrado
APA Rio Cênico Rotas Monçoeiras	State	2000	Cerrado
APA Rio D´ouro	Municipal	2004	Atlantic Forest
APA Rio Palmeiral	Municipal	2015	Cerrado
APA Rio Pardinho E Rio Vermelho	State	2008	Atlantic Forest
APA Roncador	State	2006	Caatinga
APA Rota Do Sol	State	1997	Atlantic Forest
APA Santo Antônio	Municipal	2004	Atlantic Forest
APA Santo Antônio	State	1994	Atlantic Forest
APA São Patrício	Municipal	2021	Cerrado
APA Sapucaí Mirim	State	1998	Atlantic Forest
APA Serra Branca / Raso Da Catarina	State	2001	Caatinga
APA Serra Da Ibiapaba	Federal	1996	Caatinga and Cerrado
APA Serra Da Jibóia	State	2000	Cerrado

APA Serra Da Mantiqueira	Federal	1985	Atlantic Forest
APA Serra Da Meruoca	Federal	2008	Caatinga
APA Serra Da Vargem Alegre	Municipal	1998	Atlantic Forest
APA Serra Do Itapeti	State	2018	Atlantic Forest
APA Serra Do Lajeado	State	1997	Cerrado
APA Serra Do Mar	State	1984	Atlantic Forest
APA Serra Do Sabonetal	State	1998	Caatinga
APA Serra Do Timóteo	Municipal	2003	Atlantic Forest
APA Serra Dona Francisca	Municipal	1997	Atlantic Forest
APA Serra Dos Cocais	Municipal	2020	Atlantic Forest
APA Serra Geral De Goiás	State	1996	Cerrado
APA Serra São José	State	1990	Atlantic Forest
APA Serras E Brejos Do Capibaribe	State	2020	Caatinga
APA Silveiras	State	1984	Atlantic Forest
APA Sistema Cantareira	State	1998	Atlantic Forest
APA Sítio Dos Pintos	Municipal	1996	Atlantic Forest
APA Sul-rmbh	State	1994	Atlantic Forest
APA Suruí	Municipal	2007	Atlantic Forest
APA Tanquã-rio Piracicaba	State	2018	Cerrado
APA Taruma/ponta Negra	Municipal	2008	Amazonia
APA Tietê	State	1983	Atlantic Forest
APA Tinguazinho	Municipal	2004	Atlantic Forest
APA Trizidela De Uso Sustentável	Municipal	2016	Cerrado
APA Uruana De Minas	Municipal	2018	Cerrado
APA Vale Do Morro Da Torre	Municipal	2012	Atlantic Forest
APA Vale Do Rio Manso	Municipal	2018	Cerrado
APA Vargem Das Flores	State	2006	Atlantic Forest and Cerrado
APA Várzea Do Rio Tietê	State	1987	Atlantic Forest
APA Waldeir Gonçalves - Serra Do Itaóca	Municipal	2013	Atlantic Forest

ARIE Açude De Apipucos	Municipal	1996	Atlantic Forest
ARIE Area De Relevante Interesse Ecológico- Ilhas Do Rio Paraiba Do Sul	Municipal	2005	Atlantic Forest
ARIE Area De Relevante Interesse Ecologico Mata Das Perobas Tim Ferreira	Municipal	2018	Cerrado
ARIE Beberibe	Municipal	1996	Atlantic Forest
ARIE Capetinga/taquara+a306:a356	Federal	1985	Cerrado
ARIE Capivaras	Municipal	2001	Atlantic Forest
ARIE Corredor Ecológico Lagoa Encantada / Serra Do Conduru	Municipal	2009	Atlantic Forest
ARIE Cruls	State	2008	Cerrado
ARIE Curado	Municipal	1996	Atlantic Forest
ARIE Da Barra Do Rio Camaratuba	Municipal	1998	Atlantic Forest
ARIE Da Granja Do Ipê	State	1998	Cerrado
ARIE Da Vila Estrutural	State	2007	Cerrado
ARIE Das Maritacas	Municipal	2016	Atlantic Forest
ARIE De Goiamunduba	State	2002	Caatinga
ARIE De Itapebussus	Municipal	2002	Atlantic Forest
ARIE De São Conrado	Municipal	2003	Atlantic Forest
ARIE De São Sebastião	State	2008	Atlantic Forest
ARIE Do Bosque	State	2001	Cerrado
ARIE Do Cambeba	State	2018	Caatinga
ARIE Do Citrópolis	Municipal	2016	Atlantic Forest
ARIE Do Córrego Cabeceira Do Valo	State	2007	Cerrado
ARIE Do Córrego Mato Grande	State	2004	Cerrado
ARIE Do Morro Do Boa Vista	Municipal	2003	Atlantic Forest
ARIE Do Sítio Curió	State	2006	Caatinga
ARIE Do Torto	State	2006	Cerrado
ARIE Dois Irmãos	Municipal	1996	Atlantic Forest
ARIE Dois Unidos	Municipal	1996	Atlantic Forest
ARIE Dom Bosco	State	2000	Cerrado

ARIE Fazenda Raposa	State	2020	Caatinga
ARIE Ilha Do Zeca	Municipal	2003	Atlantic Forest
ARIE Ipojuca-merepe	State	2014	Atlantic Forest
ARIE Iputinga	Municipal	1996	Atlantic Forest
ARIE Japiim Pentecoste	State	2009	Amazonia
ARIE Jiquiá	Municipal	1996	Atlantic Forest
ARIE Joana Bezerra	Municipal	1996	Atlantic Forest
ARIE Lagoa Do Araçá	Municipal	1996	Atlantic Forest
ARIE Manguezais Da Foz Do Rio Mamanguape	Federal	1985	Atlantic Forest
ARIE Mata Da Várzea	Municipal	1996	Atlantic Forest
ARIE Mata Do Barro	Municipal	1996	Atlantic Forest
ARIE Matas Do Curado	Municipal	1996	Atlantic Forest
ARIE Orla Marítima	Municipal	1996	Atlantic Forest
ARIE Paranoá Sul	State	1988	Cerrado
ARIE Parque Jk	State	1996	Cerrado
ARIE Riacho Da Matinha	State	2021	Caatinga
ARIE Rio Jordão	Municipal	1996	Atlantic Forest
ARIE Santuário De Vida Silvestre Do Riacho Fundo	State	1988	Cerrado
ARIE São Miguel	Municipal	1996	Atlantic Forest
ARIE Serra Do Orobó	State	2002	Caatinga
ARIE Sítio Grande	Municipal	2008	Atlantic Forest
ARIE Tamandaré	Municipal	1996	Atlantic Forest
ARIE Zona De Vida Silvestre Da Da Ilha Comprida	State	1989	Atlantic Forest
ESEC Bananal	State	1964	Atlantic Forest
ESEC Bita E Utinga	State	2012	Atlantic Forest
ESEC Chaúas	State	1978	Atlantic Forest
ESEC Curral Do Meio	State	2014	Caatinga
ESEC De Águas Emendadas	State	1968	Cerrado
ESEC De Aiuaba	Federal	2001	Caatinga
ESEC De Assis	State	1992	Cerrado

ESEC De Carijós	Federal	1987	Atlantic Forest
ESEC De Corumbá	State	1964	Cerrado
ESEC De Cuniã	Federal	2001	Amazonia
ESEC De Fechos	State	1994	Atlantic Forest
ESEC De Itapeti	State	1952	Atlantic Forest
ESEC De Itapeva	State	1985	Atlantic Forest
ESEC De Marília	State	2010	Atlantic Forest
ESEC De Mata Preta	Federal	2005	Atlantic Forest
ESEC De Murici	Federal	2001	Atlantic Forest
ESEC De Santa Bárbara	State	1984	Cerrado
ESEC De Tamoios	Federal	1990	Atlantic Forest
ESEC De Uruçuí-una	Federal	1981	Cerrado
ESEC Do Caiuá	State	1994	Atlantic Forest
ESEC Do Castanhão	Federal	2001	Caatinga
ESEC Do Cercadinho	State	2006	Atlantic Forest
ESEC Do Grão Pará	State	2006	Amazonia
ESEC Do Jardim Botânico	State	1992	Cerrado
ESEC Do Noroeste Paulista	State	1993	Atlantic Forest
ESEC Do Pau Brasil	State	2002	Atlantic Forest
ESEC Do Pécem	State	2012	Caatinga
ESEC Do Rio Preto	State	2005	Cerrado
ESEC Do Rio Ronuro	State	1998	Amazonia
ESEC Do Rio Roosevelt	State	1997	Amazonia
ESEC Dos Caetetus	State	1976	Atlantic Forest
ESEC Estadual Aratinga	State	1997	Atlantic Forest
ESEC Estadual Wenceslau Guimarães	State	1997	Atlantic Forest
ESEC Fernandes Pinheiro	State	2001	Atlantic Forest
ESEC Itaberá	State	1957	Atlantic Forest
ESEC Juréia-itatins	State	1986	Atlantic Forest
ESEC Mar De Espanha	State	1974	Atlantic Forest

ESEC Mico Leão Preto	Federal	2002	Atlantic Forest
ESEC Municipal Do Caetê	Municipal	2019	Atlantic Forest
ESEC Municipal Ilha Do Lameirão	Municipal	1986	Atlantic Forest
ESEC Rio Dos Touros	State	2001	Atlantic Forest
ESEC Samuel	State	1989	Amazonia
ESEC Serra Geral Do Tocantins	Federal	2001	Cerrado
ESEC Valinhos	State	1966	Atlantic Forest
ESEC Veredas De Taquarussu	Municipal	2017	Atlantic Forest
Floresta Estadual De Assis	State	2002	Atlantic Forest and Cerrado
Floresta Estadual Do Amapá	State	2006	Amazonia
Floresta Estadual Do Araguaia	State	2002	Cerrado
Floresta Estadual Do Noroeste Paulista	State	2018	Atlantic Forest
Floresta Estadual Do Passa Dois	State	1990	Atlantic Forest
Floresta Estadual Do Trombetas	State	2006	Amazonia
Floresta Estadual Do Uaimii	State	2003	Atlantic Forest
Floresta Estadual Edmundo Navarro De Andrade	State	2002	Atlantic Forest
Floresta Estadual José Zago	State	2016	Atlantic Forest
Floresta Estadual Pederneiras	State	2002	Atlantic Forest and Cerrado
Floresta Nacional Da Restinga De Cabedelo	Federal	2004	Atlantic Forest
Floresta Nacional De Açu	Federal	1950	Caatinga
Floresta Nacional De Assungui	Federal	1968	Atlantic Forest
Floresta Nacional De Balata-tufari	Federal	2005	Amazonia
Floresta Nacional De Brasília	Federal	1999	Cerrado
Floresta Nacional De Caçador	Federal	1968	Atlantic Forest
Floresta Nacional De Carajás	Federal	1998	Amazonia
Floresta Nacional De Chapecó	Federal	1968	Atlantic Forest
Floresta Nacional De Contendas Do Sincorá	Federal	1999	Caatinga
Floresta Nacional De Cristópolis	Federal	2001	Cerrado

Floresta Nacional De Goytacazes	Federal	2002	Atlantic Forest
Floresta Nacional De Humaitá	Federal	1999	Amazonia
Floresta Nacional De Itaituba I	Federal	1998	Amazonia
Floresta Nacional De Itaituba Ii	Federal	1998	Amazonia
Floresta Nacional De Jatuarana	Federal	2002	Amazonia
Floresta Nacional De Lorena	Federal	1934	Atlantic Forest
Floresta Nacional De Mário Xavier	Federal	1986	Atlantic Forest
Floresta Nacional De Pacotuba	Federal	2002	Atlantic Forest
Floresta Nacional De Palmares	Federal	2005	Cerrado
Floresta Nacional De Paraopeba	Federal	1950	Cerrado
Floresta Nacional De Passa Quatro	Federal	1968	Atlantic Forest
Floresta Nacional De Passo Fundo	Federal	1968	Atlantic Forest
Floresta Nacional De Piraí Do Sul	Federal	2004	Atlantic Forest
Floresta Nacional De São Francisco De Paula	Federal	1968	Atlantic Forest
Floresta Nacional De Sobral	Federal	1947	Caatinga
Floresta Nacional De Tapajós	Federal	1974	Amazonia
Floresta Nacional De Três Barras	Federal	1968	Atlantic Forest
Floresta Nacional Do Amazonas	Federal	1989	Amazonia
Floresta Nacional Do Araripe-apodi	Federal	1946	Caatinga
Floresta Nacional Do Ibura	Federal	2005	Atlantic Forest
Monumento Natural Atalaia	State	2018	Amazonia
Monumento Natural Canyons E Corredeiras Do Rio Sono	Municipal	2012	Cerrado
Monumento Natural Das Árvores Fossilizadas Do Estado Do Tocantins	State	2000	Cerrado
Monumento Natural Das Lagoas	Municipal	2016	Cerrado
Monumento Natural Do Itabira	Municipal	1988	Atlantic Forest
Monumento Natural Do Rio São Francisco	Federal	2009	Caatinga
Monumento Natural Dos Canions Do Subaé	State	2006	Atlantic Forest
Monumento Natural Dos Pontões Capixabas	Federal	2002	Atlantic Forest

Monumento Natural Estadual Da Serra Da Beleza	State	2017	Atlantic Forest
Monumento Natural Estadual De Itatiaia	State	2009	Atlantic Forest
Monumento Natural Estadual Gruta Rei Do Mato	State	1984	Cerrado
Monumento Natural Estadual Lnova De Vazante	State	2016	Cerrado
Monumento Natural Estadual Mantiqueira Paulista	State	2021	Atlantic Forest
Monumento Natural Estadual Peter Lund	State	2005	Cerrado
Monumento Natural Estadual Pico Do Ibituruna	State	1998	Atlantic Forest
Monumento Natural Estadual Serra Da Moeda	State	2010	Atlantic Forest
Monumento Natural Estadual Serra Das Torres	State	2010	Atlantic Forest
Monumento Natural Morro Chico Mendes	Municipal	1988	Amazonia
Monumento Natural Municipal Da Floresta	Municipal	2017	Atlantic Forest
Monumento Natural Municipal Da Galheta	Municipal	2014	Atlantic Forest
Monumento Natural Municipal Da Lagoa Do Peri	Municipal	2019	Atlantic Forest
Monumento Natural Municipal Da Pedra Bonita	Municipal	2018	Atlantic Forest
Monumento Natural Municipal Da Pedra De Inoã	Municipal	2011	Atlantic Forest
Monumento Natural Municipal Da Pedra De Itaocaia	Municipal	2010	Atlantic Forest
Monumento Natural Municipal Da Serra Da Bolívia	Municipal	2012	Atlantic Forest
Monumento Natural Municipal Do Encontro Dos Três Rios	Municipal	2010	Atlantic Forest
Monumento Natural Municipal Do Pico Do Itaguaré	Municipal	2012	Atlantic Forest
Monumento Natural Municipal Falésias De Marataízes	Municipal	2008	Atlantic Forest
Monumento Natural Municipal Gruta Nossa Senhora Da Lapa	Municipal	2011	Atlantic Forest
Monumento Natural Municipal Pedra Do Monjolo	Municipal	2015	Atlantic Forest
Monumento Natural Municipal São Simão	Municipal	2018	Atlantic Forest
Monumento Natural Municipal Serra Da Ferrugem	Municipal	2007	Atlantic Forest
Monumento Natural O Frade E A Freira	State	2007	Atlantic Forest
Monumento Natural Serra Da Calçada	Municipal	2013	Atlantic Forest
Monumento Natural Vale Dos Dinossauros	State	2002	Caatinga
Parque Distrital Salto Do Tororó	State	2015	Cerrado

Parque Estadual Águas Lindas	State	2019	Cerrado
Parque Estadual Biribiri	State	1998	Cerrado
Parque Estadual Botânico Do Ceará	State	1996	Caatinga
Parque Estadual Caverna Do Diabo	State	2008	Atlantic Forest
Parque Estadual Cunhambebe	State	2008	Atlantic Forest
Parque Estadual Da Cantareira	State	1968	Atlantic Forest
Parque Estadual Da Costa Do Sol	State	2011	Atlantic Forest
Parque Estadual Da Fonte Grande	Municipal	1986	Atlantic Forest
Parque Estadual Da Lagoa Do Açu	State	2012	Atlantic Forest
Parque Estadual Da Lgrande	State	2006	Cerrado
Parque Estadual Da Pedra Selada	State	2012	Atlantic Forest
Parque Estadual Da Serra Da Concórdia	State	2002	Atlantic Forest
Parque Estadual Da Serra Da Tiririca	State	1993	Atlantic Forest
Parque Estadual Da Serra Do Cabral	State	2005	Cerrado
Parque Estadual Da Serra Do Conduru	State	1997	Atlantic Forest
Parque Estadual Da Serra Do Mar	State	1977	Atlantic Forest
Parque Estadual Da Serra Do Tabuleiro	State	1975	Atlantic Forest
Parque Estadual Da Serra Dourada	State	2003	Cerrado
Parque Estadual Das Nascentes Do Rio Taquari	State	1999	Cerrado
Parque Estadual Das Sete Passagens	State	2000	Caatinga
Parque Estadual Das Trilhas	State	2017	Atlantic Forest
Parque Estadual Das Várzeas Do Rio Ivinhema	State	1998	Atlantic Forest
Parque Estadual De Águas Quentes	State	1978	Cerrado
Parque Estadual De Amaporã	State	2011	Atlantic Forest
Parque Estadual De Botumirim	State	2018	Cerrado
Parque Estadual De Campinhos	State	1960	Atlantic Forest
Parque Estadual De Dois Irmãos	State	1987	Atlantic Forest
Parque Estadual De Espigão Alto	State	1949	Atlantic Forest
Parque Estadual De Guajará-mirim	State	1990	Amazonia
Parque Estadual De Ilhabela	State	1977	Atlantic Forest

Parque Estadual De Itaberaba	State	2010	Atlantic Forest
Parque Estadual De Itapetinga	State	2010	Atlantic Forest
Parque Estadual De Itapeva	State	2002	Atlantic Forest
Parque Estadual De Itapuã	State	1991	Pampa
Parque Estadual De Itaúnas	State	1991	Atlantic Forest
Parque Estadual De Mata Das Flores	State	1992	Atlantic Forest
Parque Estadual De Monte Alegre	State	2001	Amazonia
Parque Estadual De Paracatu	State	2011	Cerrado
Parque Estadual De Paraúna	State	2002	Cerrado
Parque Estadual De Santa Clara	State	2006	Atlantic Forest
Parque Estadual De Terra Ronca	State	1989	Cerrado
Parque Estadual De Vassununga	State	1970	Atlantic Forest
Parque Estadual Do Aguapeí	State	1998	Atlantic Forest
Parque Estadual Do Bacanga	State	1980	Amazonia
Parque Estadual Do Boguaçu	State	1998	Atlantic Forest
Parque Estadual Do Cantão	State	1998	Cerrado
Parque Estadual Do Caxambu	State	1979	Atlantic Forest
Parque Estadual Do Cocó	State	2017	Caatinga
Parque Estadual Do Delta Do Jacuí	State	1976	Pampa
Parque Estadual Do Desengano	State	1970	Atlantic Forest
Parque Estadual Do Itacolomi	State	1967	Atlantic Forest
Parque Estadual Do Jalapão	State	2001	Cerrado
Parque Estadual Do João Leite	State	2014	Cerrado
Parque Estadual Do Juquery	State	1993	Atlantic Forest
Parque Estadual Do Lajeado	State	2001	Cerrado
Parque Estadual Do Matupiri	State	2009	Amazonia
Parque Estadual Do Mendanha	State	2013	Atlantic Forest
Parque Estadual Do Morro Do Chapéu	State	1998	Caatinga
Parque Estadual Do Morro Do Diabo	State	1941	Atlantic Forest
Parque Estadual Do Papagaio-charão	State	1982	Atlantic Forest

			and Pampa
Parque Estadual Do Poeta E Repentista Juvenal De Oliveira	State	2004	Caatinga
Parque Estadual Do Rio Da Onça	State	1981	Atlantic Forest
Parque Estadual Do Rio Doce	State	1944	Atlantic Forest
Parque Estadual Do Rio Peixe	State	2002	Atlantic Forest
Parque Estadual Do Rio Turvo	State	2008	Atlantic Forest
Parque Estadual Do Rio Vermelho	State	2007	Atlantic Forest
Parque Estadual Do Sítio Do Rangedor	State	2005	Amazonia
Parque Estadual Do Utinga	State	1993	Amazonia
Parque Estadual Dom Osório Stoffel	State	2002	Cerrado
Parque Estadual Dos Pirineus	State	1987	Cerrado
Parque Estadual Grão Mogol	State	1998	Cerrado
Parque Estadual Lagamar De Cananeia	State	2008	Atlantic Forest
Parque Estadual Lagoa Do Cajueiro	State	1988	Caatinga
Parque Estadual Massairo Okamura	State	2000	Cerrado
Parque Estadual Mata De Duas Lagoas	State	1987	Atlantic Forest
Parque Estadual Mata Do Zumbi	State	1987	Atlantic Forest
Parque Estadual Mata Seca	State	2000	Caatinga
Parque Estadual Matas Do Segredo	State	2000	Cerrado
Parque Estadual Nascentes Do Paranapanema	State	2012	Atlantic Forest
Parque Estadual Nova Baden	State	1974	Atlantic Forest
Parque Estadual Paulo César Vinha	State	1990	Atlantic Forest
Parque Estadual Ponta Da Tulha	State	2015	Atlantic Forest
Parque Estadual Restinga De Bertioga	State	2010	Atlantic Forest
Parque Estadual Serra Azul	State	1994	Cerrado
Parque Estadual Serra Das Araras	State	1998	Cerrado
Parque Estadual Serra Do Aracá	State	1990	Amazonia
Parque Estadual Serra Do Ouro Branco	State	2009	Atlantic Forest
Parque Estadual Serra Do Rola Moça	State	1994	Atlantic Forest

