diversity

MDPI

Article

Mammalian Roadkill in a Semi-Arid Region of Brazil: Species, Landscape Patterns, Seasonality, and Hotspots

Raul Santos [1,*], Ayko Shimabukuro [1], Itainara Taili [1], Roberto Muriel [2], Artur Lupinetti-Cunha [3], Simone Rodrigues Freitas [4] and Cecilia Calabuig [1,*]

[1] Center for Biological and Health Sciences, Ecology and Wildlife Conservation Laboratory, Semi-arid Rural Federal University, Mossoró 59625-900, Brazil; ayko_shimabukuro@yahoo.com.br (A.S.); itainarataili@hotmail.com (I.T.)

[2] Estación Ecologica de Doñana, Consejo Superior de Investigaciones Científicas, 41092 Sevill, Spain; rmuriel@ebd.csic.es

[3] Department of Ecology, Biosciences Institute, University of São Paulo, São Paulo 05508-090, Brazil; artlupinetti@gmail.com

[4] Center for Natural and Human Sciences, Federal University of ABC, Santo André 09210-580, Brazil; simonerfreitas.ufabc@gmail.com

* Correspondence: raull_santtos@hotmail.com (R.S.); cecicalabuig@ufersa.edu.br (C.C.)

Abstract: Roadkill is one of the principal causes of the loss of biodiversity around the world. The effects of roads on mammals are still poorly understood in regions with a semi-arid climate, where many knowledge gaps persist. The present study provides an inventory of the mammalian species affected on highways in northeastern Brazil, as well as identifying roadkill hotspots and contributing to the understanding of how seasonality and the landscape may influence the roadkill patterns of wild mammals. A total of 6192.52 km of road were sampled in 53 field surveys conducted between 2013 and 2017. Landsat 8 satellite images and data from the MapBiomas platform were used to classify land use and cover for analysis. Buffers of 1 km, 5 km, and 10 km were created around the study roads to identify the landscape variables associated with roadkill events. Ripley's 2D K-Statistics and the 2D HotSpot test were used to identify roadkill aggregations and hotspots; GLMMs were generated for the landscape variables and evaluated using the Akaike Information Criterion. The Kruskal–Wallis test was applied to investigate the potential effects of seasonality. A total of 527 wild animal carcasses were recorded as a result of vehicular collision. The species with the highest roadkill records were *Cerdocyon thous*, *Euphractus sexcinctus*, and *Procyon cancrivorus*, while two species—*Leopardus emiliae* and *Herpailurus yagouaroundi*—are considered to be under threat of extinction. For mammals in general, the best GLMM indicated an increase in roadkills with increasing density of local vegetation areas, and a decrease as urban areas increased. The model also found that the mammals were less impacted in the vicinity of a protected area. In the specific case of *C. thous*, the roadkill rate was lower when urban infrastructure was more common than dense vegetation; the rate increased as areas of dense vegetation increased. In the case of *P. cancrivorus* and *E. sexcinctus*, the best models of roadkill patterns included an area of exposed soil and sparse vegetation, respectively. Roadkill rates were higher in the rainy season for all the mammals, with the exception of *C. thous*. These results reflect the ecological characteristics of the species with the highest roadkill rates. The findings of the present study raise concerns with regard to the impact of highways on the populations of *C. thous*, as well as the region's most threatened species. They also indicate the potential functionality of the local protected area, as well as identifying roadkill hotspots, which will support the development of effective mitigation measures.