Parque Estadual Serra Do Sobrado	State	2010	Cerrado
Parque Estadual Serra Negra	State	1998	Atlantic Forest and Cerrado
Parque Estadual Serra Ricardo Franco	State	1997	Amazonia
Parque Estadual Serra Santa Bárbara	State	1997	Amazonia
Parque Estadual Serra Verde	State	2007	Cerrado
Parque Estadual Sete Salões	State	1998	Atlantic Forest
Parque Estadual Sítio Fundão	State	2008	Caatinga
Parque Estadual Tucumã	State	2002	Amazonia
Parque Estadual Turístico Do Alto Do Ribeira	State	1958	Atlantic Forest
Parque Estadual Vitório Piassa	State	2009	Atlantic Forest
Parque Estadual Zé Bolo Flô	State	2000	Cerrado
Parque Municipal Natural Da Boa Esperança	Municipal	2001	Atlantic Forest
Parque Municipal Natural Tamarino De Ávila E Silva	Municipal	2016	Atlantic Forest
Parque Nacional Cavernas Do Peruaçu	Federal	1999	Caatinga
Parque Nacional Da Amazônia	Federal	1974	Amazonia
Parque Nacional Da Chapada Diamantina	Federal	1985	Caatinga
Parque Nacional Da Chapada Dos Guimarães	Federal	1989	Cerrado
Parque Nacional Da Chapada Dos Veadeiros	Federal	1961	Cerrado
Parque Nacional Da Serra Da Bocaina	Federal	1971	Atlantic Forest
Parque Nacional Da Serra Da Bodoquena	Federal	2000	Cerrado
Parque Nacional Da Serra Da Canastra	Federal	1972	Cerrado
Parque Nacional Da Serra Da Capivara	Federal	1979	Caatinga
Parque Nacional Da Serra Das Lontras	Federal	2010	Atlantic Forest
Parque Nacional Da Serra De Itabaiana	Federal	2005	Atlantic Forest
Parque Nacional Da Serra Do Cipó	Federal	1984	Atlantic Forest and Cerrado
Parque Nacional Da Serra Do Gandarela	Federal	2014	Atlantic Forest
Parque Nacional Da Serra Do Itajaí	Federal	2004	Atlantic Forest
Parque Nacional Da Serra Dos Orgãos	Federal	1939	Atlantic Forest

Parque Nacional Da Serra Geral	Federal	1992	Atlantic Forest
Parque Nacional Da Tijuca	Federal	1961	Atlantic Forest
Parque Nacional Das Araucárias	Federal	2005	Atlantic Forest
Parque Nacional Das Emas	Federal	1961	Cerrado
Parque Nacional Das Nascentes Do Rio Parnaiba	Federal	2002	Cerrado
Parque Nacional De Aparados Da Serra	Federal	1959	Atlantic Forest
Parque Nacional De Boa Nova	Federal	2010	Atlantic Forest and Caatinga
Parque Nacional De Brasília	Federal	1961	Cerrado
Parque Nacional De Caparaó	Federal	1961	Atlantic Forest
Parque Nacional De Ilha Grande	Federal	1997	Atlantic Forest
Parque Nacional De Jericoacoara	Federal	2013	Caatinga
Parque Nacional De Saint-hilaire/lange	Federal	2001	Atlantic Forest
Parque Nacional De São Joaquim	Federal	1961	Atlantic Forest
Parque Nacional De Sete Cidades	Federal	1961	Cerrado
Parque Nacional De Ubajara	Federal	1953	Caatinga
Parque Nacional Do Araguaia	Federal	1959	Cerrado
Parque Nacional Do Boqueirão Da Onça	Federal	2018	Caatinga
Parque Nacional Do Catimbau	Federal	2002	Caatinga
Parque Nacional Do Descobrimento	Federal	1999	Atlantic Forest
Parque Nacional Do Iguaçu	Federal	1939	Atlantic Forest
Parque Nacional Do Itatiaia	Federal	1937	Atlantic Forest
Parque Nacional Do Jamanxim	Federal	2006	Amazonia
Parque Nacional Do Juruena	Federal	2006	Amazonia
Parque Nacional Do Monte Pascoal	Federal	1961	Atlantic Forest
Parque Nacional Do Pico Da Neblina	Federal	1979	Amazonia
Parque Nacional Dos Campos Gerais	Federal	2006	Atlantic Forest
Parque Nacional Dos Lençois Maranhenses	Federal	1981	Cerrado
Parque Nacional Guaricana	Federal	2014	Atlantic Forest
Parque Nacional Restinga De Jurubatiba	Federal	1998	Atlantic Forest

Parque Nacional Serra Das Confusões	Federal	1998	Caatinga
Parque Natural Municipal Antônio Sansão Pacheco	Municipal	2021	Atlantic Forest
Parque Natural Municipal Banhado Da Imperatriz	Municipal	2005	Atlantic Forest
Parque Natural Municipal Bosque Da Barra	Municipal	1983	Atlantic Forest
Parque Natural Municipal Chico Mendes	Municipal	1989	Atlantic Forest
Parque Natural Municipal Claudino Francio	Municipal	2018	Cerrado
Parque Natural Municipal Da Água Escondida	Municipal	2008	Atlantic Forest
Parque Natural Municipal Da Cachoeira De Santo Antônio	Municipal	2015	Atlantic Forest
Parque Natural Municipal Da Cascata Do Salso	Municipal	2021	Pampa
Parque Natural Municipal Da Catacumba	Municipal	1979	Atlantic Forest
Parque Natural Municipal Da Cidade	Municipal	2008	Atlantic Forest
Parque Natural Municipal Da Freguesia	Municipal	1992	Atlantic Forest
Parque Natural Municipal Da Lagoinha Do Leste	Municipal	2018	Atlantic Forest
Parque Natural Municipal Da Macaqueiras	Municipal	2003	Caatinga
Parque Natural Municipal Da Mata Atlântica	Municipal	2017	Atlantic Forest
Parque Natural Municipal Da Mata Atlântica	Municipal	2010	Atlantic Forest
Parque Natural Municipal Da Mata Atlântica Aldeense	Municipal	2013	Atlantic Forest
Parque Natural Municipal Da Restinga De Praia Do Forte	Municipal	2008	Atlantic Forest
Parque Natural Municipal Da Restinga Do Barreto	Municipal	2016	Atlantic Forest
Parque Natural Municipal Da Ronda	Municipal	2007	Atlantic Forest
Parque Natural Municipal Da Serra De São Domingos	Municipal	1988	Atlantic Forest
Parque Natural Municipal Da Serra Do Mendanha	Municipal	1994	Atlantic Forest
Parque Natural Municipal Das Araucarias	Municipal	1991	Atlantic Forest
Parque Natural Municipal Das Dunas Da Lagoa Da Conceição	Municipal	2018	Atlantic Forest
Parque Natural Municipal Das Dunas Da Sabiaguaba	Municipal	2006	Caatinga
Parque Natural Municipal David Victor Farina	Municipal	1995	Atlantic Forest
Parque Natural Municipal De Bicanga	Municipal	2007	Atlantic Forest

Parque Natural Municipal De Castanhal/pará	Municipal	2018	Amazonia
Parque Natural Municipal De Conceição Da Barra	Municipal	2015	Atlantic Forest
Parque Natural Municípal De Domingos Martins	Municipal	2010	Atlantic Forest
Parque Natural Municipal De Fechos	Municipal	2015	Atlantic Forest
Parque Natural Municipal De Glória De Dourados	Municipal	2019	Atlantic Forest
Parque Natural Municipal De Itaperuna	Municipal	2014	Atlantic Forest
Parque Natural Municipal De Jacarenema	Municipal	2003	Atlantic Forest
Parque Natural Municipal De Marapendi	Municipal	1978	Atlantic Forest
Parque Natural Municipal De Niterói	Municipal	2014	Atlantic Forest
Parque Natural Municipal De Petrópolis	Municipal	2007	Atlantic Forest
Parque Natural Municipal De Redenção	Municipal	2020	Amazonia
Parque Natural Municipal De São Roque	Municipal	1999	Atlantic Forest
Parque Natural Municipal Do Aricanga Waldemar Devens	Municipal	1997	Atlantic Forest
Parque Natural Municipal Do Atalaia	Municipal	2007	Atlantic Forest
Parque Natural Municipal Do Banhado	Municipal	2012	Atlantic Forest
Parque Natural Municipal Do Córrego Cumandaí	Municipal	2001	Atlantic Forest
Parque Natural Municipal Do Córrego Mimoso	Municipal	2019	Cerrado
Parque Natural Municipal Do Curió	Municipal	2002	Atlantic Forest
Parque Natural Municipal Do Distrito De Santa Terezinha	Municipal	2004	Atlantic Forest
Parque Natural Municipal Do Dourado	Municipal	2002	Atlantic Forest
Parque Natural Municipal Do Forte De Tamandare	Municipal	2003	Atlantic Forest
Parque Natural Municipal Do Intelecto	Municipal	1991	Atlantic Forest
Parque Natural Municipal Do Livramento	Municipal	2018	Atlantic Forest
Parque Natural Municipal Do Maciço Da Costeira	Municipal	2018	Atlantic Forest
Parque Natural Municipal Do Manguezal De Itanguá	Municipal	2007	Atlantic Forest
Parque Natural Municipal Do Morro Da Cruz	Municipal	2013	Atlantic Forest
Parque Natural Municipal Do Morro Dos Ventos	Municipal	2019	Amazonia
Parque Natural Municipal Do Pampa	Municipal	2014	Pampa

Parque Natural Municipal Do Paragem	Municipal	2007	Atlantic Forest
Parque Natural Municipal Do Pequi	Municipal	2012	Cerrado
Parque Natural Municipal Do Poxim	Municipal	2016	Atlantic Forest
Parque Natural Municipal Do Setor Santa Cruz	Municipal	2004	Cerrado
Parque Natural Municipal Dos Corais De Armação Dos Búzios	Municipal	2009	Atlantic Forest
Parque Natural Municipal Dos Pinheiros	Municipal	2020	Atlantic Forest
Parque Natural Municipal Dos Puris	Municipal	2013	Atlantic Forest
Parque Natural Municipal Dujardes Caldeira	Municipal	2017	Cerrado
Parque Natural Municipal Elci Rolla Guerra	Municipal	1988	Atlantic Forest
Parque Natural Municipal Eli Bastos	Municipal	2018	Cerrado
Parque Natural Municipal Entre Trevos	Municipal	2021	Cerrado
Parque Natural Municipal Estoril - Virgílio Simionato	Municipal	2013	Atlantic Forest
Parque Natural Municipal Fazenda Do Viegas	Municipal	1996	Atlantic Forest
Parque Natural Municipal Floresta Do Baldeador	Municipal	2021	Atlantic Forest
Parque Natural Municipal Fonte Da Saudade	Municipal	2000	Atlantic Forest
Parque Natural Municipal Freymund Germer	Municipal	2011	Atlantic Forest
Parque Natural Municipal Gruta Da Onça	Municipal	1988	Atlantic Forest
Parque Natural Municipal Ilha Das Capivaras/sibara	Municipal	2006	Atlantic Forest
Parque Natural Municipal Jaceguava	Municipal	2012	Atlantic Forest
Parque Natural Municipal Jardim Botânico	Municipal	2018	Amazonia
Parque Natural Municipal José Guilherme Merquior	Municipal	2000	Atlantic Forest
Parque Natural Municipal Lagoa Das Garças	Municipal	1996	Amazonia
Parque Natural Municipal Logemann	Municipal	2021	Atlantic Forest
Parque Natural Municipal Montanhas De Teresópolis	Municipal	2009	Atlantic Forest
Parque Natural Municipal Morro Do Céu	Municipal	2008	Atlantic Forest
Parque Natural Municipal Morro Do Ouro	Municipal	2004	Atlantic Forest
Parque Natural Municipal Morro José Lutzenberger	Municipal	2013	Pampa
Parque Natural Municipal Nascentes De Paranapiacaba	Municipal	2003	Atlantic Forest

Parque Natural Municipal Olesio Dos Santos	Municipal	2005	Atlantic Forest
Parque Natural Municipal Parque Florestal De Sinop	Municipal	2014	Amazonia
Parque Natural Municipal Pedra Dos Olhos	Municipal	2003	Atlantic Forest
Parque Natural Municipal Pedro Geraldo De Menezes	Municipal	2012	Cerrado
Parque Natural Municipal Penhasco Dois Irmãos - Arquiteto Sérgio Bernardes	Municipal	1992	Atlantic Forest
Parque Natural Municipal Piray	Municipal	2004	Cerrado
Parque Natural Municipal Raimundo Gonçalez Malta	Municipal	1993	Atlantic Forest
Parque Natural Municipal Rego Dos Carrapatos	Municipal	2012	Atlantic Forest
Parque Natural Municipal Riacho Estrela	Municipal	2018	Cerrado
Parque Natural Municipal Ribeirão Da Prata	Municipal	2014	Cerrado
Parque Natural Municipal Saint Hilaire	Municipal	2015	Pampa
Parque Natural Municipal Salão De Pedras	Municipal	1999	Atlantic Forest
Parque Natural Municipal Senhorinha Lemos Do Prado	Municipal	2017	Cerrado
Parque Natural Municipal Três Coqueiros	Municipal	2009	Atlantic Forest
Parque Natural Municipal Vale Do Esperança	Municipal	2017	Amazonia
Parque Natural Municipal Vale Do Itaim	Municipal	2018	Atlantic Forest
Parque Natural Municipal Vale Do Mulembá	Municipal	2002	Atlantic Forest
Parque Natural Municipal Verde Vale	Municipal	2008	Atlantic Forest
Parque Natural Municipal Vista Alegre	Municipal	2012	Atlantic Forest
Parque Natural Municipal Voçoroca Do Córrego Do Cravo	Municipal	2010	Atlantic Forest
Parque Natural Municipal Voçoroca Do Lar Dos Idosos	Municipal	2010	Atlantic Forest
Parque Natural Municipal Xokleng	Municipal	2020	Atlantic Forest
Parque Natural Municipal Zabele	Municipal	2002	Caatinga and Cerrado
RDS Alcobaça	State	2002	Amazonia
RDS Campo Das Mangabas	State	2016	Amazonia
RDS Dos Pinheirinhos	State	2008	Atlantic Forest
RDS Estadual Concha D´ostra	State	2007	Atlantic Forest

RDS Estadual Ponta Do Tubarão	State	2003	Caatinga
RDS Igapó-açu	State	2009	Amazonia
RDS Municipal Do Manguezal De Cariacica	Municipal	2007	Atlantic Forest
RDS Municipal Papagaio	Municipal	2011	Atlantic Forest
RDS Municipal Piraque-açú E Piraque-mirim	Municipal	1986	Atlantic Forest
RDS Pucuruí - Ararão	State	2002	Amazonia
RDS Quilombos De Barra Do Turvo	State	2008	Atlantic Forest
RDS Rio Amapá	State	2005	Amazonia
RDS Veredas Do Acari	State	2003	Cerrado
REBIO Bom Jesus	Federal	2012	Atlantic Forest
REBIO Da Contagem	Federal	2002	Cerrado
REBIO Da Mata Escura	Federal	2003	Atlantic Forest
REBIO Das Araucárias	Federal	2006	Atlantic Forest
REBIO Das Perobas	Federal	2006	Atlantic Forest
REBIO De Araras	State	1977	Atlantic Forest
REBIO De Pinheiro Grosso	Municipal	1987	Atlantic Forest
REBIO De Saltinho	Federal	1983	Atlantic Forest
REBIO De Serra Negra	Federal	1982	Caatinga
REBIO De Sooretama	Federal	1982	Atlantic Forest
REBIO De Una	Federal	1980	Atlantic Forest
REBIO Do Cerradão	State	1998	Cerrado
REBIO Do Gama	State	1988	Cerrado
REBIO Do Guará	State	1988	Cerrado
REBIO Do Mato Grande	State	1975	Pampa
REBIO Do Rio Descoberto	State	2005	Cerrado
REBIO Do São Donato	State	1975	Pampa
REBIO Do Sassafrás	State	1977	Atlantic Forest
REBIO Do Tinguá	Federal	1989	Atlantic Forest
REBIO Estadual De Guaratiba	State	1914	Atlantic Forest
REBIO Estadual Mata Paludosa	State	1998	Atlantic Forest

REBIO Guaribas	Federal	1990	Atlantic Forest
REBIO Municipal Das Aves	Municipal	2019	Atlantic Forest
REBIO União	Federal	1998	Atlantic Forest
RESEX Acaú-goiana	Federal	2007	Atlantic Forest
RESEX Arapiranga-tromaí	Federal	2018	Amazonia
RESEX Chico Mendes	Federal	1990	Amazonia
RESEX Chocoaré-mato Grosso	Federal	2002	Amazonia
RESEX De Canavieiras	Federal	2006	Atlantic Forest
RESEX De Cassurubá	Federal	2009	Atlantic Forest
RESEX De Cururupu	Federal	2004	Amazonia
RESEX Do Lago Do Capanã Grande	Federal	2004	Amazonia
RESEX Do Recanto Das Araras De Terra Ronca	Federal	2006	Cerrado
RESEX Guariba-roosevelt	State	1996	Amazonia
RESEX Ipaú-anilzinho	Federal	2005	Amazonia
RESEX Lago Do Cedro	Federal	2006	Cerrado
RESEX Mae Grande De Curuça	Federal	2002	Amazonia
RESEX Mandira	Federal	2002	Atlantic Forest
RESEX Maracanã	Federal	2002	Amazonia
RESEX Marinha Arai-peroba	Federal	2005	Amazonia
RESEX Marinha Arraial Do Cabo	Federal	1997	Atlantic Forest
RESEX Marinha Caetétaperaçu	Federal	2005	Amazonia
RESEX Marinha Cuinarana	Federal	2014	Amazonia
RESEX Marinha Da Baia De Iguapé	Federal	2000	Atlantic Forest
RESEX Marinha Da Lagoa Do Jequiá	Federal	2001	Atlantic Forest
RESEX Marinha De Gurupi-piriá	Federal	2005	Amazonia
RESEX Marinha De Itaipu	State	2013	Atlantic Forest
RESEX Marinha De Soure	Federal	2001	Amazonia
RESEX Marinha Mestre Lucindo	Federal	2014	Amazonia
RESEX Marinha Mocapajuba	Federal	2014	Amazonia
RESEX Marinha Pirajubaé	Federal	1992	Atlantic Forest