Keywords: road ecology; roadkill rates; seasonality; Caatinga; Brazil

Citation: Santos, R.; Shimabukuro, A.; Taili, I.; Muriel, R.; Lupinetti-Cunha, A.; Freitas, S.R.; Calabuig, C. Mammalian Roadkill in a Semi-Arid Region of Brazil: Species, Landscape Patterns, Seasonality, and Hotspots. *Diversity* **2023**, *15*, 780. https://doi.org/10.3390/d15060780

Academic Editor: Stephen Blake

Received: 18 April 2023
Revised: 7 June 2023
Accepted: 9 June 2023
Published: 16 June 2023

1. Introduction

Roads are linear structures that have a major impact on biodiversity [1–3], including negative effects on populations of all vertebrate classes [2,4,5]. Being struck by a vehicle is a significant source of anthropogenic mortality for many wild vertebrates [1,4]. It has been estimated that at least 475 million incidents of roadkill of wild species occur annually in Brazil [6], of which 14.7 million involve vertebrates [7], and approximately 2 million events refer to wild mammals [8]. A recent extrapolation, which took detectability and removal into account, indicated that the number of medium–large mammals killed on Brazilian roads may reach 9 million yearly [9]. However, the effect of roads still needs to be understood more systematically in Brazil, given that research in road ecology is still incipient [2], and most studies are concentrated in the south and southeast regions of the country, primarily in the Pampa and Atlantic Forest biomes [7]. Other regions, such as the semi-arid Caatinga, are under-sampled, and, thus, lack data on biodiversity and road ecology [10–12]. These data are essential for the identification of the species that are most vulnerable to roadkill and to understand how they are being affected by highway infrastructure.

Roads contribute significantly to population decline through habitat fragmentation, the reduction in dispersal between habitat patches, and roadkill [13,14], which may intensify the risk of extinction of some species [3,15]. Many different factors, such as traffic flow and speed, the layout of the road (primarily, its width, but also the presence of curves, slopes, and speed bumps), and the distribution of natural habitats in the surrounding area, are of fundamental relevance, given their influence on the magnitude of the impact of a road, and the spatial scale of its effects [16,17]. Data generated by road ecology studies provide crucial information for the understanding of the ecology, spatial distribution, and population density of species and their sensitivity to roads, which is essential to the development of more effective conservation measures [18,19].

Mammalia is one of the most studied vertebrate classes and roadkill mortality is well documented in its species [20]. The relatively extensive research involving this class is probably related to the large size of many mammals, their visibility, and the interest in understanding their biology [1,16]. In addition to intrinsic concerns for the conservation of mammalian species, collisions with large mammals are a threat to human safety and represent a potentially important economic cost to society [21].

Mammals are exposed to traffic when traveling on highways that traverse their home ranges or when they are attracted to patches of resources [15], which may concentrate roadkill rates in certain specific stretches of a highway [22]. Species with large home ranges, such as top predators, tend to cross more roads and, thus, encounter more traffic, which intensifies the negative impacts on these species [23,24]. These impacts also disproportionately affect species that are better adapted to anthropogenic habitats [25]. Similarly, roadkill appears to be more intense in species with nocturnal habits, as their activity period coincides with a reduction in visibility for drivers [15,26] and the obfuscation of these organisms [27]. On the other hand, some species are more sensitive to the presence of roads and tend to avoid them [15,26,28], and, thus, experience relatively fewer impacts and roadkill events [26,28]. Even in these cases, however, roads may have negative effects on the species by significantly reducing gene flow, for example [4,29].

The varying spatial patterns of a landscape strongly influence the presence of species and their relationships with the environment [30]. Research has shown a positive relationship between roadkill "hotspots" and certain landscape parameters [17,31]. Bodies of water, for example, specific types of vegetation, pabular species, habitat connectivity, and anthropization are key variables determining the formation of roadkill hotspots of wild mammals [32–37]. Roads that traverse or border protected areas, for example, tend to have relatively high roadkill rates [38], which may increase the vulnerability of species that are already under some degree of threat [4]. Seasonality is another important factor in the Caatinga biome, given the extreme fluctuations in conditions, which may concentrate the potential for roadkill during certain periods of the year, such as the reproductive [39] or mating [40,41] season. In semi-arid environments, such as the Caatinga, seasonality (dry vs. rainy periods) may have a major effect on the availability of food and water resources [10,42], which can also influence the distribution and concentration of roadkill events.

The effective mitigation of faunal roadkill requires the systematic analysis of the factors that determine the distribution of the areas of greatest impact. The success of any measures will depend on the specific characteristics of the target species or taxonomic group, as well as the associated biotic, abiotic, landscape, and ecological variables [29,36,43].

The Caatinga biome is among the most biodiverse semi-arid regions in the world [11], although its mammalian fauna is still poorly studied and the understanding of the impacts of roads on the group is still incipient [18]. In this context, the present study investigated (a) which wild mammal species are most affected by roadkill in the Caatinga biome, (b) the distribution of the principal roadkill hotspots in the study area, highlighting the relationship between roadkill events and the characteristics of the surrounding landscape, (c) whether there is seasonal variation (dry vs. rainy periods) in roadkill patterns, and (d) the possible relationship between roadkill patterns and the distance from a federal protected area.

In particular, mammals are likely to be more susceptible to roadkill on specific stretches of a road according to the local landscape characteristics. Species in less altered environments would also be expected to be more vulnerable to roadkill than those in more anthropized areas. Similarly, as protected areas tend to provide more resources, they generally support denser populations of a greater diversity of species, and roadkill would be expected to be positively related to the proximity of protected areas due to the greater potential for the dispersal of animals between habitat patches separated by roads. Given the relatively arid conditions and marked seasonality of the Caatinga, where the availability of water is a limiting resource for many species, fluctuations in climatic conditions would also be expected to influence roadkill patterns, with a greater impact during the rainy season, when food is more abundant and many mammals breed.

2. Materials and Methods

2.1. Study Area

The present study was conducted along stretches of the BR427 Brazilian federal highway, and state highways RN118, RN288, and PB323, in the vicinity of the Seridó Ecological Station (ESEC-Seridó), in the southwestern extreme of the Central Potiguar mesoregion (Figure 1). The (691993W, 9273362S; Universal Transverse Mercator-UTM, zone 24S) is a federal protected area encompassing approximately 1123.61 ha, located in the north of the municipality of Serra Negra, Rio Grande do Norte (RN) state, and totally within the Caatinga biome. This protected area is located in the Sertaneja Depression and has a mean annual rainfall of 497 mm, which occurs mainly between January and May, and a mean relative humidity of 68.1% [44]. The region has typical steppe savanna vegetation and high floristic and faunal biodiversity [44] in comparison with other semi-arid areas [11]. Altogether, 164 species of plants and 180 species of wild vertebrates have been recorded in the ESEC-Seridó, of which 25 are mammals, belonging to 13 families, with most (70%) being small mammals [44].

2.2. Roadkill Data

The data analyzed in the present study were collected over a period of four years and four months (September 2013 through December 2017). Monitoring was conducted by two observers traveling by car in the early hours of the day (to reduce the probability of the removal of carcasses by scavengers) at an average speed of 50 km/h. Each survey covered a total extension of approximately 116.86 km of two-lane paved roads in two-day sessions. On the first day of each session, the starting point was located at 6.69636W, 92.96897S, and the endpoint at 7.14350W, 92.83136S, while two routes were surveyed on the second day, between 7.14350W, 92.83136S and 6.98302W, 92.57140S, and between 6.78440W, 92.63656S and 7.00451W, 92.87920S. Each survey was conducted over two consecutive mornings.