RESEX Marinha Tracuateua	Federal	2005	Amazonia
RESEX Mata Grande	Federal	1992	Cerrado
RESEX Quilombo Do Frechal	Federal	1992	Amazonia
RESEX Rio Ouro Preto	Federal	1990	Amazonia
RESEX Riozinho Da Liberdade	Federal	2005	Amazonia
RESEX São João Da Ponta	Federal	2002	Amazonia
REVIS - Fazenda São Lázaro	Municipal	2018	Atlantic Forest
REVIS Da Floresta Do Camboatá	Municipal	2021	Atlantic Forest
REVIS Da Lagoa Do Taí	Municipal	2021	Atlantic Forest
REVIS Da Serra Da Estrela	State	2017	Atlantic Forest
REVIS Da Serra Dos Montes Altos	State	2010	Caatinga
REVIS Da Ventania	Municipal	2010	Atlantic Forest
REVIS De Boa Nova	Federal	2010	Atlantic Forest and Caatinga
REVIS De Santa Cruz	Federal	2010	Atlantic Forest
REVIS De Una	Federal	2007	Atlantic Forest
REVIS Do Chaua	Municipal	2013	Atlantic Forest
REVIS Do Sagui Da Serra Escuro	Municipal	2014	Atlantic Forest
REVIS Dos Campos De Palmas	Federal	2006	Atlantic Forest
REVIS Dos Morros Do Caraunã E Do Padre	State	2012	Caatinga
REVIS Engenho Moreninho	State	1987	Atlantic Forest
REVIS Estadual Da Lagoa Da Turfeira	State	2016	Atlantic Forest
REVIS Estadual Do Médio Paraíba	State	2016	Atlantic Forest
REVIS Estadual Dos Rios Tijuco E Da Prata	State	2011	Atlantic Forest
REVIS Estadual Macaúbas	State	2013	Cerrado
REVIS Mata Da Usina São José	State	1987	Atlantic Forest
REVIS Mata De Bom Jardim	State	1987	Atlantic Forest
REVIS Mata De Jaguaribe	State	1987	Atlantic Forest
REVIS Mata De Miritiba	State	1987	Atlantic Forest
REVIS Mata De Mussaíba	State	1987	Atlantic Forest

REVIS Mata De Santa Cruz	State	1987	Atlantic Forest
REVIS Mata Do Amparo	State	1987	Atlantic Forest
REVIS Mata Do Buraquinho	State	2014	Atlantic Forest
REVIS Mata Do Contra-açude	State	1987	Atlantic Forest
REVIS Mata Do Curado	State	1987	Atlantic Forest
REVIS Mata Do Engenho Salgadinho	State	1987	Atlantic Forest
REVIS Mata Do Engenho Uchôa	State	1987	Atlantic Forest
REVIS Mata Do Junco	State	2007	Atlantic Forest
REVIS Mata Engenho Macaxeira	State	1987	Atlantic Forest
REVIS Mata São João Da Várzea	State	1987	Atlantic Forest
REVIS Matas De Siriji	State	2014	Atlantic Forest
REVIS Matas Do Sistema Gurjaú	State	1987	Atlantic Forest
REVIS Municipal Andre Ruschi	Municipal	2017	Atlantic Forest
REVIS Municipal Da Mata Paludosa	Municipal	2018	Atlantic Forest
REVIS Municipal Das Serras De Maricá	Municipal	2011	Atlantic Forest
REVIS Municipal Do Morro Do Lampião	Municipal	2021	Atlantic Forest
REVIS Municipal Meiembipe	Municipal	2021	Atlantic Forest
REVIS Padre Sérgio Tonetto	State	2016	Amazonia
REVIS Periquito Cara-suja	State	2018	Caatinga
REVIS Refúgio Estadual De Vida Silvestre Libélulas Da Serra De São José	State	2004	Atlantic Forest
REVIS Riacho Pontal	State	2014	Caatinga
REVIS Serra Do Cumaru	State	1987	Atlantic Forest
REVIS Serras Caatingueiras	State	2019	Caatinga
REVIS Tatu-bola	State	2015	Caatinga
REVIS Veredas Do Oeste Baiano	Federal	2002	Cerrado
RPPN Águia Branca	State	2017	Atlantic Forest
RPPN Albert Scharle	State	2014	Atlantic Forest
RPPN Alto Do Palacio	State	2006	Cerrado
RPPN Alto Gururu	State	2016	Atlantic Forest

RPPN Alto Sereno	State	2015	Atlantic Forest
RPPN Armil	Federal	2018	Caatinga
RPPN Aves Gerais	Federal	2012	Atlantic Forest
RPPN Barra De Santana	State	2019	Atlantic Forest
RPPN Benjamim Vicente Pereira	State	2018	Atlantic Forest
RPPN Bico Do Javaés	Federal	2011	Cerrado
RPPN Boa Vista	State	2011	Atlantic Forest
RPPN Brava Beach Internacional	Federal	2018	Atlantic Forest
RPPN Cabeceira Da Lagoa	State	2011	Cerrado
RPPN Cachoeira Alta	Federal	2008	Atlantic Forest
RPPN Cachoeira Da Fumaça	State	2011	Atlantic Forest
RPPN Cachoeiras Do São Bento	State	2010	Cerrado and Pantanal
RPPN Caldeirão	State	2013	Atlantic Forest
RPPN Cambuí Velho	State	2003	Atlantic Forest
RPPN Canto Dos Pássaros	State	2013	Atlantic Forest
RPPN Canto Dos Pássaros Ii	State	2013	Atlantic Forest
RPPN Chácara Edith	Federal	2001	Atlantic Forest
RPPN Chacara Santa Inez	State	2015	Atlantic Forest
RPPN Chanceler Edson Queiroz	Federal	2006	Caatinga
RPPN Cícero Almeida	Federal	2013	Caatinga
RPPN Córrego Do Macaco	State	2020	Cerrado
RPPN Corvo Branco	Federal	2012	Atlantic Forest
RPPN Cotinga-crejoá	State	2016	Atlantic Forest
RPPN Curucaca 1	Federal	2009	Atlantic Forest
RPPN Curucaca 2	Federal	2009	Atlantic Forest
RPPN Curucaca 3	Federal	2009	Atlantic Forest
RPPN Curucaca 4	Federal	2008	Atlantic Forest
RPPN Da Unisc	Federal	2009	Atlantic Forest
RPPN Das Dunas	Federal	2004	Atlantic Forest

RPPN Do Caju	Federal	2011	Atlantic Forest
RPPN Douglas Vieira Soares	State	2010	Atlantic Forest
RPPN Duas Pedras	State	2010	Atlantic Forest
RPPN Dubinha Guimarães	State	2017	Atlantic Forest
RPPN Dunas De Santo Antônio	Federal	2001	Atlantic Forest
RPPN Dutra Pimenta	State	2016	Atlantic Forest
RPPN Estadual Aroeira Vermelha	State	2019	Atlantic Forest
RPPN Estadual Complexo Serra Da Farofa	State	2014	Atlantic Forest
RPPN Estadual Das Cascatas	State	2015	Atlantic Forest
RPPN Estadual Icap - Industria E Comércio Catarinense De Pescados Ltda	State	2022	Atlantic Forest
RPPN Estadual Natureza Viva Brf	State	2020	Atlantic Forest
RPPN Estadual Parque Das Araucárias	State	2018	Atlantic Forest
RPPN Estadual Valdir Baldin	State	2020	Atlantic Forest
RPPN Fazenda Arizona	Federal	2013	Caatinga
RPPN Fazenda Arte Verde	Federal	1998	Atlantic Forest
RPPN Fazenda Boa Esperança	Federal	1998	Atlantic Forest
RPPN Fazenda Figueira	Federal	1994	Atlantic Forest
RPPN Fazenda Juazeiro	State	2022	Caatinga
RPPN Fazenda Lageado	Federal	1990	Cerrado
RPPN Fazenda Minas Gerais	State	2013	Atlantic Forest
RPPN Fazenda Rio Negro	State	2001	Pantanal
RPPN Fazenda Salobro	Federal	1994	Caatinga
RPPN Fazenda Sambaiba	State	2008	Atlantic Forest
RPPN Fazenda Santa Helena - Rn	Federal	2006	Caatinga
RPPN Fazenda Santa Sofia	State	1999	Pantanal
RPPN Fazenda Suspiro	Federal	1999	Atlantic Forest
RPPN Freisleben	State	2011	Atlantic Forest
RPPN Frilson Matheus Vieira	State	2010	Atlantic Forest
RPPN Gália	Federal	2012	Caatinga

RPPN Gotas Azuis	State	2008	Atlantic Forest
RPPN Guanandi	Federal	2012	Atlantic Forest
RPPN Ilan	State	2018	Atlantic Forest
RPPN Japurá	State	2021	Atlantic Forest
RPPN Jardim De Mukunda	State	2010	Atlantic Forest
RPPN José Abdon Malta Marques	State	2009	Caatinga
RPPN Klagesi	Federal	2005	Amazonia
RPPN Koehler	State	2015	Atlantic Forest
RPPN Lafigueira Naturarte	Federal	2017	Atlantic Forest
RPPN Lemke	Federal	2010	Atlantic Forest
RPPN Linda Sofia	State	2013	Atlantic Forest
RPPN Luizinho Alencar	Federal	2013	Caatinga
RPPN Madeiras	State	2010	Atlantic Forest
RPPN Mahayana	State	2008	Atlantic Forest
RPPN Marina Do Conde	State	2013	Atlantic Forest
RPPN Mata Do Cedro	State	2014	Atlantic Forest
RPPN Mata Estrela	Federal	2000	Atlantic Forest
RPPN Monte Alegre 1a	State	2011	Atlantic Forest
RPPN Não Pensei	State	2019	Atlantic Forest
RPPN Nossa Senhora Aparecida	Federal	2008	Atlantic Forest
RPPN Oasis Araripe	Federal	2016	Caatinga
RPPN Oiutrem	State	2006	Atlantic Forest
RPPN Osório Reimão	Federal	2009	Amazonia
RPPN Osvaldo Timóteo	State	2007	Atlantic Forest
RPPN Papagaio De Peito Roxo	Federal	2017	Atlantic Forest
RPPN Papagaio-de-altitude	Federal	2018	Atlantic Forest
RPPN Paraíso	State	2008	Atlantic Forest
RPPN Parque Botânico Dos Kaiapós	Federal	2013	Cerrado
RPPN Passaredo	Federal	2012	Caatinga
RPPN Pedra Branca	State	2013	Atlantic Forest

RPPN Pilar	State	2013	Atlantic Forest
RPPN Pilões	Federal	2007	Atlantic Forest
RPPN Ponte Do Baião	State	2011	Atlantic Forest
RPPN Portal Da Água Branca	Federal	2012	Atlantic Forest
RPPN Portal Das Nascentes	Federal	2010	Atlantic Forest
RPPN Portal Das Nascentes Ii	Federal	2011	Atlantic Forest
RPPN Pousada Campos Da Bocaina	State	2010	Atlantic Forest
RPPN Prati	Federal	2010	Atlantic Forest
RPPN Rabicho Da Serra	State	2008	Atlantic Forest
RPPN Raibert	State	2019	Atlantic Forest
RPPN Refúgio Do Bugio	State	2012	Atlantic Forest
RPPN Refúgio Ecológico Fazenda Gato Do Mato	State	2019	Atlantic Forest
RPPN Regina Clara	State	2016	Atlantic Forest
RPPN Reserva Calaça	Federal	2007	Caatinga
RPPN Reserva Cultura Permanente	Federal	2011	Caatinga
RPPN Reserva Da Pousada Graciosa	Federal	2011	Atlantic Forest
RPPN Reserva Fazenda Recanto Das Águas Claras	Federal	2007	Cerrado
RPPN Reserva Florestal Engenheiro João Furtado De Mendonça	Federal	2008	Atlantic Forest
RPPN Reserva Hinayana	State	2014	Atlantic Forest
RPPN Reserva Jacuruna	State	2018	Atlantic Forest
RPPN Reserva Jurema	Federal	2007	Caatinga
RPPN Reserva Maragato	Federal	2007	Pampa
RPPN Reserva Mato Grosso Ii	State	2008	Atlantic Forest
RPPN Reserva Mestre Bonina	State	2013	Atlantic Forest
RPPN Reserva Particular Do Patrimonio Natural Cisalpina	State	2016	Atlantic Forest
RPPN Reserva Siriema	Federal	2007	Caatinga
RPPN Reserva Umburana	Federal	2007	Caatinga
RPPN Reserva Yogo	State	2018	Atlantic Forest

RPPN Riacho Das Pedras	Federal	2008	Atlantic Forest
RPPN Rica Paulo De Frontin	State	2014	Atlantic Forest
RPPN Rio Capitão	Federal	2004	Atlantic Forest
RPPN Rio Vermelho (SC)	Federal	2016	Atlantic Forest
RPPN Saint Michel 1	State	2017	Atlantic Forest
RPPN Saint Michel 2	State	2017	Atlantic Forest
RPPN Saint Michel 3	State	2017	Atlantic Forest
RPPN São Elias	State	2016	Atlantic Forest
RPPN Sereno	State	2018	Atlantic Forest
RPPN Serra Da Bocaina	State	2019	Atlantic Forest
RPPN Sesc Tepequém	Federal	2001	Amazonia
RPPN Sítio Bica	State	2019	Atlantic Forest
RPPN Sítio Grande	State	2017	Cerrado
RPPN Sítio Lagoa	Federal	2018	Caatinga
RPPN Sítio Picada	State	2013	Atlantic Forest
RPPN Sítio São Pedro	State	2014	Atlantic Forest
RPPN Tayná	Federal	2009	Atlantic Forest
RPPN Terras Frias	State	2019	Atlantic Forest
RPPN Toca Da Onça	State	2011	Atlantic Forest
RPPN Três Pontões	Federal	2004	Atlantic Forest
RPPN Urú	Federal	2004	Atlantic Forest
RPPN Vale Verdejante	State	2014	Atlantic Forest
RPPN Verbicaro	State	2010	Atlantic Forest
RPPN Veredas Do Pratudinho	Federal	2011	Cerrado
RPPN Vila Amanda	Federal	2005	Cerrado
RPPN Vovó Dindinha	State	2010	Atlantic Forest
RPPN Yara Brunini	State	2010	Atlantic Forest

APÊNDICE II - MATERIAL SUPLEMENTAR DO CAPÍTULO 2

Supplementary Material

Table S1. Species list of roadkill animals recorded from Chapada Diamantina between 2022 and 2023. IUCN: The species are categorized according to IUCN Red List of Threatened Species (IUCN). BR: The species are categorized according to National List of Endangered Species from Brazil (Brasil, 2022).

CLASS / **Order** /Family	*Species*	Common name	IUCN	BR
AMPHIBIA				
Anura				
Bufonidae	*Rhinella diptycha*	Cane toad	LC	-
	Rhinella sp.	Cane toad	-	-
Hylidae	*Boana crepitans*	Emerald-eyed Treefrog	LC	-
	Boana sp.	Frog	-	-
Leptodactylidae	*Leptodactylus macrosternum*	Miranda's White-lipped Frog	LC	-
	Leptodactylus sp.	Frog	-	-
Microhylidae	*Dermatonotus muelleri*	Müller's Termite Frog	LC	-
Phyllomedusidae	*Phyllomedusa bahiana*	Bahia Leaf Frog	LC	-
	Pithecopus nordestinus	Leaf Frog	LC	-
	Phyllomedusa sp.	Leaf Frog	-	-
N.I.	N.I.	Toad	-	-
BIRDS				
Apodiformes				
Trochilidae	*Chrysolampis mosquitus*	Ruby-topaz Hummingbird	LC	-
	Colibri serrirostris	White-vented Violetear	LC	-
	Heliactin bilophus	Horned Sungem	LC	-
Caprimulgiformes				
Caprimulgidae	*Antrostomus rufus*	Rufous Nightjar	LC	-
N.I.	N.I.	Nightjar	-	-
Cathartiformes				
Cathartidae	*Coragyps atratus*	Black Vulture	LC	-
Columbiformes				
Columbidae	*Columbina picui*	Picui Ground-Dove	LC	-
	Columbina sp.	Dove	-	-
Falconiformes				
Falconidae	*Caracara plancus*	Crested Caracara	LC	-
Galliformes				
Cracidae	*Ortalis araucuan*	East Brazilian Chachalaca	LC	-
	Penelope superciliaris	Rusty-margined Guan	LC	-

Passeriformes				
Furnariidae	*Furnarius figulus*	Wing-banded Hornero	LC	-
	Furnarius leucopus	Pale-legged Hornero	LC	-
	Synallaxis sp.	Spinetail	-	-
	Synallaxis spixi	Spix's Spinetail	LC	-
Hirundinidae	*Progne chalybea*	Gray-breasted Martin	LC	-
Icteridae	*Molothrus bonariensis*	Shiny Cowbird	LC	-
Mimidae	*Mimus saturninus*	Chalk-browed Mockingbird	LC	-
Pipridae	N.I.	Manakin	-	-
Thamnophilidae	*Thamnophilus torquatus*	Rufous-winged Antshrike	LC	-
Thraupidae	*Coryphospingus pileatus*	Pileated Finch	LC	-
	Paroaria dominicana	Red-cowled Cardinal	LC	-
	Sicalis flaveola	Saffron Finch	LC	-
	Sicalis sp.	Yellow-finch	-	-
	Sporophila albogularis	White-throated Seedeater	LC	-
	Sporophila sp.	Seedeater	-	-
	Stilpnia cayana	Burnished-buff Tanager	LC	-
	Thraupis sayaca	Sayaca Tanager	LC	-
	Volatinia jacarina	Blue-black Grassquit	LC	-
Troglodytidae	*Troglodytes musculus*	Southern House Wren	LC	-
Tyrannidae	*Elaenia* sp.	Elaenia	-	-
	Machetornis rixosa	Cattle Tyrant	LC	-
	Megarynchus pitangua	Boat-billed Flycatcher	LC	-
	Pitangus sulphuratus	Great Kiskadee	LC	-
	N.I.	Bird	-	-
Vireonidae	*Cyclarhis gujanensis*	Rufous-browed Peppershrike	LC	-
Psittaciformes				
Psittacidae	*Eupsittula cactorum*	Cactus Parakeet	LC	-
Strigiformes				
Strigidae	*Aegolius harrisii*	Buff-fronted Owl	LC	-
	Asio clamator	Striped Owl	LC	-
	Athene cunicularia	Burrowing Owl	LC	-
	Megascops choliba	Tropical Screech-Owl	LC	-
Tytonidae	*Tyto furcata*	American Barn Owl	LC	-
Tinamiformes				
Tinamidae	*Crypturellus zabele*	Zabele Tinamou	-	VU
N.I.	N.I.	Bird		-
MAMMALIA				

Carnivora				
Canidae	*Cerdocyon thous*	Crab-eating Fox	LC	-
	Lycalopex vetulus	Hoary Fox	NT	VU
Felidae	*Leopardus emiliae*	Northern Tiger Cat	VU	EN
Mephitidae	*Conepatus semistriatus*	Striped Hog-nosed Skunk	LC	-
Mustelidae	*Eira barbara*	Tayra	LC	-
Procyonidae	*Procyon cancrivorus*	Crab-eating Raccoon	LC	-
Chiroptera				
Molossidae	*Molossus* sp.	Bat	-	-
Phyllostomidae	N.I.	Bat	-	-
N.I.	N.I.	Bat	-	-
Cingulata				
Dasypodidae	*Dasypus novemcinctus*	Nine-banded Armadillo	LC	-
Didelphimorphia				
Didelphidae	*Didelphis albiventris*	White-eared Opossum	LC	-
Pilosa				
Myrmecophagidae	*Tamandua tetradactyla*	Southern Tamandua	LC	-
Primates				
Callitrichidae	*Callithrix penicillata*	Black-pencilled Marmoset	LC	-
Rodentia				
N.I.	N.I.	Rat	-	-
N.I.	N.I.	Mammal	-	-
REPTILIA				
Squamata				
Amphisbaenidae	*Amphisbaena alba*	Red Worm Lizard	LC	-
	Amphisbaena sp.	Worm lizard	-	-
Boidae	*Boa constrictor*	Red-tailed Boa	LC	-
	Epicrates assisi	Caatinga rainbow boa	LC	-
	Epicrates sp.	Rainbow boa	-	-
Colubridae	*Oxybelis aeneus*	Brown Vinesnake	LC	-
	Spilotes pullatus	Chicken Snake	LC	-
Dipsadidae	*Clelia clelia*	Black Mussurana	LC	-
	Dipsas mikanii	Garden snake	LC	-
	Erythrolamprus reginae	Royal Ground Snake	LC	-
	Oxyrhopus guibei	False Coral Snake	LC	-
	Oxyrhopus sp.	False Coral Snake	-	-
	Oxyrhopus trigeminus	Brazilian False Coral Snake	LC	-
	Philodryas nattereri	Paraguay Green Racer	LC	-
	Philodryas olfersii	Lichtenstein's Green Racer	LC	-

	Philodryas patagoniensis	Patagonia Green Racer	LC	-
	Phimophis guerini	Argentine Pampas Snake	LC	-
	Philodryas sp.	Green Racer Snake	-	-
	Pseudoboa nigra	Black False Boa	LC	-
Elapidae	*Micrurus ibiboboca*	Caatinga Coral Snake	DD	-
	Micrurus sp.	Coral Snake	-	-
Polychrotidae	*Polychrus acutirostris*	Brazilian Bush Anole	LC	-
Teiidae	*Salvator merianae*	Black-and-white Tegu	LC	-
Tropiduridae	*Tropidurus* sp.	Lizard	-	-
Viperidae	*Bothrops moojeni*	Brazilian Lancehead	LC	-
	Crotalus durissus	Cascabel Rattlesnake	LC	-
	Xenodon sp.	Boipeva	-	-
N.I.	N.I.	Snake		-
Testudines				
Chelidae	*Phrynops* sp.	Tortoise	-	-

Table S2. Species list of roadkill animals recorded for peoples living around Chapada Diamantina National Park between 2022 and 2023. IUCN: The species are categorized according to IUCN Red List of Threatened Species (IUCN). BR: The species are categorized according to National List of Endangered Species from Brazil (Brasil, 2022).