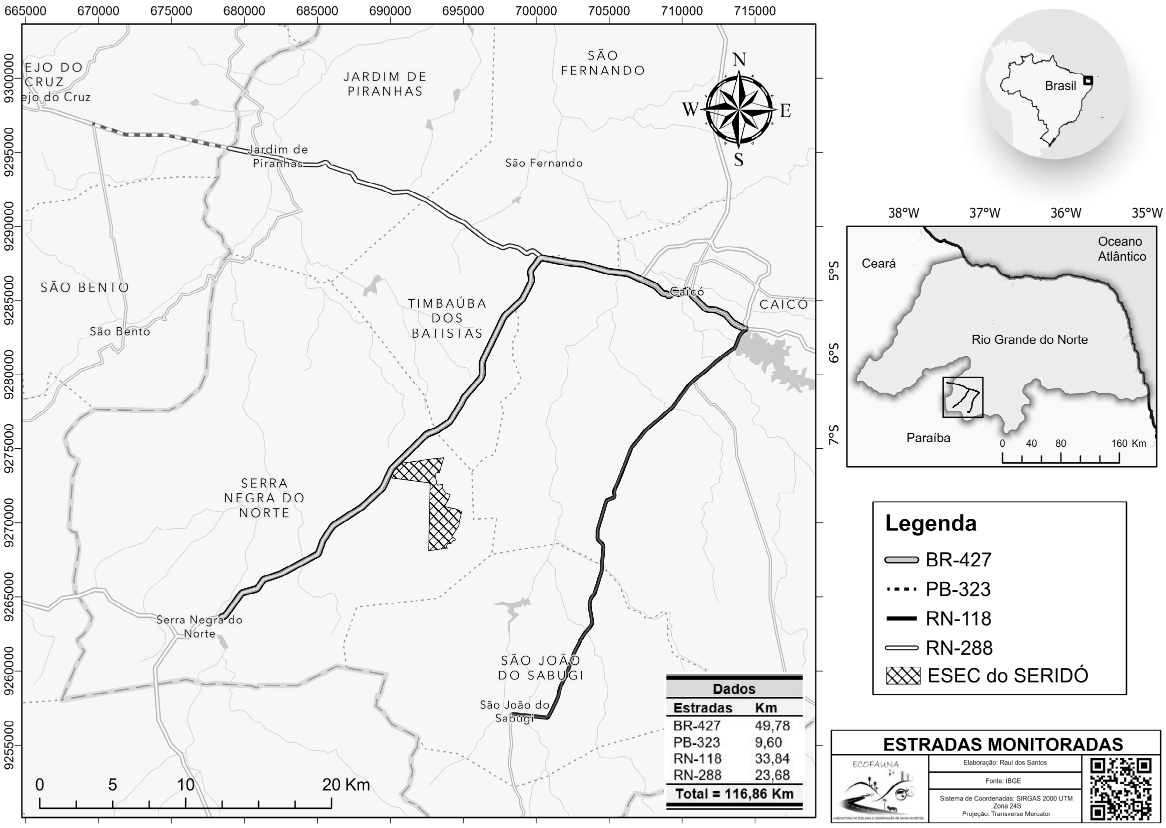

Figure 1. The stretches of the highways monitored in the present study, located in the Seridó region, in the semi-arid Caatinga biome of Rio Grande do Norte, northeastern Brazil.

The location of each carcass was recorded by Global Positioning System (GPS) and the animal was identified according to species. The taxonomic classification of species followed Quintela et al. [45] for felines and Carmignotto and Astúa [46] for all other species, while the conservation status of each species was obtained from the Brazilian Chico Mendes Institute for Biodiversity Conservation, ICMBio [47] and International Union for Conservation of Nature red lists [48], and the Official List of threatened Brazilian species [49].

2.3. Landscape and Seasonal Variables

To depict the differences in the Caatinga landscape in the dry and rainy seasons, spatial variables were obtained from two sources: (1) Landsat 8 satellite image with a spatial resolution of 30 m acquired from the United States Geological Survey (USGS) website (https://www.usgs.gov/core-science-systems/nli/landsat, accessed on 13 April 2021), and (2) land use and land cover (LULC) data from the MapBiomas collection 5 [50]. The MapBiomas dataset (collection 5) is also based on Landsat 8 images and has a mean overall accuracy of 81.8% for the Caatinga biome (for more details, see https://mapbiomas.org/en/accuracy-statistics?cama_set_language=en, accessed on 13 April 2021).

First, bands 6 (near infrared), 5 (red), and 4 (green) were composed and then adjusted finely to ensure that the color tone of each landscape element in the satellite image possessed the contrast necessary for the supervised classification using ArcGIS 10.5 software. The image was then cropped to cover only the areas of interest, which facilitated processing, and the LULC was classified using the following classes: dense vegetation, sparse vegetation, wetland, body of water, and exposed soil.

The MapBiomas data were then used to obtain the classes of urban infrastructure and farming. The farming class was obtained by grouping pasture and plantations, which largely coincided with the most degraded areas of vegetation observed in the Google Earth satellite images.

After the images were assigned to LULC classes, they were converted into polygons and grouped with the farming and urban infrastructure data, with the latter being superimposed on the mosaics created by the supervised classification, so that part of what was classified as exposed soil and sparse vegetation was replaced by farmland and urban infrastructure. To prevent both layers generated by the MapBiomas data from overlapping with bodies of water, this layer was added only in the final overlap. The layers were then grouped and cleaned, and the area of each polygon was calculated in hectares. All the geoprocessing procedures described above were run in the ArcGIS 10.5 software. A total of seven landscape variables (or seven LULC classes) were generated: dense vegetation, sparse vegetation, wetland, body of water, exposed soil, farmland, and urban infrastructure. The landscape variables were defined following Queiroz et al. [51]; that is, dense vegetation is the equivalent of forest, with a high concentration of arboreal vegetation; sparse vegetation is predominantly shrubby, with isolated trees; wetland has humid soils that favor greener vegetation (generally associated with areas of drainage); bodies of water have surface water, either perennial or intermittent; exposed soil lacks vegetation; farmland is generally considered smallholdings or family farms; and urban infrastructure refers to environments dominated by constructed substrates and anthropogenic habitats.

The Kappa index was used to analyze the accuracy of the supervised classifications, where $K \leq 0.20$ is considered to be bad, 0.21–0.40 fair, 0.41–0.60 good, 0.61–0.8 very good, and $K \geq 0.81$ is considered to be excellent [51]. The stretches of highway monitored in the present study were then divided into 1 km long sections and three buffers with a radius of 1 km, 5 km, and 10 km were generated [48,49]. These buffers were intended to cover the home range sizes of the different mammal species [52,53]. The area covered by each LULC class within each buffer was extracted, and the number of roadkill records within each area was counted. Finally, the distance in meters between the midpoint of the section and the ESEC-Seridó was calculated using the Euclidean distance tool of ArcGIS 10.5.

These procedures were repeated for the rainy and dry season periods between 2014 and 2017. Four satellite images were needed to cover the full extension of the study area, with a total of 32 images being used to generate the LULC classification. The year was divided into rainy (January to June) and dry seasons (July to December) based on precipitation levels. The precipitation data were obtained from the Rio Grande do Norte Agricultural Research Company (EMPARN) website, which acquired the data from the meteorological station of the municipality of Caicó, RN.

2.4. Statistical Analysis

Hotspot, landscape, and seasonal analyses were run for the mammals as a whole, except for *Cerdocyon thous*, which was analyzed separately to avoid interference due to the exceptionally large number of records obtained for this species. In addition to the general analysis, hotspot, landscape, and seasonal analyses were also run separately for *Procyon cancrivorus* and *Euphractus sexcinctus*.

2.4.1. Hotspots

Ripley's 2D K-Statistics test was used to determine the potential existence of roadkill aggregations, or hotspots, and the spatial scale at which they are found [52]. Initially, a radius of 100 m was used, although this was extended to 500 m, with the confidence interval set at 95%, and a total of 1000 simulations being run. The scales for the analyses were chosen specifically for mammals, and to meet the mitigation criteria for this class of vertebrate [16]. The 2D HotSpot test was used to identify the location of the roadkill hotspots [52]. Different weights were then assigned to each roadkill record according to the degree of vulnerability of the species [52]. In this case, threatened species received a weighting of 2 while non-threatened species were weighted 1. All the statistical analyses described above were run in the *Siriema* V 2.0 software [52].