CLASS / Order /Family	*Species*	Common name	IUCN	BR
AMPHIBIA				
Anura				
Leptodactylidae	*Leptodactylus* sp.	Frog	-	-
BIRDS				
Cathartiformes				
Cathartidae	*Coragyps atratus*	Black Vulture	LC	-
Falconiformes				
Falconidae	*Caracara plancus*	Crested Caracara	LC	-
Galliformes				
Cracidae	*Penelope superciliaris*	Rusty-margined Guan	LC	-
Passeriformes				
Mimidae	*Mimus saturninus*	Chalk-browed Mockingbird	LC	-
Thraupidae	*Sporophila nigricollis*	Yellow-bellied Seedeater	LC	-
Tyrannidae	*Elaenia cristata*	Plain-crested Elaenia	LC	-
	Eleania sp.	Elaenia	-	-
Strigiformes				
Strigidae	*Asio clamator*	Striped Owl	LC	-
	Megascops choliba	Tropical Screech-Owl	LC	-
	N.I.	Owl	-	-
Tytonidae	*Tyto furcata*	American Barn Owl	LC	-
MAMMALIA				
Carnivora				
Canidae	*Cerdocyon thous*	Crab-eating Fox	LC	-
Felidae	*Leopardus* sp.	Wild cat	-	-
	Leopardus emiliae	Northern Tiger Cat	VU	EN
Mephitidae	*Conepatus semistriatus*	Striped Hog-nosed Skunk	LC	-
Mustelidae	*Eira barbara*	Tayra	LC	-
Procyonidae	*Procyon cancrivorus*	Crab-eating Raccoon	LC	-
Cingulata				
Dasypodidae	*Dasypus novemcinctus*	Nine-banded Armadillo	LC	-
Didelphimorphia				
Didelphidae	*Didelphis albiventris*	White-eared Opossum	LC	-
Lagomorpha				

Leporidae	*Sylvilagus* sp.	Tapiti	-	-
Pilosa				
Myrmecophagidae	*Tamandua tetradactyla*	Southern Tamandua	LC	-
Rodentia				
Echimyidae	*Thrichomys* sp.	Rat	-	-
REPTILIA				
Squamata				
Amphisbaenidae	*Amphisbaena* sp.	Worm lizard	-	-
Boidae	*Boa constrictor*	Red-tailed Boa	LC	-
	Epicrates assisi	Caatinga rainbow boa	LC	-
Colubridae	*Spilotes pullatus*	Chicken Snake	LC	-
Dipsadidae	*Clelia clelia*	Black Mussurana	LC	-
	Oxyrhopus guibei	False Coral Snake	LC	-
	Philodryas olfersii	Lichtenstein's Green Racer	LC	-
Elapidae	*Micrurus ibiboboca*	Caatinga Coral Snake	DD	-
Testudines				
Chelidae	*Phrynops* sp.	Tortoise	-	-

Supplementary Material - S3

Results of the Roadkill Hotspots Analysis. Each figure corresponds to a route (AND, LEC, and MUC) and a taxonomic group. Note: Taxonomic groups that did not show significant spatial aggregation in Ripley's K test were excluded from the roadkill hotspots analysis (see Methodology).

AND – Amphibians

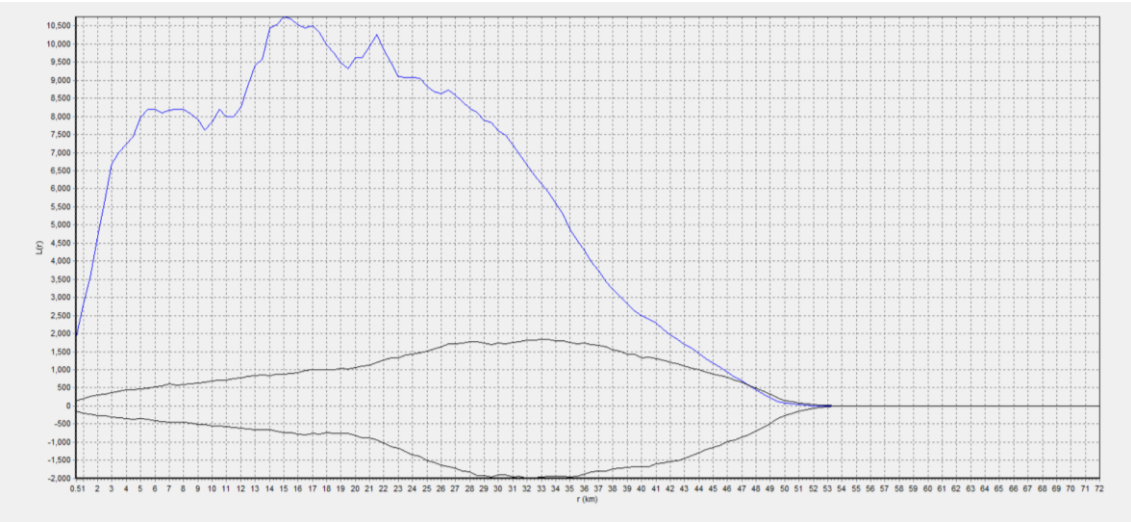


Figure S3.1. Ripley's K test results. Blue line: function L(r); Black lines: confidence limits; L(r): test function; r (km): radius in kilometers. When the blue line crosses the upper confidence limit, it indicates significant spatial aggregation.

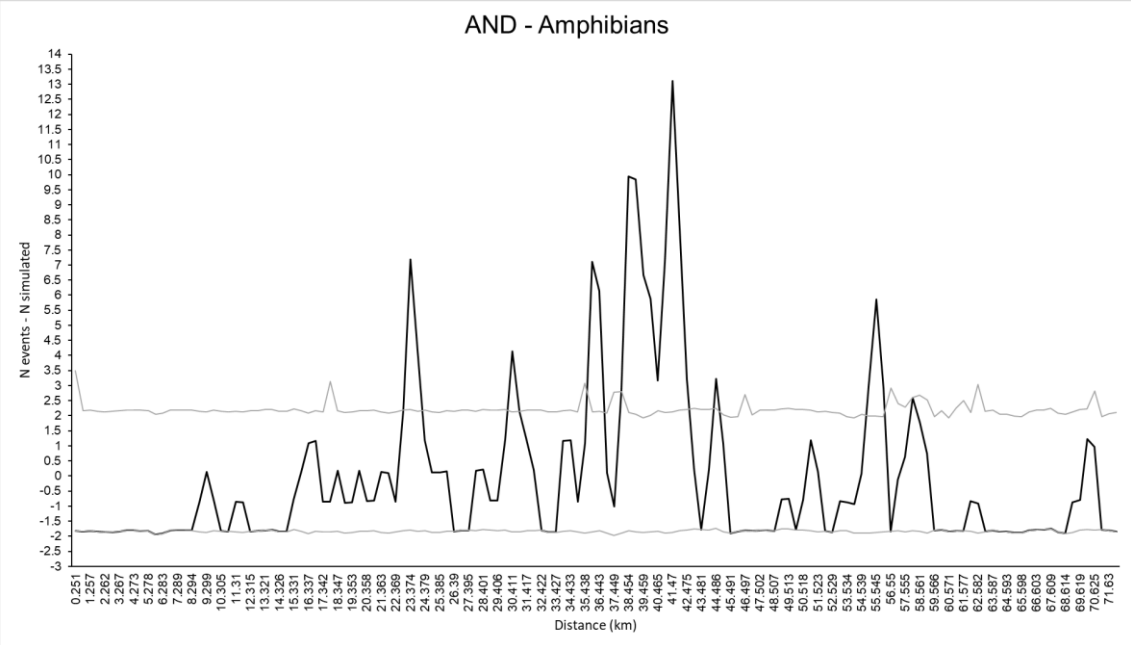


Figure S3.2. 2D Hotspot test results. Black line: N events – N simulated function; Gray lines: confidence limits. When the black line crosses the upper confidence limit, it indicates significant spatial aggregation (roadkill hotspot).

AND – Reptiles

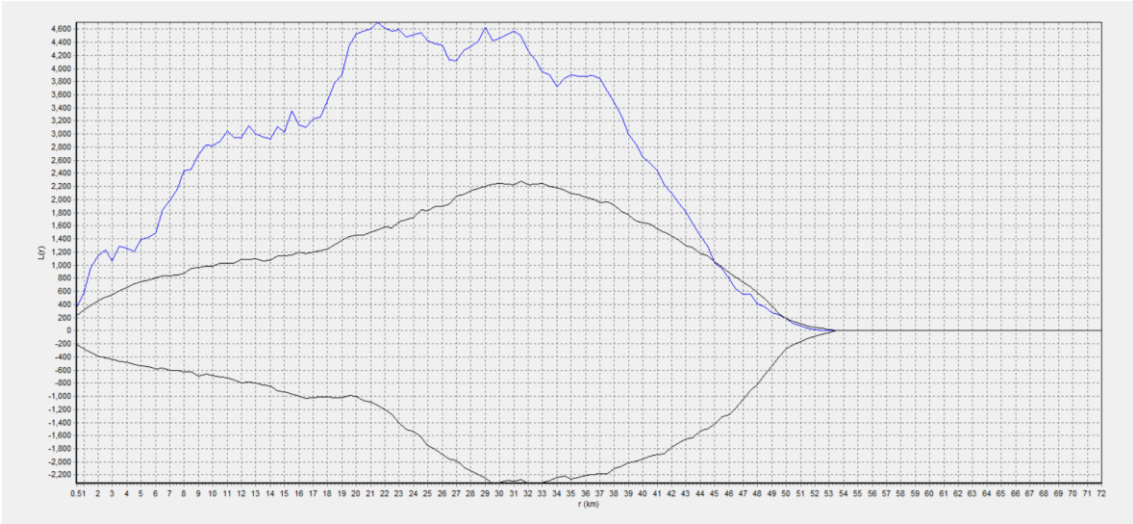


Figure S3.3. Ripley's K test results. Blue line: function L(r); Black lines: confidence limits; L(r): test function; r (km): radius in kilometers. When the blue line crosses the upper confidence limit, it indicates significant spatial aggregation.

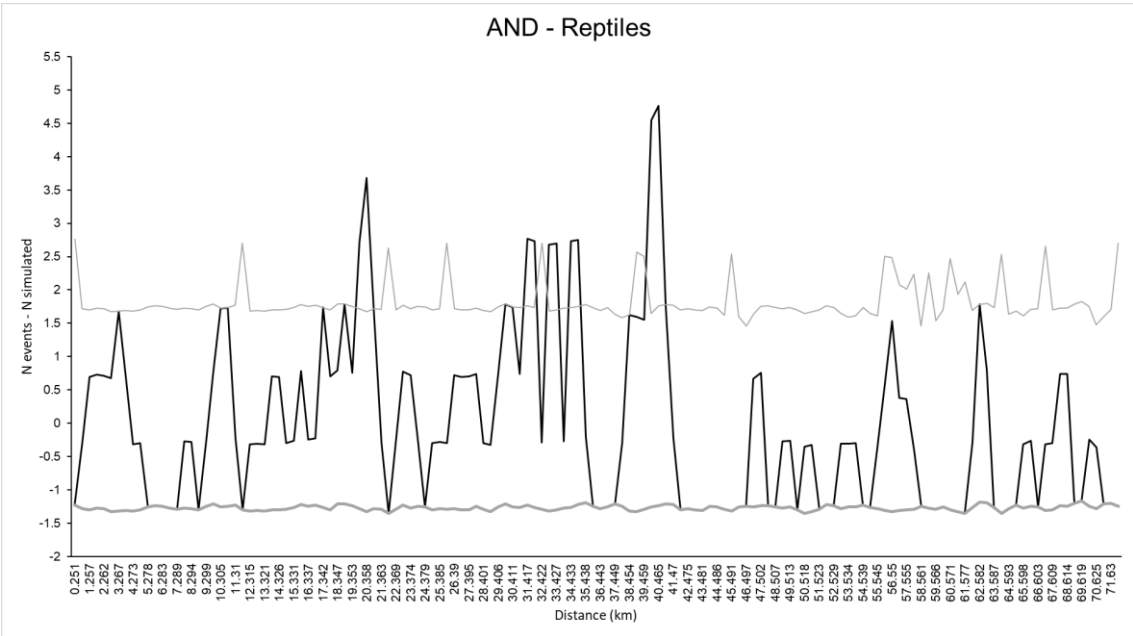


Figure S3.4. 2D Hotspot test results. Black line: N events – N simulated function; Gray lines: confidence limits. When the black line crosses the upper confidence limit, it indicates significant spatial aggregation (roadkill hotspot).

AND – Birds

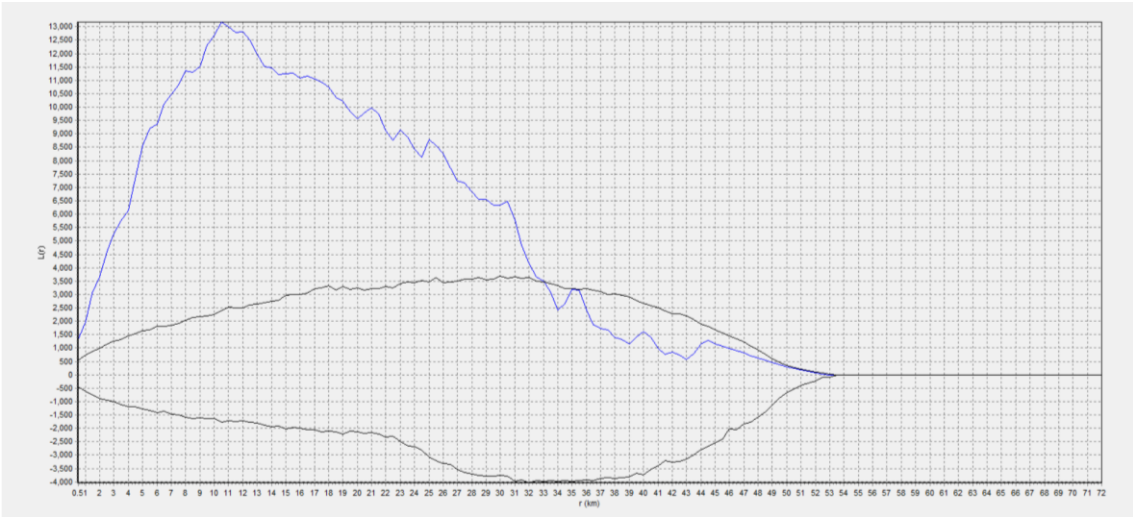


Figure S3.5. Ripley's K test results. Blue line: function L(r); Black lines: confidence limits; L(r): test function; r (km): radius in kilometers. When the blue line crosses the upper confidence limit, it indicates significant spatial aggregation.

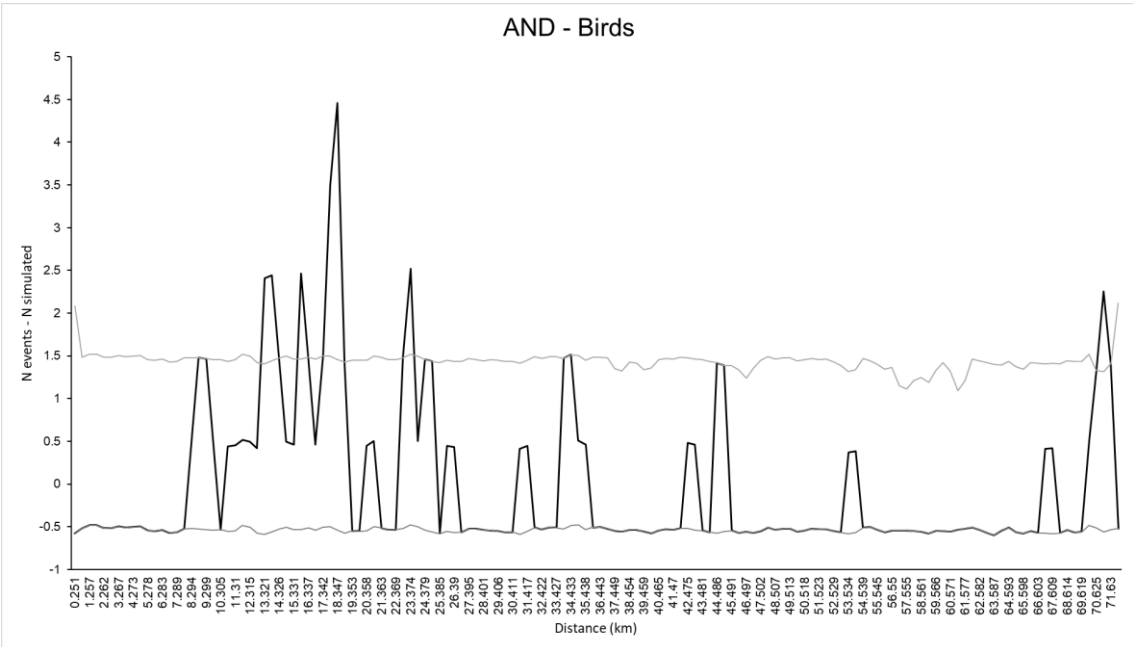


Figure S3.6. 2D Hotspot test results. Black line: N events – N simulated function; Gray lines: confidence limits. When the black line crosses the upper confidence limit, it indicates significant spatial aggregation (roadkill hotspot).

AND – Mammals

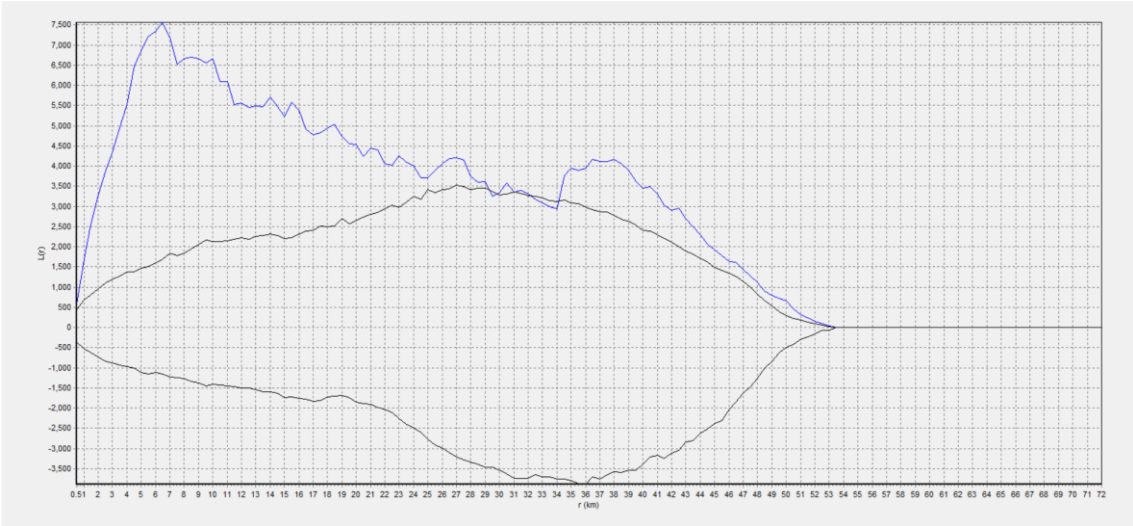


Figure S3.7. Ripley's K test results. Blue line: function L(r); Black lines: confidence limits; L(r): test function; r (km): radius in kilometers. When the blue line crosses the upper confidence limit, it indicates significant spatial aggregation.