2.4.2. Landscape versus Roadkill

Five groups of models were developed to evaluate the possible influence of landscape characteristics on the roadkill of all mammals and of the three species with the most records (*Cerdocyon thous*, *Euphractus sexcinctus*, and *Procyon cancrivorus*): (1) Generalized Linear Mixed-Effect Models (GLMMs) containing only one landscape variable (independent variable); (2) GLMMs with one landscape variable + season (dry or rainy); (3) GLMMs with two, non-interacting landscape variables + season + the distance from the protected area in meters; (4) GLMMs with two, interacting landscape variables + season + distance from the protected area, and (5) the null model. Interacting variables refer to predictor variables that are used in combination to examine their joint effect on the response variable, accounting for the possibility that the relationship between the predictors and the response is not constant across different levels or combinations of predictors. In all the models, the response variable was the number of roadkill records for each target species (i.e., all mammals, *Cerdocyon thous*, *Procyon cancrivorus,* and *Euphractus sexcinctus*) in the stretch of highway analyzed, with the year and road section as the random variables. Given the nature of the response variable, the Poisson distribution family was used [53]. *Cerdocyon thous* was excluded from the general analysis because this species accounts for more than 80% of the total records (see Section 3).

Models were fitted by the Maximum Likelihood method to permit the comparison of different fixed-effect structures, and were ranked according to the Akaike Information Criterion, corrected for small sample sizes (AICc), and the difference in the AICc value between each model and the top model with the lowest AICc (ΔAICc) was calculated. The models with a ΔAICc of less than 2 had strong support and were considered to be equivalent [54]. Natural model-averaging (without shrinkage), based on the relative model weight (*Wi*), was then applied to the subset of the top models (ΔAICc < 2) to account for the uncertainty in the selection of the models, and to derive robust parameter estimates for the fixed effects [55,56]. In this case, the models were generated for each of the buffers, at 1 km, 5 km, and 10 km. The Kruskal–Wallis test was also applied to compare the distribution of roadkill events in the two seasons. Statistical significance was set at $p < 0.05$ in all the analyses, which were run in the RStudio software using the packages bbmle [57], lme4 [58], MASS [59], car [60], ggplot2 [61], and effects [62].

3. Results

3.1. LULC Classification

The Kappa statistic for the supervised classification of the Landsat 8 images (Table 1) ranged from good to excellent [63]. The analysis of the resulting maps revealed clear variation in the composition of the landscape between the rainy and dry seasons, with a more extensive area of dense forest and water during the rainy season, in contrast with the sparser vegetation, wetlands, and bare soil observed during the dry season.

3.2. Roadkill

A total of 527 roadkill events involving wild mammal were recorded between September 2013 and December 2017, with a total sampling effort of 6193.58 km. These mammals belonged to 10 species from 6 orders, in particular, the Carnivora and Cingulata. The vast majority of the events (n = 423, 80.3%) involved *Cerdocyon thous*, while 32 (6.1%) involved *Procyon cancrivorus*, and 30 (5.7%) involved *Euphractus sexcinctus* (Table 2).

Table 1. Variation in the proportions (km^2 and %) of land use and land cover classes between the rainy and dry seasons from 2014 to 2017, and the Kappa quality index of the study area in the Caatinga of the Seridó region of Rio Grande do Norte, northeastern Brazil.

	2014		2015		2016		2017	
Landscape Variable	**Rainy (km^2)**	**Dry (km^2)**	**Rainy (km^2)**	**Dry (km^2)**	**Rainy (km^2)**	**Dry (km^2)**	**Rainy (km^2)**	**Dry (km^2)**
Body of water	50.57	23.22	39.20	14.13	22.37	12.36	21.63	9.38
Wetland	43.25	63.35	74.70	91.22	45.53	100.28	39.86	47.43
Urban infrastructure	16.58	16.59	16.89	16.90	17.44	17.06	19.45	21.19
Farming	417.89	422.79	453.24	457.32	449.68	452.26	454.02	456.74
Exposed soil	25.78	34.66	42.62	57.08	29.75	44.11	18.96	163.78
Dense vegetation	617.71	449.13	598.86	513.68	531.10	336.29	563.01	577.86
Sparse vegetation	1216.10	1378.16	1162.39	1237.56	1292.01	1425.71	1270.92	1111.47
Landscape variable	Rainy (%)	Dry (%)	Rainy (%)	Dry (%)	Rainy (%)	Dry (%)	Rainy (%)	Dry (%)
Body of water	2.12	0.97	1.64	0.59	0.94	0.52	0.91	0.39
Wetland	1.81	2.65	3.13	3.82	1.91	4.20	1.67	1.99
Urban infrastructure	0.69	0.69	0.71	0.71	0.73	0.71	0.81	0.89
Farming	17.50	17.71	18.98	19.15	18.83	18.94	19.01	19.13
Exposed soil	1.08	1.45	1.78	2.39	1.25	1.85	0.79	6.86
Dense vegetation	25.87	18.81	25.08	21.51	22.24	14.08	23.58	24.20
Sparse vegetation	50.93	57.71	48.68	51.83	54.11	59.70	53.22	46.55
Kappa	0.80	0.81	0.81	0.79	0.80	0.79	0.78	0.81

Table 2. Wild mammals found dead on the BR427, RN118, RN288, and PB323 highways in the Caatinga of the Seridó region of Rio Grande do Norte, northeastern Brazil. Total number of roadkill events (2013–2017), annual roadkill rate, mean rate, and the conservation status of the species according to the Brazilian and International Union for Conservation of Nature [48]. LC = Least Concern, VU = Vulnerable, EN = Endangered [47,48].

Taxon	Common Name	Number of Roadkills	Roadkill Rates (ind/km/Day)						Status (Brazil/IUCN)
			2013	**2014**	**2015**	**2016**	**2017**	**Mean**	
CARNIVORA Canidae *Cerdocyon thous* (Linnaeus, 1766)	Crab-eating fox	423	0.068	0.061	0.085	0.053	0.073	0.068	LC/LC
Felidae *Leopardus emiliae* (Thomas, 1914)	Northern tiger cat	8	0	0.002	0.001	0.001	0.002	0.001	EN/VU
Herpailurus yagouaroundi (É, Geoffroy Saint-Hilare, 1803)	Jaguarundi	5	0.003	0.001	0.001	0.001	0	0.001	VU/LC
Procyonidae *Procyon cancrivorus* (G, [Baron] Cuvier, 1798)	Crab-eating raccoon	32	0.003	0.005	0.007	0.003	0.006	0.005	LC/LC
CINGULATA Dasypodidae *Euphractus sexcinctus* (Linnaeus, 1758)	Six-banded armadillos	30	0	0.003	0.003	0.013	0.003	0.005	LC/LC
DIDELPHIMORPHIA Didelphidae *Didelphis albiventris* (Lund, 1840)	White-eared opossum	4	0	0.002	0.001	0	0	0.001	LC/LC
ARTIODACTYLA *Sus scrofa scrofa* (Linnaeus, 1758)	Wild boar	1	0	0.001	0	0	0	0.000	LC/LC
RODENTIA Caviidae *Galea spixii* (Wagler, 1831)	Yellow-toothed cavy	5	0	0.002	0.001	0	0.001	0.001	LC/LC
Echimyidae *Thrichomys laurentius* (Thomas, 1904)	São Lourenço's punaré	2	0.003	0	0	0.001	0	0.000	LC/LC
PRIMATES Callitrichidae *Callithrix jacchus* (Linnaeus, 1758)	Common marmoset	1	0	0.001	0	0	0	0.000	LC/LC
Unidentified Mammal		16	0	0.001	0.001	0.009	0.002	0.003	
TOTAL		527	0.077	0.076	0.099	0.080	0.088	0.085	