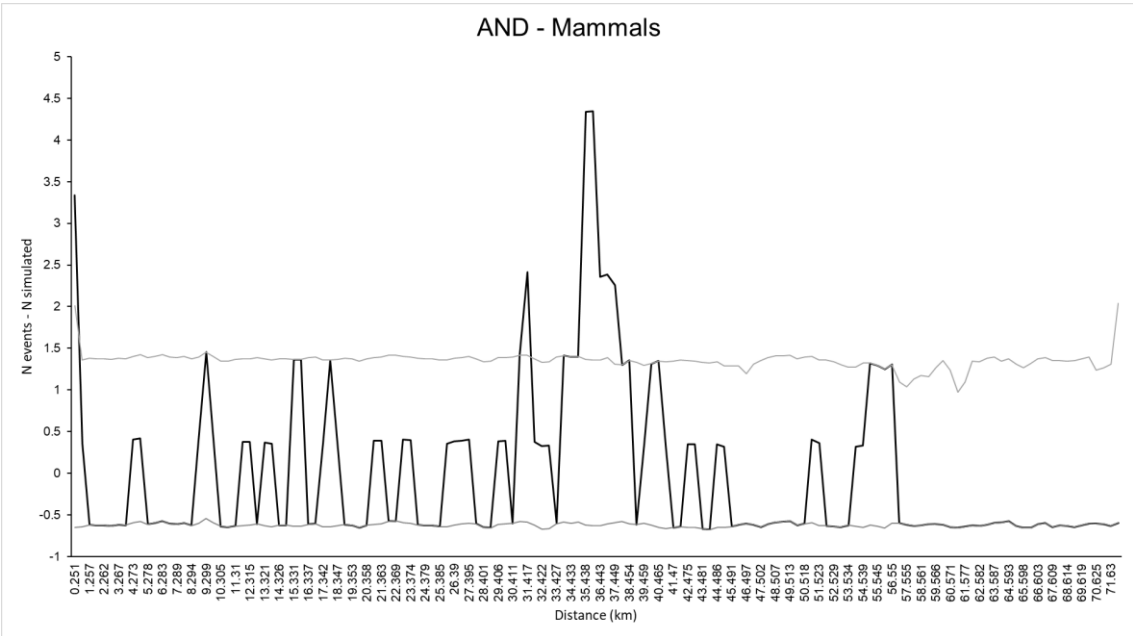


Figure S3.8. 2D Hotspot test results. Black line: N events – N simulated function; Gray lines: confidence limits. When the black line crosses the upper confidence limit, it indicates significant spatial aggregation (roadkill hotspot).

AND – Total

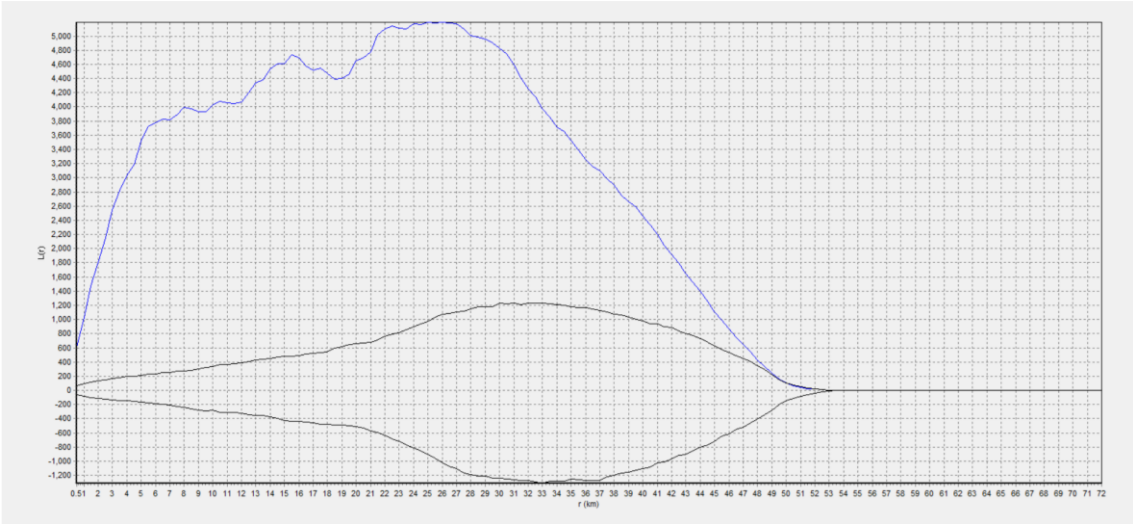


Figure S3.9. Ripley's K test results. Blue line: function L(r); Black lines: confidence limits; L(r): test function; r (km): radius in kilometers. When the blue line crosses the upper confidence limit, it indicates significant spatial aggregation.

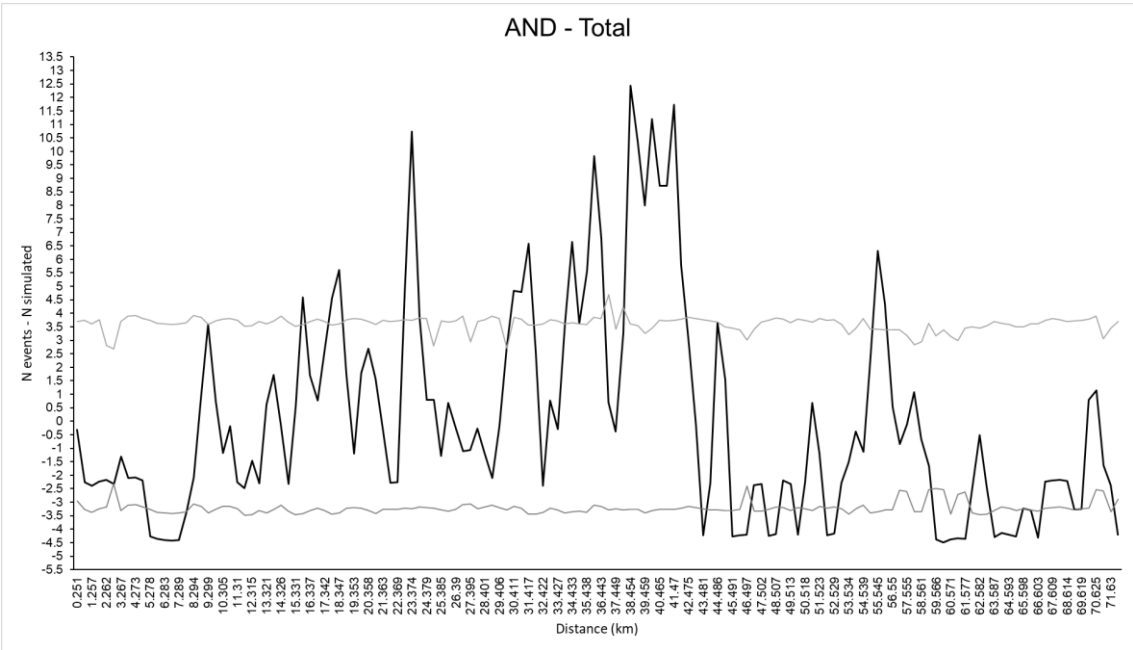


Figure S3.10. 2D Hotspot test results. Black line: N events – N simulated function; Gray lines: confidence limits. When the black line crosses the upper confidence limit, it indicates significant spatial aggregation (roadkill hotspot).

LEC – Amphibians

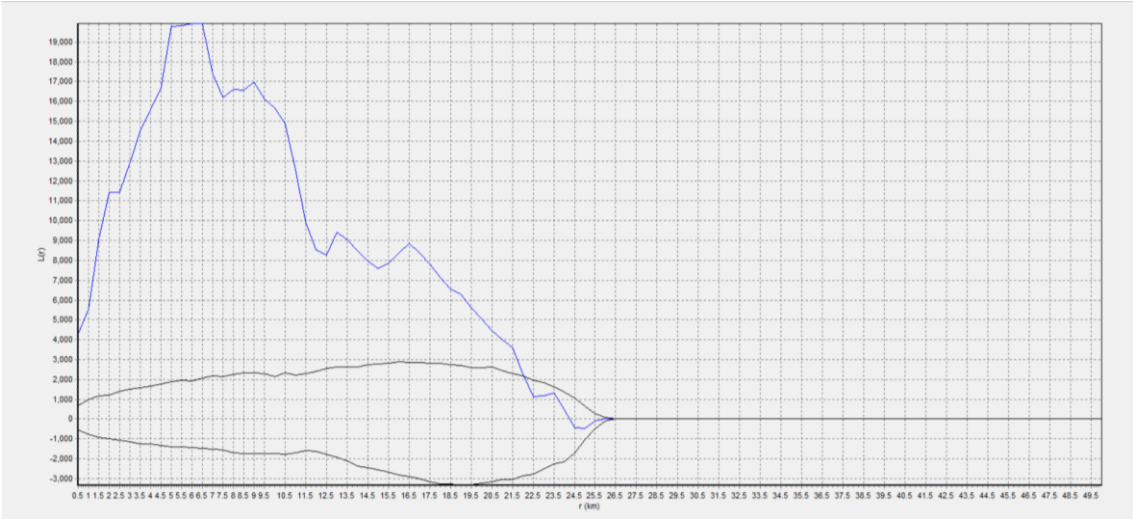


Figure S3.11. Ripley's K test results. Blue line: function L(r); Black lines: confidence limits; L(r): test function; r (km): radius in kilometers. When the blue line crosses the upper confidence limit, it indicates significant spatial aggregation.

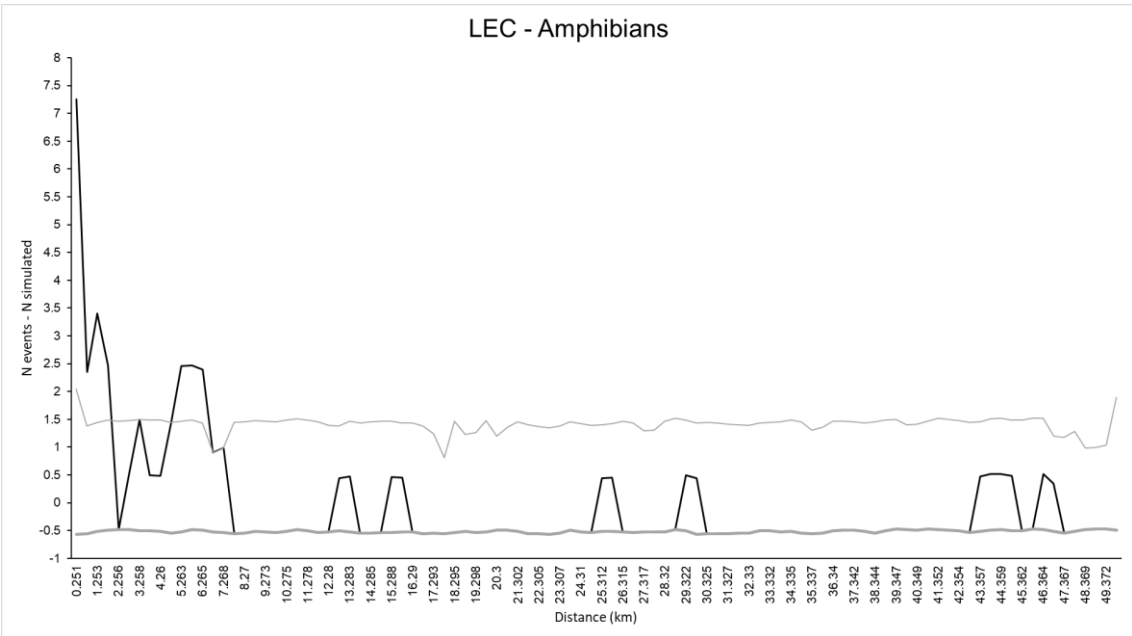


Figure S3.12. 2D Hotspot test results. Black line: N events – N simulated function; Gray lines: confidence limits. When the black line crosses the upper confidence limit, it indicates significant spatial aggregation (roadkill hotspot).

LEC – Reptile

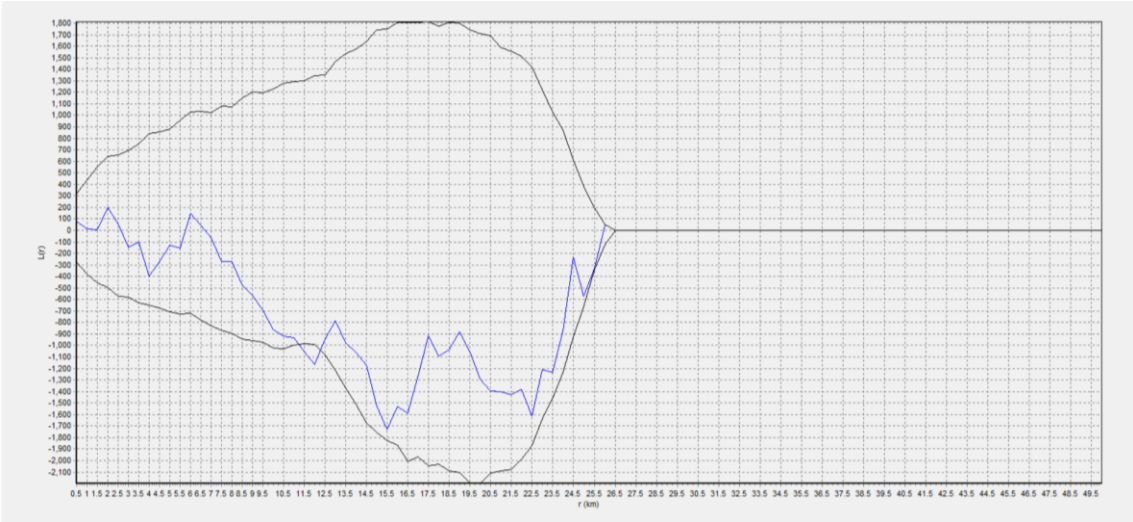


Figure S3.13. Ripley's K test results. Blue line: function L(r); Black lines: confidence limits; L(r): test function; r (km): radius in kilometers. When the blue line crosses the upper confidence limit, it indicates significant spatial aggregation. Reptiles did not show aggregation.

LEC – Birds

Figure S3.14. Ripley's K test results. Blue line: function L(r); Black lines: confidence limits; L(r): test function; r (km): radius in kilometers. When the blue line crosses the upper confidence limit, it indicates significant spatial aggregation.

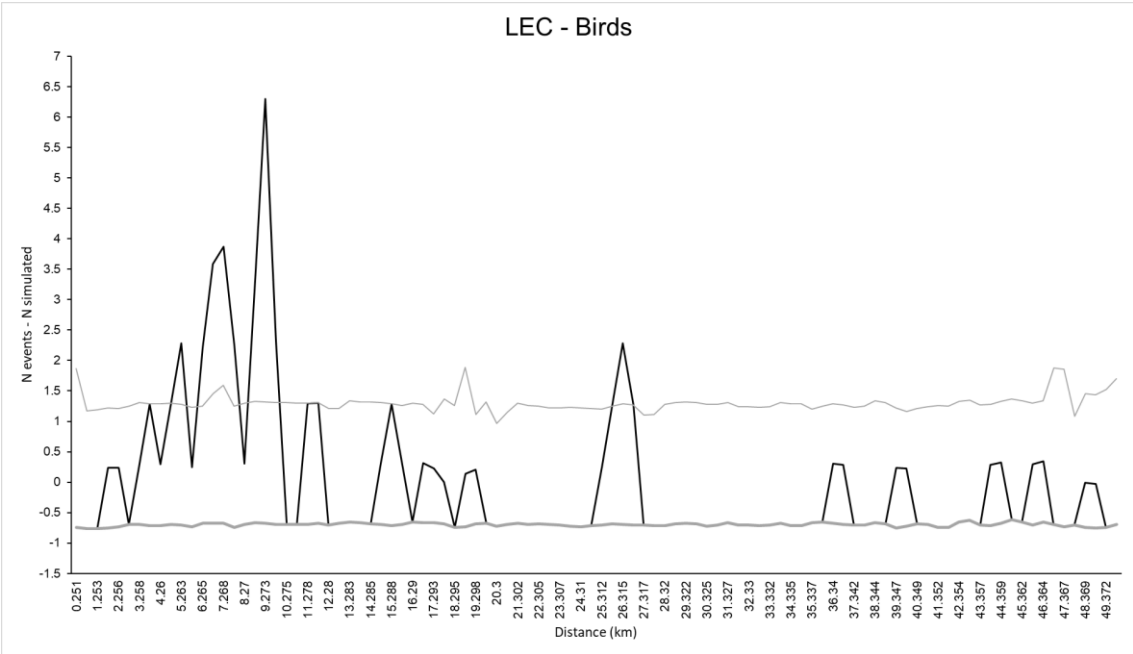


Figure S3.15. 2D Hotspot test results. Black line: N events – N simulated function; Gray lines: confidence limits. When the black line crosses the upper confidence limit, it indicates significant spatial aggregation (roadkill hotspot).

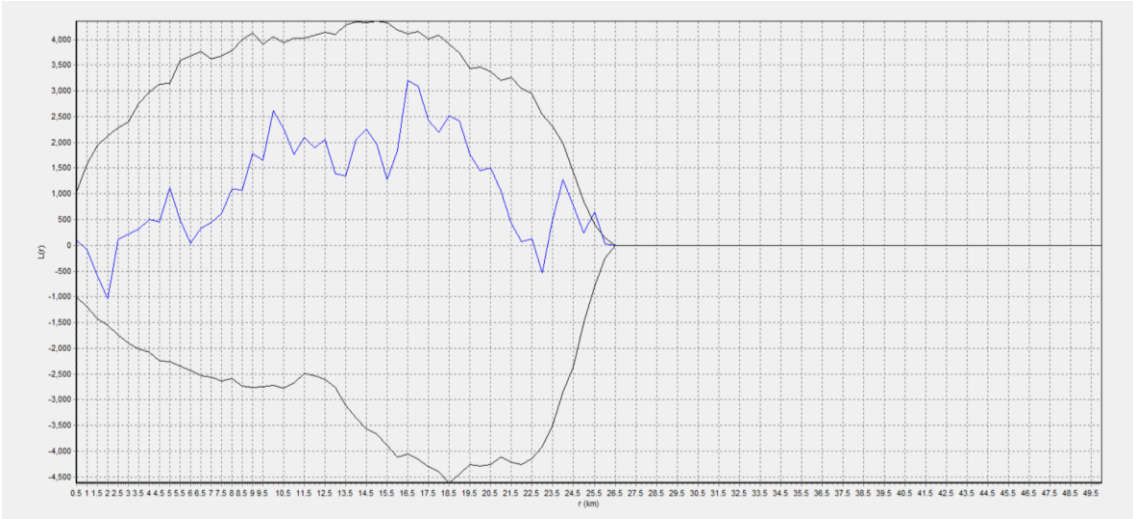


Figure S3.16. Ripley's K test results. Blue line: function L(r); Black lines: confidence limits; L(r): test function; r (km): radius in kilometers. When the blue line crosses the upper confidence limit, it indicates significant spatial aggregation. Mammals did not show aggregation.

LEC – Total

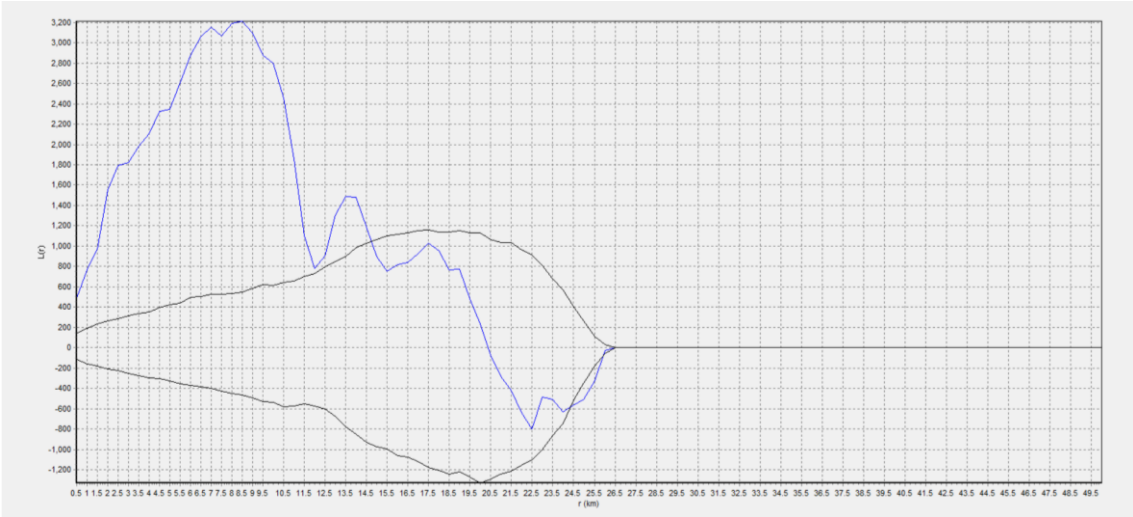


Figure S3.17. Ripley's K test results. Blue line: function L(r); Black lines: confidence limits; L(r): test function; r (km): radius in kilometers. When the blue line crosses the upper confidence limit, it indicates significant spatial aggregation.

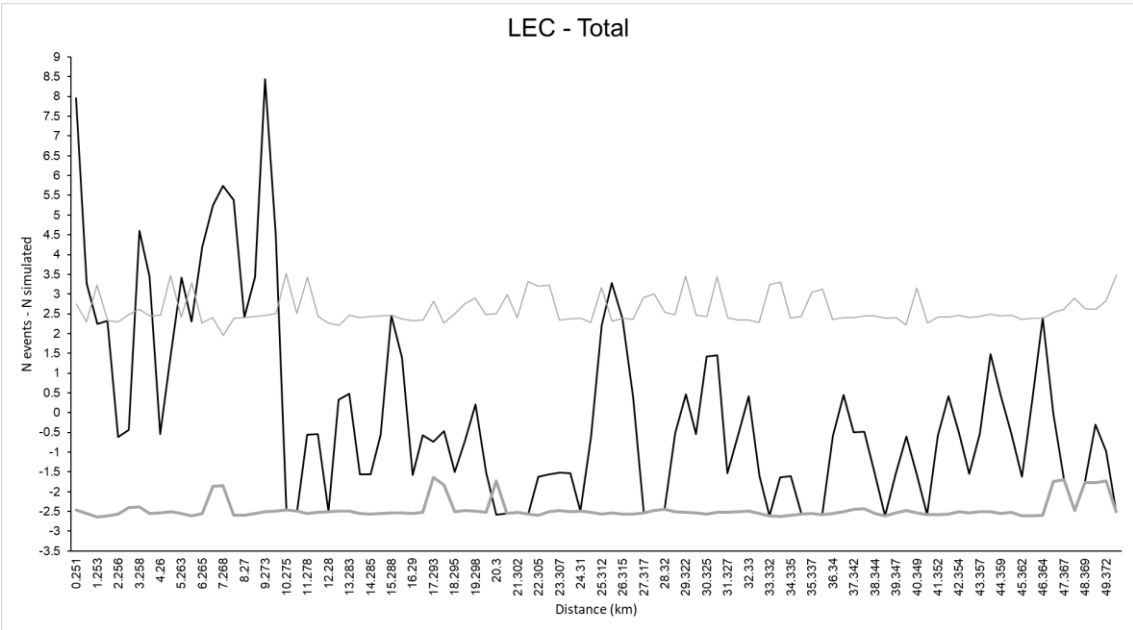


Figure S3.18. 2D Hotspot test results. Black line: N events – N simulated function; Gray lines: confidence limits. When the black line crosses the upper confidence limit, it indicates significant spatial aggregation (roadkill hotspot).

MUC – Amphibians

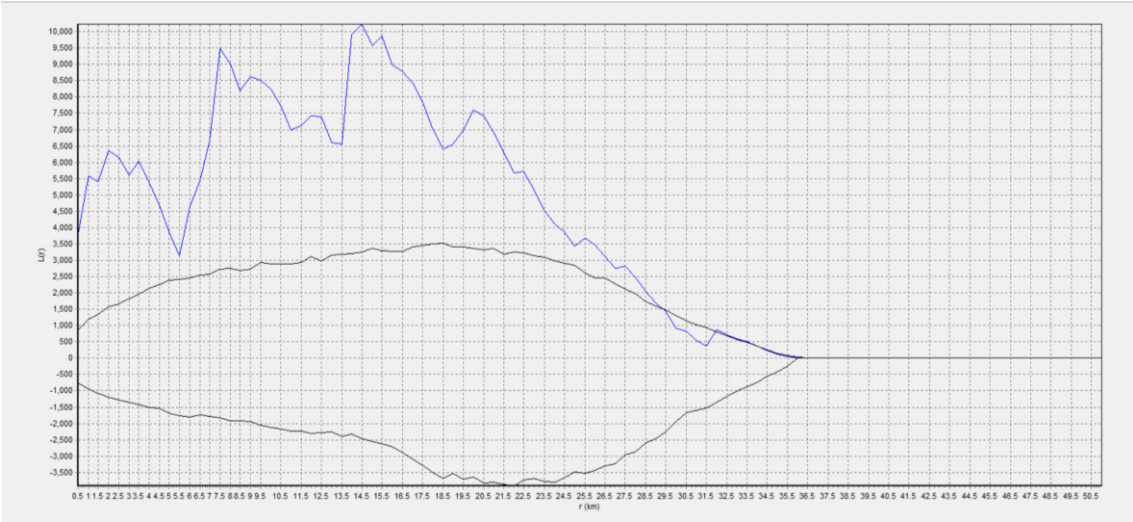


Figure S3.19. Ripley's K test results. Blue line: function L(r); Black lines: confidence limits; L(r): test function; r (km): radius in kilometers. When the blue line crosses the upper confidence limit, it indicates significant spatial aggregation.

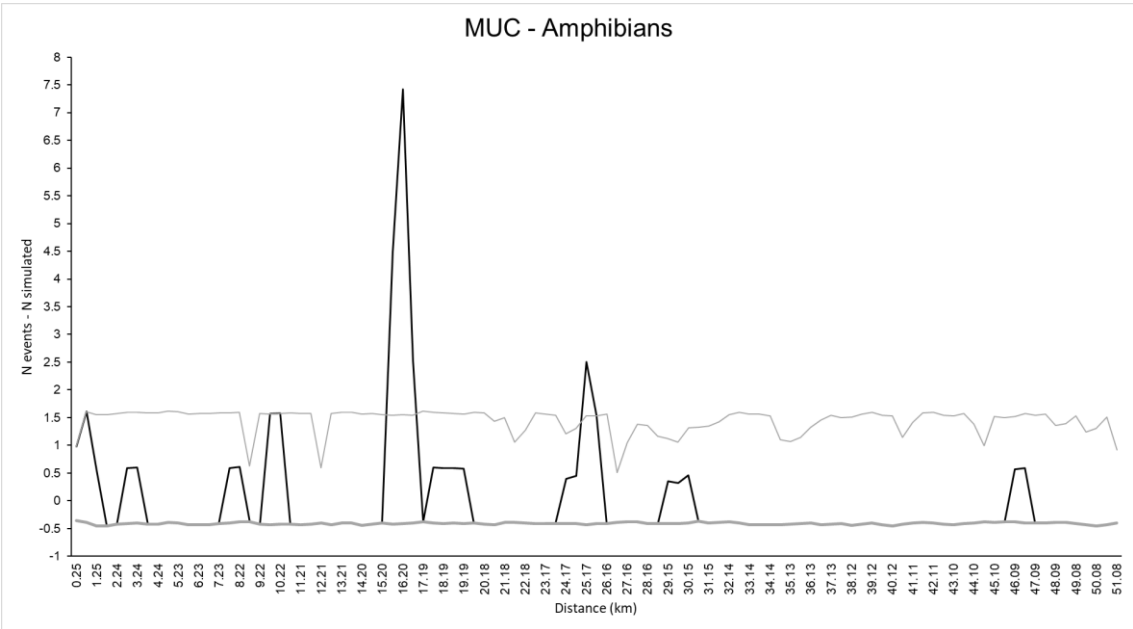


Figure S3.20. 2D Hotspot test results. Black line: N events – N simulated function; Gray lines: confidence limits. When the black line crosses the upper confidence limit, it indicates significant spatial aggregation (roadkill hotspot).

MUC – Reptile

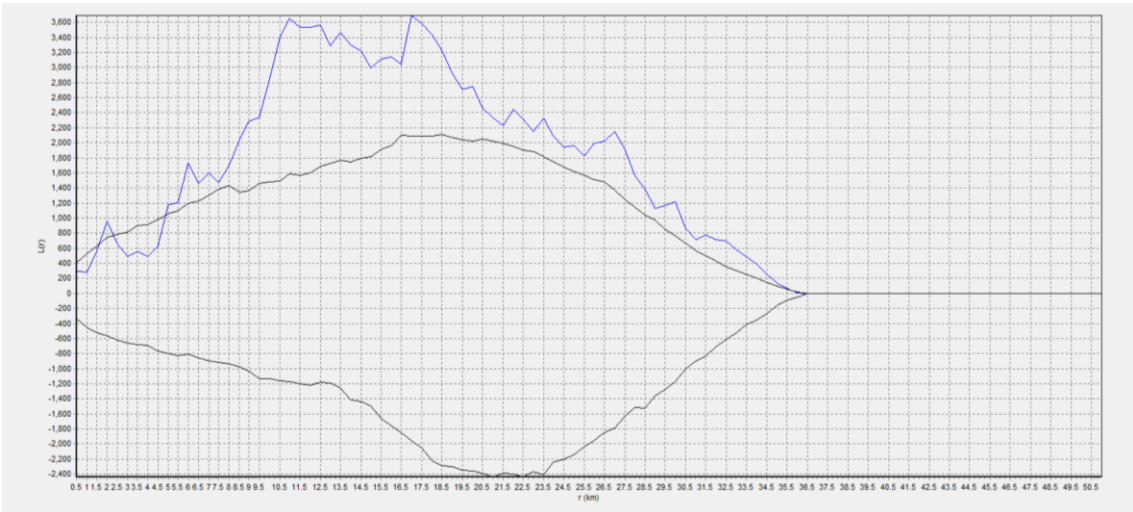


Figure S3.21. Ripley's K test results. Blue line: function L(r); Black lines: confidence limits; L(r): test function; r (km): radius in kilometers. When the blue line crosses the upper confidence limit, it indicates significant spatial aggregation. We used the 2km radius, because it was the smallest radius that showed aggregation.

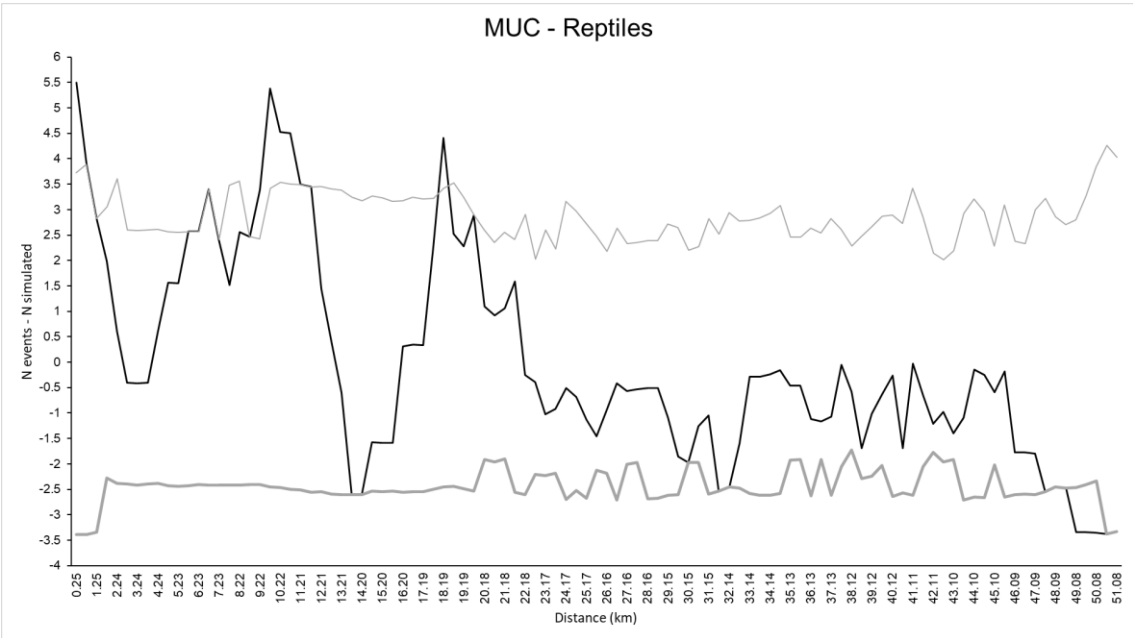


Figure S3.22. 2D Hotspot test results. Black line: N events – N simulated function; Gray lines: confidence limits. When the black line crosses the upper confidence limit, it indicates significant spatial aggregation (roadkill hotspot).

MUC – Birds

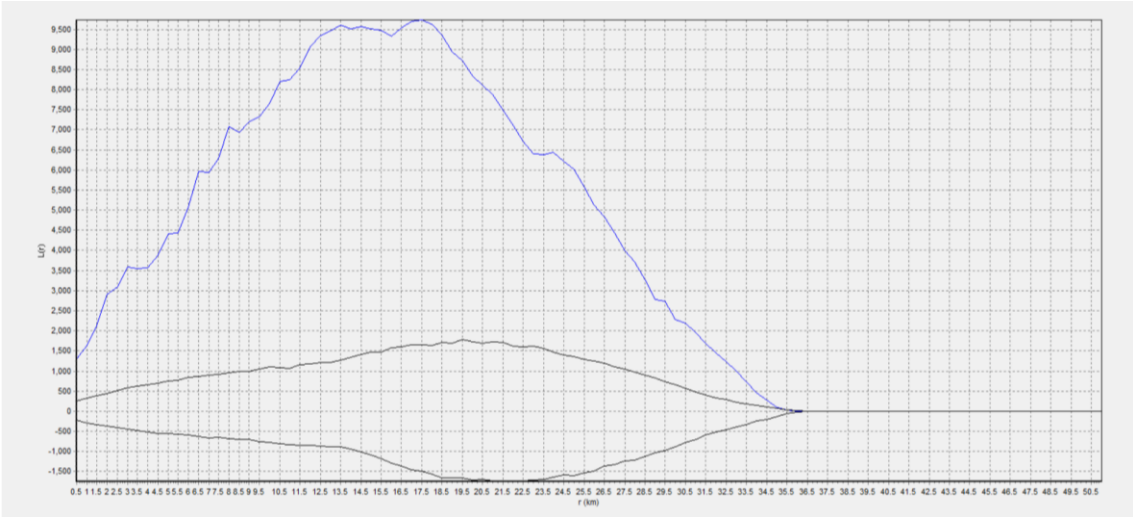


Figure S3.23. Ripley's K test results. Blue line: function L(r); Black lines: confidence limits; L(r): test function; r (km): radius in kilometers. When the blue line crosses the upper confidence limit, it indicates significant spatial aggregation.

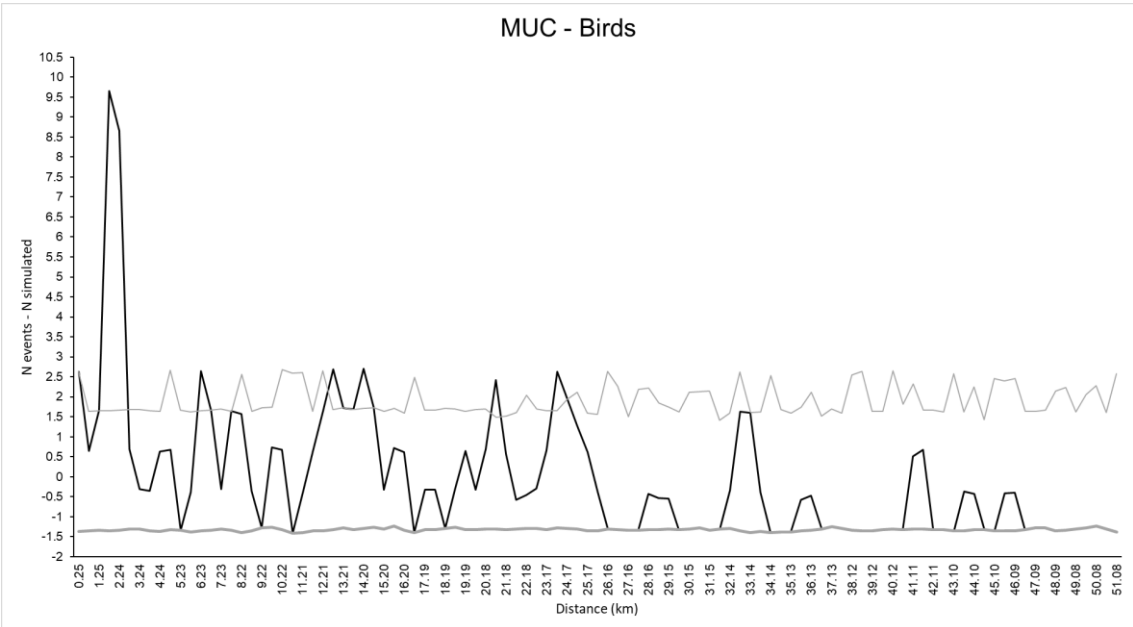


Figure S3.24. 2D Hotspot test results. Black line: N events – N simulated function; Gray lines: confidence limits. When the black line crosses the upper confidence limit, it indicates significant spatial aggregation (roadkill hotspot).

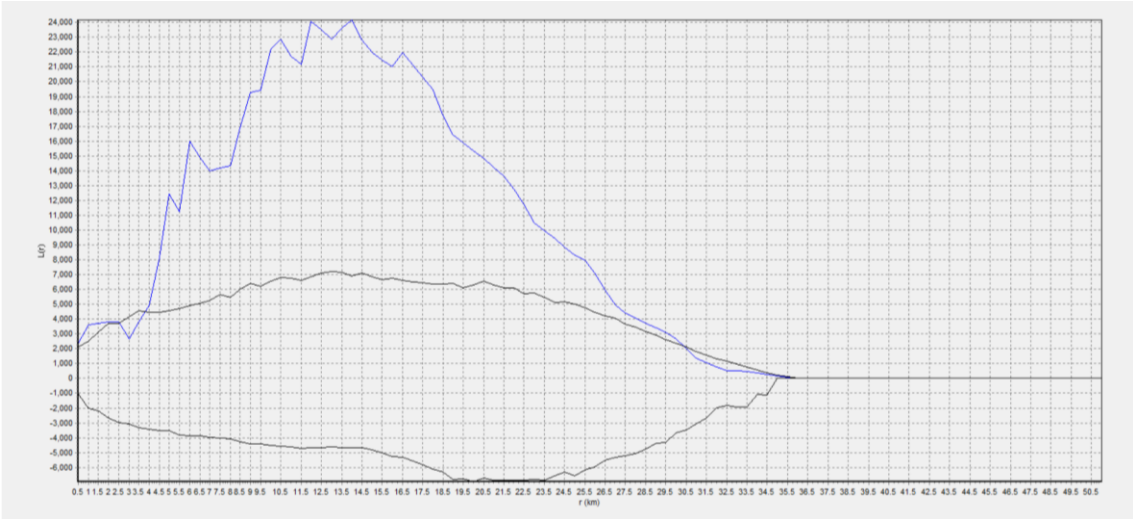


Figure S3.25. Ripley's K test results. Blue line: function L(r); Black lines: confidence limits; L(r): test function; r (km): radius in kilometers. When the blue line crosses the upper confidence limit, it indicates significant spatial aggregation.

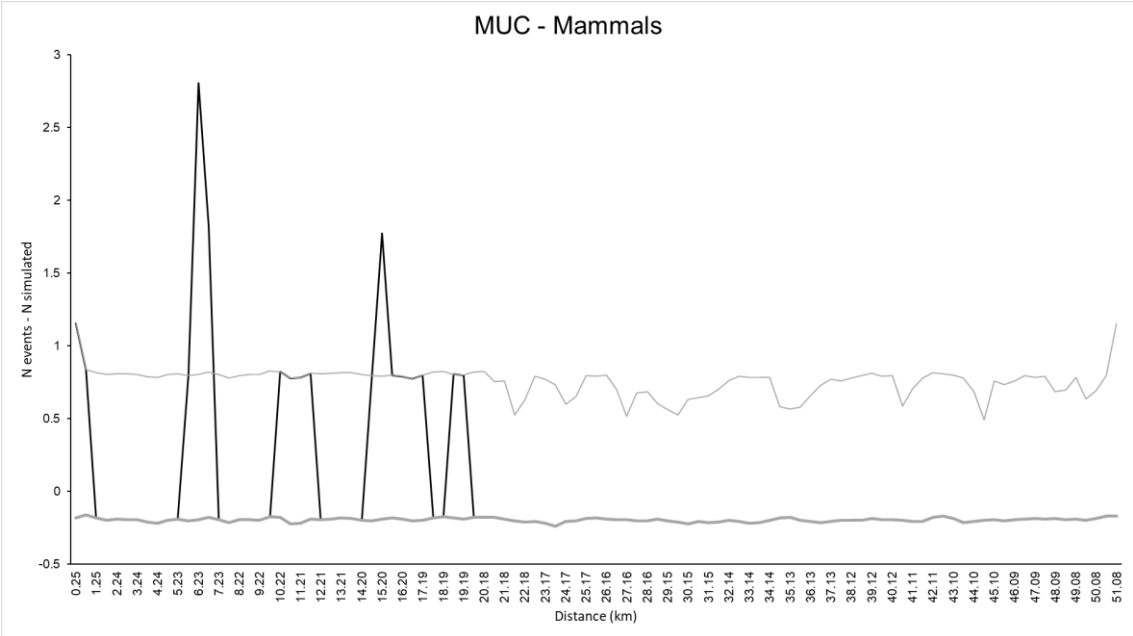


Figure S3.26. 2D Hotspot test results. Black line: N events – N simulated function; Gray lines: confidence limits. When the black line crosses the upper confidence limit, it indicates significant spatial aggregation (roadkill hotspot).

MUC – Total

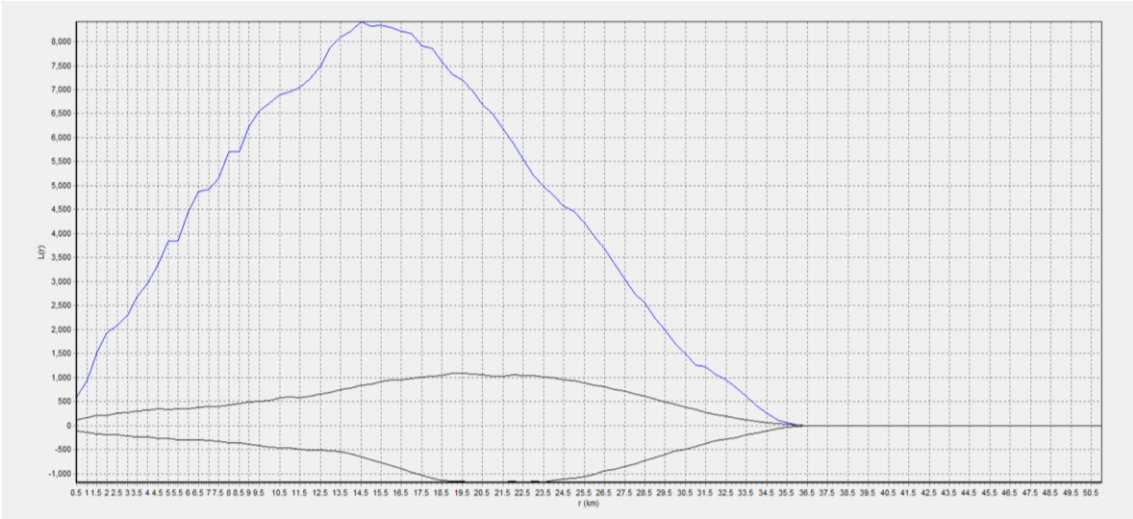


Figure S3.27. Ripley's K test results. Blue line: function L(r); Black lines: confidence limits; L(r): test function; r (km): radius in kilometers. When the blue line crosses the upper confidence limit, it indicates significant spatial aggregation.

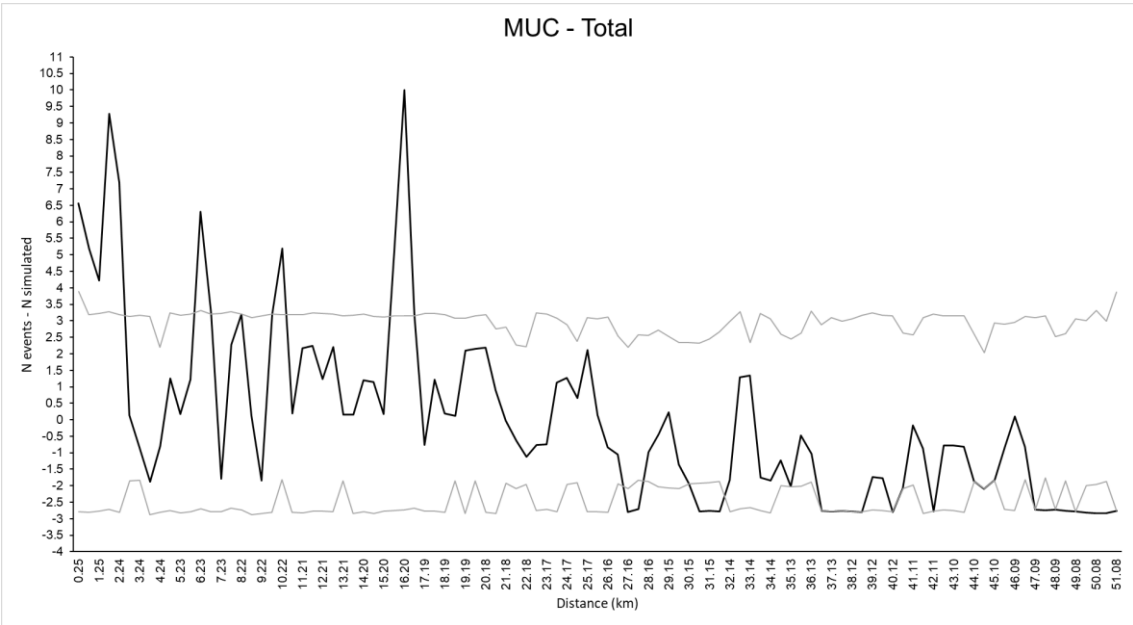


Figure S3.28. 2D Hotspot test results. Black line: N events – N simulated function; Gray lines: confidence limits. When the black line crosses the upper confidence limit, it indicates significant spatial aggregation (roadkill hotspot).

APÊNDICE III - MATERIAL SUPLEMENTAR DO CAPÍTULO 3

Appendix 1. List of bird species recorded near the highways from Chapada Diamantina region. IUCN: The species are categorized according to IUCN Red List of Threatened Species (IUCN). BR: The species are categorized according to National List of Endangered Species from Brazil (Brasil, 2022). Rec: if the species was recorded roadkill (R) or near highway (N).

Order	*Species*	Name	IUCN	BR	Rec
Accipitriformes	*Rupornis magnirostris*	Roadside Hawk	LC	-	N
Apodiformes	Augastes lumachella	Hooded Visorbearer	NT	EN	N
	Chionomesa lactea	Sapphire-spangled Emerald	LC	-	N
	Chlorostilbon lucidus	Glittering-bellied Emerald	LC	-	N
	Chrysolampis mosquitus	Ruby-topaz Hummingbird	LC	-	R,N
	Colibri delphinae	Brown Violetear	LC	EN	N
	Colibri serrirostris	White-vented Violetear	LC	-	R,N
	Eupetomena macroura	Swallow-tailed Hummingbird	LC	-	N
	Heliactin bilophus	Horned Sungem	LC	-	R
	Phaethornis pretrei	Planalto Hermit	LC	-	N
	Phaethornis ruber	Reddish Hermit	LC	-	N
Caprimulgiformes	*Antrostomus rufus*	Rufous Nightjar	LC	-	R
	Hydropsalis torquata	Scissor-tailed Nightjar	LC	-	N
Cariamiformes	*Cariama cristata*	Red-legged Seriema	LC	-	N
	Cathartes burrovianus	Lesser Yellow-headed Vulture	LC	-	N
	Coragyps atratus	Black Vulture	LC	-	R,N
Charadriiformes	*Tringa solitaria*	Solitary Sandpiper	LC	-	N
	Vanellus chilensis	Southern Lapwing	LC	-	N
	Columbina picui	Picui Ground-Dove	LC	-	R,N
	Columbina squammata	Scaled Dove	LC	-	N
	Columbina talpacoti	Ruddy Ground-Dove	LC	-	N
	Columbina sp.	Ground-Dove	-	-	R
	Leptotila verreauxi	White-tipped Dove	LC	-	N
	Patagioenas picazuro	Picazuro Pigeon	LC	-	N
Cuculiformes	*Coccyzus melacoryphus*	Dark-billed Cuckoo	LC	-	N
	Crotophaga ani	Smooth-billed Ani	LC	-	N
	Guira guira	Guira Cuckoo	LC	-	N
	Piaya cayana	Squirrel Cuckoo	LC	-	N
	Tapera naevia	Striped Cuckoo	LC	-	N
Falconiformes	*Caracara plancus*	Crested Caracara	LC	-	R,N
	Falco sparverius	American Kestrel	LC	-	N
	Herpetotheres cachinnans	Laughing Falcon	LC	-	N
	Micrastur ruficollis	Barred Forest-Falcon	LC	-	N
	Milvago chimachima	Yellow-headed Caracara	LC	-	N
Galbuliformes	*Galbula ruficauda*	Rufous-tailed Jacamar	LC	-	N
	Nystalus maculatus	Spot-backed Puffbird	LC	-	N
Galliformes	*Ortalis araucuan*	East Brazilian Chachalaca	LC	-	R,N
	Penelope superciliaris	Rusty-margined Guan	LC	-	R
Gruiformes	*Gallinula galeata*	Common Gallinule	LC	-	N
Passeriformes	*Agelaioides fringillarius*	Pale Baywing	LC	-	R,N
	Ammodramus humeralis	Grassland Sparrow	LC	-	N
	Antilophia galeata	Helmeted Manakin	LC	-	N
	Cacicus haemorrhous	Red-rumped Cacique	LC	-	N

Camptostoma obsoletum	Southern Beardless-Tyrannulet	LC	-	N
Cantorchilus longirostris	Long-billed Wren	LC	-	N
Certhiaxis cinnamomeus	Yellow-chinned Spinetail	LC	-	N
Chiroxiphia pareola	Blue-backed Manakin	LC	-	N
Coereba flaveola	Bananaquit	LC	-	N
Compsothraupis loricata	Scarlet-throated Tanager	LC	-	N
Conirostrum speciosum	Chestnut-vented Conebill	LC	-	N
Coryphospingus pileatus	Pileated Finch	LC	-	R,N
Cranioleuca semicinerea	Gray-headed Spinetail	LC	-	N
Culicivora caudacuta	Sharp-tailed Tyrant	VU	-	N
Cyanocorax cyanopogon	White-naped Jay	LC	-	N
Cyanoloxia brissonii	Ultramarine Grosbeak	LC	-	N
Cyclarhis gujanensis	Rufous-browed Peppershrike	LC	-	R,N
Dacnis cayana	Blue Dacnis	LC	-	N
Dendrocolaptes platyrostris	Planalto Woodcreeper	LC	-	N
Dendroplex picus	Straight-billed Woodcreeper	LC	-	N
Elaenia chilensis	Chilean Elaenia	LC	-	N
Elaenia cristata	Plain-crested Elaenia	LC	-	N
Elaenia flavogaster	Yellow-bellied Elaenia	LC	-	N
Elaenia spectabilis	Large Elaenia	LC	-	N
Elaenia spectabilis	Large Elaenia	LC	-	N
Elaenia sp.	Elaenia	-	-	R
Emberizoides herbicola	Wedge-tailed Grass-Finch	LC	-	N
Embernagra longicauda	Pale-throated Pampa-Finch	LC	-	N
Empidonomus varius	Variegated Flycatcher	LC	-	N
Euphonia chlorotica	Purple-throated Euphonia	LC	-	N
Euscarthmus meloryphus	Tawny-crowned Pygmy-Tyrant	LC	-	N
Euscarthmus rufomarginatus	Rufous-sided Pygmy-Tyrant	NT	-	N
Fluvicola nengeta	Masked Water-Tyrant	LC	-	N
Formicivora grantsaui	Sincora Antwren	EN	EN	N
Formicivora melanogaster	Black-bellied Antwren	LC	-	N
Formicivora rufa	Rusty-backed Antwren	LC	-	N
Furnarius figulus	Wing-banded Hornero	LC	-	R,N
Furnarius leucopus	Pale-legged Hornero	LC	-	R,N
Furnarius rufus	Rufous Hornero	LC	-	N
Geothlypis aequinoctialis	Masked Yellowthroat	LC	-	N
Gnorimopsar chopi	Chopi Blackbird	LC	-	N
Hemithraupis flavicollis	Yellow-backed Tanager	LC	-	N
Hemitriccus margaritaceiventer	Pearly-vented Tody-tyrant	LC	-	N
Hemitriccus striaticollis	Stripe-necked Tody-Tyrant	LC	-	N
Hirundinea ferruginea	Cliff Flycatcher	LC	-	N
Hylopezus ochroleucus	White-browed Antpitta	NT	-	N
Hylophilus amaurocephalus	Gray-eyed Greenlet	LC	-	N
Icterus cayanensis	Epaulet Oriole	LC	-	N
Icterus jamacaii	Campo Troupial	LC	-	N
Lepidocolaptes angustirostris	Narrow-billed Woodcreeper	LC	-	N
Machetornis rixosa	Cattle Tyrant	LC	-	R,N
Megarynchus pitangua	Boat-billed Flycatcher	LC	-	R,N
Megaxenops parnaguae	Great Xenops	LC	-	N

Melanopareia torquata	Collared Crescentchest	LC	-	N
Mimus saturninus	Chalk-browed Mockingbird	LC	-	R,N
Molothrus bonariensis	Shiny Cowbird	LC	-	R,N
Myiarchus ferox	Short-crested Flycatcher	LC	-	N
Myiarchus tyrannulus	Brown-crested Flycatcher	LC	-	N
Myiodynastes maculatus	Streaked Flycatcher	LC	-	N
Myiopagis caniceps	Gray Elaenia	LC	-	N
Myiopagis viridicata	Greenish Elaenia	LC	-	N
Myiophobus fasciatus	Bran-colored Flycatcher	LC	-	N
Myiothlypis flaveola	Flavescent Warbler	LC	-	N
Myiozetetes similis	Social Flycatcher	LC	-	N
Myrmorchilus strigilatus	Stripe-backed Antbird	LC	-	N
Nemosia pileata	Hooded Tanager	LC	-	N
Pachyramphus polychopterus	White-winged Becard	LC	-	N
Pachyramphus viridis	Green-backed Becard	LC	-	N
Paroaria dominicana	Red-cowled Cardinal	LC	-	R,N
Passer domesticus	House Sparrow	LC	-	N
Phacellodomus rufifrons	Rufous-fronted Thornbird	LC	-	N
Phaeomyias murina	Mouse-colored Tyrannulet	LC	-	N
Pheugopedius genibarbis	Moustached Wren	LC	-	N
Phyllomyias fasciatus	Planalto Tyrannulet	LC	-	N
Pitangus sulphuratus	Great Kiskadee	LC	-	R,N
Polioptila plumbea	Tropical Gnatcatcher	LC	-	N
Progne chalybea	Gray-breasted Martin	LC	-	R
Progne tapera	Brown-chested Martin	LC	-	N
Pseudoseisura cristata	Caatinga Cacholote	LC	-	N
Radinopsyche sellowi	Caatinga Antwren	LC	-	N
Sakesphoroides cristatus	Silvery-cheeked Antshrike	LC	-	N
Saltator similis	Green-winged Saltator	LC	-	N
Saltatricula atricollis	Black-throated Saltator	LC	-	N
Schistochlamys ruficapillus	Cinnamon Tanager	LC	-	N
Serpophaga subcristata	White-crested Tyrannulet	LC	-	N
Sicalis citrina	Stripe-tailed Yellow-Finch	LC	-	N
Sicalis flaveola	Saffron Finch	LC	-	R,N
Sicalis luteola	Grassland Yellow-Finch	LC	-	N
Sicalis sp.	Canary	-	-	R
Sittasomus griseicapillus	Olivaceous Woodcreeper	LC	-	N
Spinus yarrellii	Yellow-faced Siskin	VU	VU	N
Sporophila albogularis	White-throated Seedeater	LC	-	R,N
Sporophila nigricollis	Yellow-bellied Seedeater	LC	-	N
Sporophila sp.	Seedeater	-	-	R
Stelgidopteryx ruficollis	Southern Rough-winged Swallow	LC	-	N
Stigmatura napensis	Lesser Wagtail-Tyrant	LC	VU	N
Stilpnia cayana	Burnished-buff Tanager	LC	-	R,N
Sublegatus modestus	Southern Scrub-Flycatcher	LC	-	N
Suiriri suiriri	Suiriri Flycatcher	LC	-	N
Synallaxis albescens	Pale-breasted Spinetail	LC	-	N
Synallaxis frontalis	Sooty-fronted Spinetail	LC	-	N
Synallaxis spixi	Spix's Spinetail	LC	-	R,N

	Synallaxis sp.	Bird	-	-	R
	Tachyphonus rufus	White-lined Tanager	LC	-	N
	Taraba major	Great Antshrike	LC	-	N
	Thamnophilus caerulescens	Variable Antshrike	LC	VU	N
	Thamnophilus capistratus	Caatinga Antshrike	LC	-	N
	Thamnophilus pelzelni	Planalto Slaty-Antshrike	LC	-	N
	Thamnophilus torquatus	Rufous-winged Antshrike	LC	-	R,N
	Thraupis palmarum	Palm Tanager	LC	-	N
	Thraupis sayaca	Sayaca Tanager	LC	-	R,N
	Tityra inquisitor	Black-crowned Tityra	LC	-	N
	Todirostrum cinereum	Common Tody-Flycatcher	LC	-	N
	Tolmomyias flaviventris	Yellow-breasted Flycatcher	LC	-	N
	Troglodytes musculus	Southern House Wren	-	-	R,N
	Turdus amaurochalinus	Creamy-bellied Thrush	LC	-	N
	Turdus leucomelas	Pale-breasted Thrush	LC	-	N
	Turdus rufiventris	Rufous-bellied Thrush	LC	-	N
	Tyrannus melancholicus	Tropical Kingbird	LC	-	N
	Volatinia jacarina	Blue-black Grassquit	LC	-	R,N
	Xenops rutilans	Streaked Xenops	LC	-	N
	Xolmis irupero	White Monjita	LC	-	N
	Zonotrichia capensis	Rufous-collared Sparrow	LC	-	N
Pelecaniformes	*Tigrisoma lineatum*	Rufescent Tiger-Heron	LC	-	N
Piciformes	*Colaptes campestris*	Campo Flicker	LC	-	N
	Colaptes melanochloros	Green-barred Woodpecker	LC	-	N
	Melanerpes candidus	White Woodpecker	LC	-	N
	Picumnus pygmaeus	Spotted Piculet	LC	-	N
	Veniliornis passerinus	Little Woodpecker	LC	-	N
Psittaciformes	*Eupsittula cactorum*	Cactus Parakeet	LC	-	R,N
	Forpus xanthopterygius	Blue-winged Parrotlet	LC	-	N
	Pionus maximiliani	Scaly-headed Parrot	LC	-	N
Strigiformes	*Asio clamator*	Striped Owl	LC	-	R
	Athene cunicularia	Burrowing Owl	LC	-	R
	Glaucidium brasilianum	Ferruginous Pygmy-Owl	LC	-	N
	Megascops choliba	Tropical Screech-Owl	LC	-	R,N
	Tyto furcata	American Barn Owl	LC	-	R
Tinamiformes	*Crypturellus parvirostris*	Small-billed Tinamou	LC	-	N
	Crypturellus zabele	Zabele Tinamou	-	VU	R,N
	Rhynchotus rufescens	Red-winged Tinamou	LC	-	N
Trogoniformes	*Trogon surrucura*	Surucua Trogon	LC	-	N

Appendix 2. List of mammal species recorded near the highways from Chapada Diamantina region. IUCN: The species are categorized according to IUCN Red List of Threatened Species (IUCN). BR: The species are categorized according to National List of Endangered Species from Brazil (Brasil, 2022). Rec: if the species was recorded roadkill (R) or near highway (N).

Order	Species name	Common name	IUCN	BR	Rec
Artiodactyla	*Subulo gouazoubira*	Gray Brocket	LC	-	N
	Cervidade	Brocket	-	-	N
Carnivora	*Cerdocyon thous*	Crab-eating Fox	LC	-	R,N
	Conepatus semistriatus	Striped Hog-nosed Skunk	LC	-	R,N
	Eira barbara	Tayra	LC	-	R,N
	Galictis cuja	Lesser Grison	LC	-	N
	Leopardus emiliae	Tiger cat	-	-	R,N
	Leopardus pardalis	Ocelot	LC	-	N
	Leopardus sp.	Tiger cat	-	-	N
	Lycalopex vetulus	Hoary Fox	NT	VU	R,N
	Procyon cancrivorus	Crab-eating Raccoon	LC	-	R,N
	Herpailurus yagouaroundi	Jaguarundi	LC	VU	N
	Cabassous tatouay	Greater Naked-tailed Armadillo	LC	-	N
	Dasypus novemcinctus	Nine-banded Armadillo	LC	-	R,N
Didelphimorphia	*Didelphis albiventris*	White-eared Opossum	LC	-	R,N
Lagomorpha	*Sylvilagus* sp.	Tapeti	-	-	N
Pilosa	*Tamandua tetradactyla*	Southern Tamandua	LC	-	R,N
Primates	*Callithrix penicillata*	Black-pencilled Marmoset			R
Rodentia	*Coendou longicaudatus*	Porcupine	-	-	N
	Hydrochoerus hydrochaeris	Capybara	LC	-	N
	Kerodon rupestris	Rock Cavy	LC	VU	N

APÊNDICE IV – REGISTRO DAS ATIVIDADES DE CAMPO

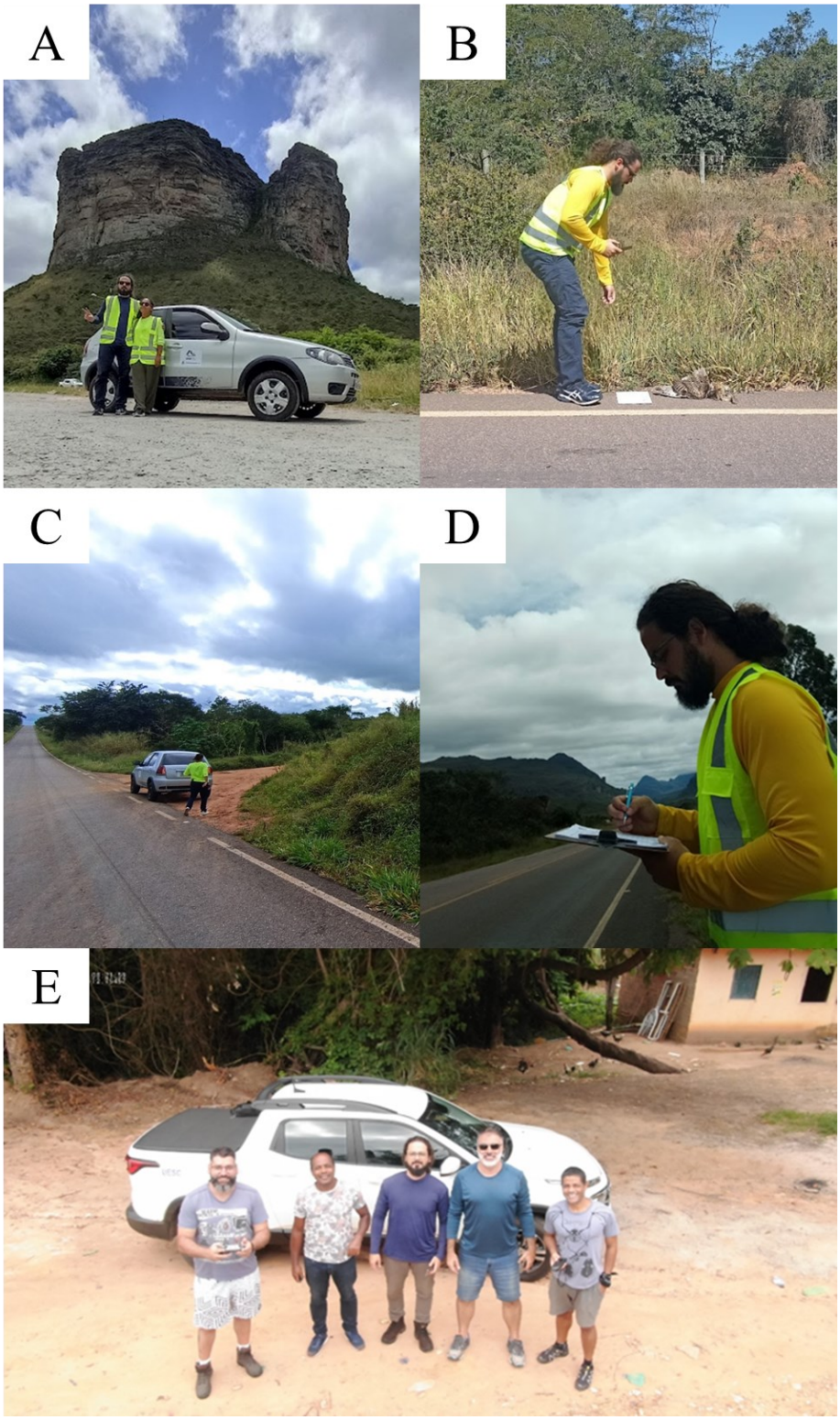


Figura 1. Registros de campo. A: Equipe de campo em 24 de março de 2023, composta por Jefferson Miranda e Ana Clara. B: Realizando o registro de uma coruja-orelhuda (*Asio clamator*) atropelada, em 10 de março de 2023, entre Mucugê e a Vinícola UVVA. C: Parada para registrar animal atropelado na BA-142, próximo de Andaraí – BA. D: Parada para contagem de veículos na BA-142. E: Equipe de campo para registro de fotografia nas áreas de Hotspots e Coldspots de atropelamentos. Na foto: Jorge (piloto), Renato (motorista da UESC), Jefferson (doutorando UESC), Alexandre (orientador), Franger (mestrando UESC).

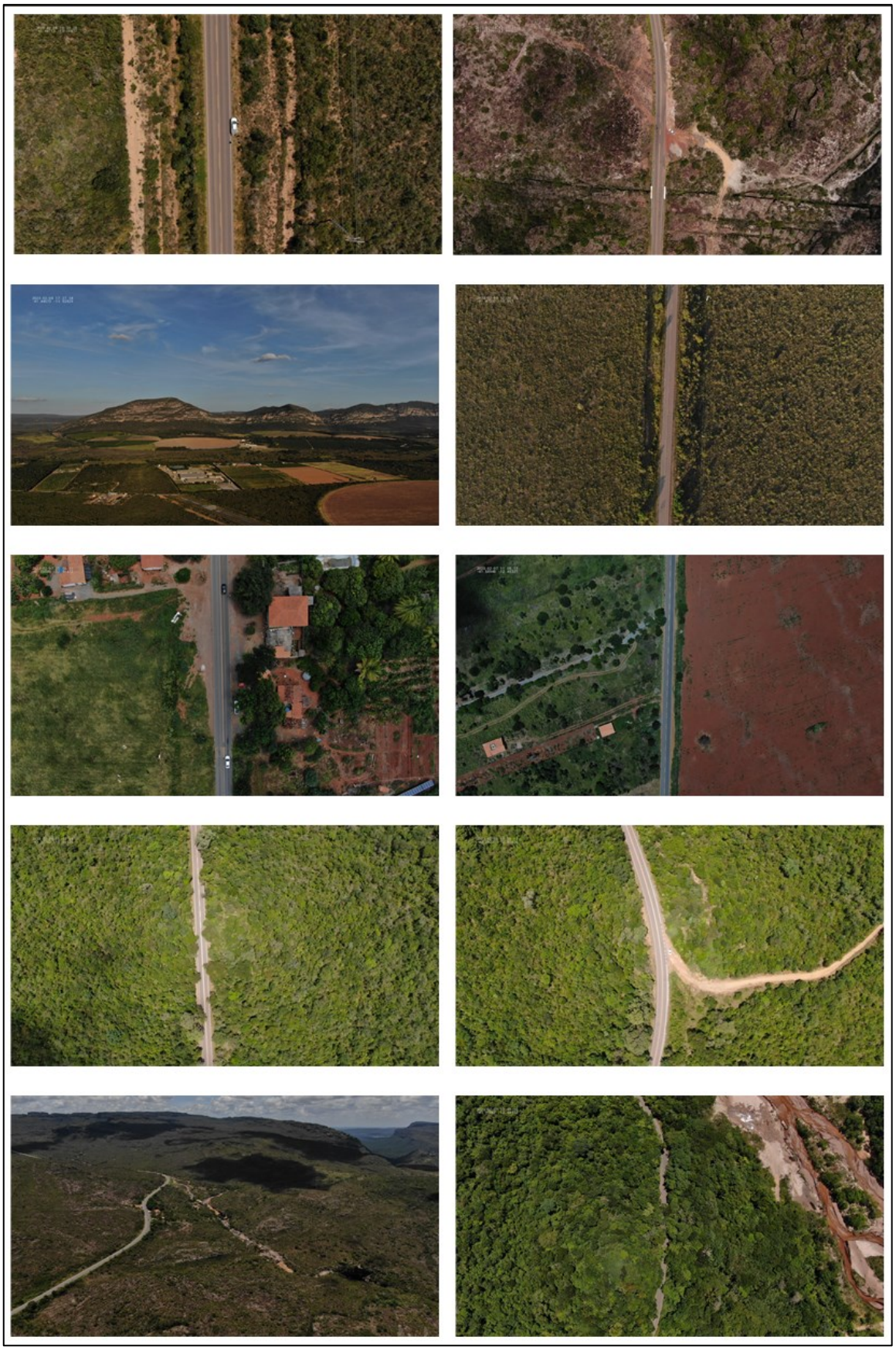


Figura 2. Prancha com diversas fotografias do entorno das rodovias, tiradas com drone. Autoria: Jorge Eduardo Zaidan

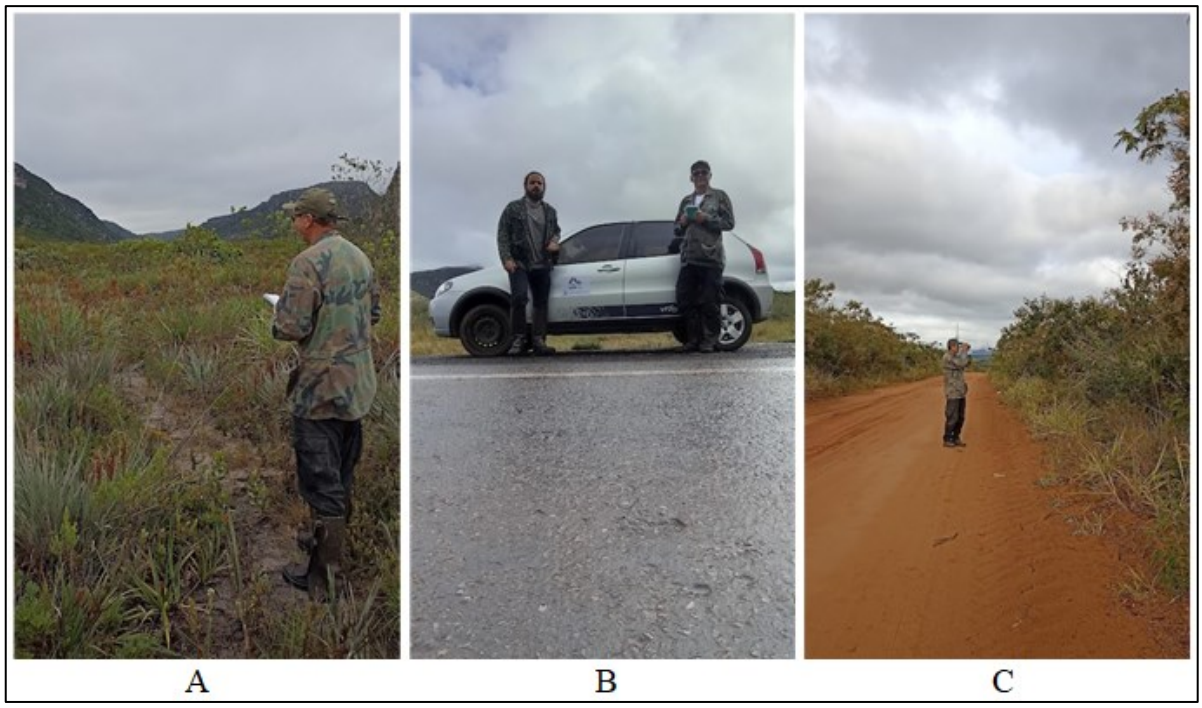


Figura 3. Primeira campanha de amostragem de aves no entorno das rodovias, na região da Chapada Diamantina. Março de 20223. A: Sidnei Sampaio dos Santos; B: Jefferson Miranda e Sidnei S. dos Santos; C: Sidnei S. dos Santos.

Figura 4. Terceira campanha de amostragem de aves no entorno das rodovias, na região da Chapada Diamantina. Maio de 20223. Foto tirada no módulo da BA-142, próximo à Fecularia Comunitária, Andaraí, BA.

Figura 5. Registros de alguns pontos de amostragem dentro do Parque Nacional da Chapada Diamantina. A: Região do Pantanal dos Marimbus; B: Região próxima da Cachoeira da Moça Loira; C. Rodovia BA-142 e estrada sentido à Cachoeira da Sibéria; D. Estrada sentido Mirante do Capa-Bode.

Figura 6. Registros de alguns pontos de amostragem fora do Parque Nacional da Chapada Diamantina. A: Um dos pontos de escuta no módulo localizado nas proximidades da Vinícola UVVA, entorno da BA-142; B: Ponto de escuta no módulo próximo da Fecularia Comunitária, em Andaraí; C: Ponto de escuta no módulo próximo da Fazenda Dois Irmãos, Mucugê; D: Um dos pontos de escuta no módulo próximo ao Rancho Morro Encantado, Andaraí.

Figura 7. Fotos da equipe e áreas do módulo da Brigada do PNCD, em Mucugê. Equipe da foto: Jefferson Miranda, Ana Clara (bióloga) e Luciano (brigadista).

Figura 8. Fotos com Sr. Fulô (de verde), líder da Comunidade Gamelas, em Andaraí, com Enoque (de branco), dono de uma das propriedades na comunidade, e das áreas de instalação das armadilhas dentro do módulo Gamelas.

Figura 9. Devolutiva à sociedade. Apresentação da palestra na Virada Ambiental de Lençóis em junho de 2024. Na ocasião também foi a equipe do PELD Chapada Diamantina, gerenciado pela

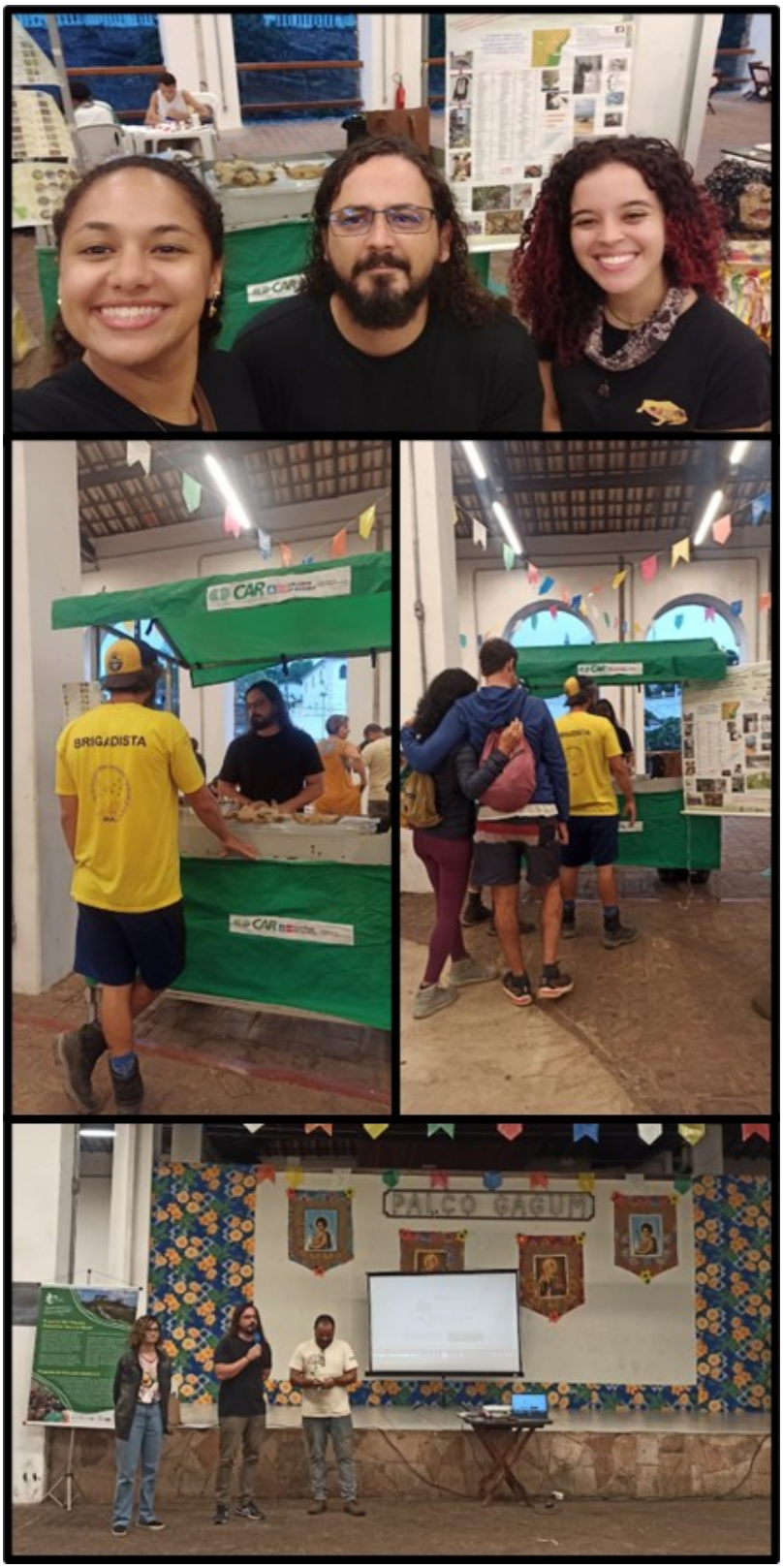


Figura 10. Devolutiva à sociedade. Apresentando exposição sobre fauna atropelada na Chapada Diamantina durante o evento de entrega do material do Plano de Ação Territorial Chapada Diamantina-Serra da Jiboia, em junho de 2024. Participação de Vivian Ferraz Gonçalves (UESC)

e Ana Clara Abadia (IFMT).

Figura 11. Devolutiva à sociedade. Realização de oficina sobre os mamíferos da Chapada Diamantina, confeccionando rastros de mamíferos, juntamente com o Plano de Ação Territorial Chapada Diamantina-Serra da Jiboia. Participação de Vivian Ferraz Gonçalves (UESC) e Ana Clara Abadia (IFMT).