Based on the total survey distance, the overall mean roadkill rate was ≅31 ind/km/year (Table 2). The mean roadkill rate for *C. thous* was 25.92 ind/km/year, while that for *P. cancrivorus* was 1.89 ind/km/year, and that for *E. sexcinctus* was 1.77 ind/km/year. The two vulnerable feline species, *Leopardus emiliae* and *Herpailurus yagouaroundi* [47,48], had roadkill rates of 0.47 ind/km/year and 0.29 ind/km/year, respectively (Table 2). Overall, 3% of the specimens were so deteriorated that they could not be identified reliably during the study, and were, thus, excluded from the analyses (Figure 2).

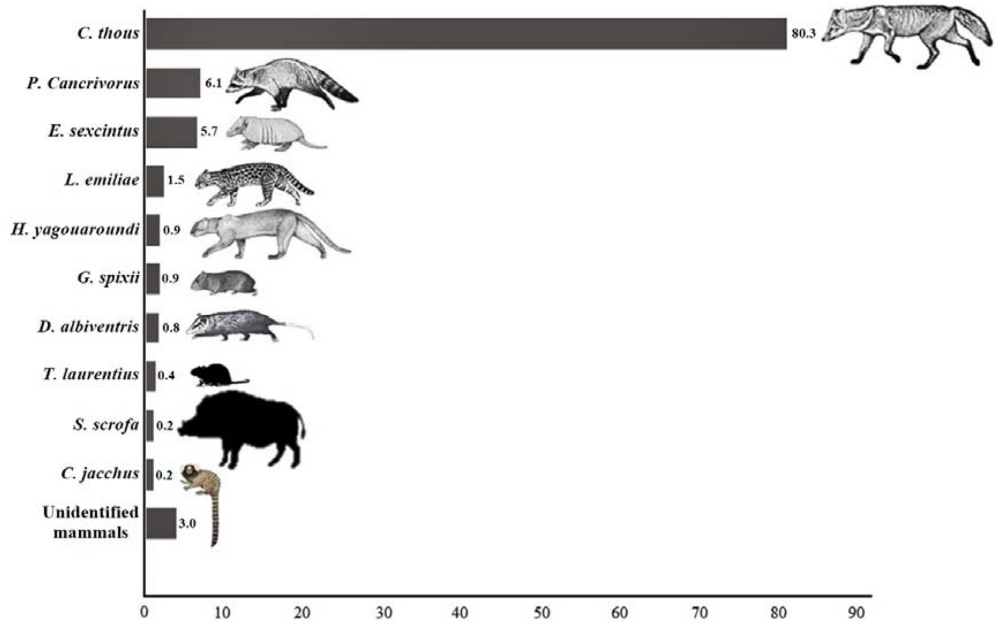

Figure 2. Frequency (%) of roadkill events in the 10 species of wild mammal recorded on the BR427, RN118, RN288, and PB323 highways in the Caatinga of the Seridó region in Rio Grande do Norte, northeastern Brazil, between 2013 and 2017.

The species accumulation curve (Figure 3) approached stability but was still sloping upward at the end of the study, which indicates that some local mammal species have yet to be detected. The K-statistics revealed significant aggregations for mammals as a whole, in addition to *C. thous*, *P. cancrivorus*, and *E. sexcinctus* separately (Table S1 in the Supplementary Material). The results indicate minimum aggregations at 100 m for mammals in general and for each of the species with sufficient records for analysis.

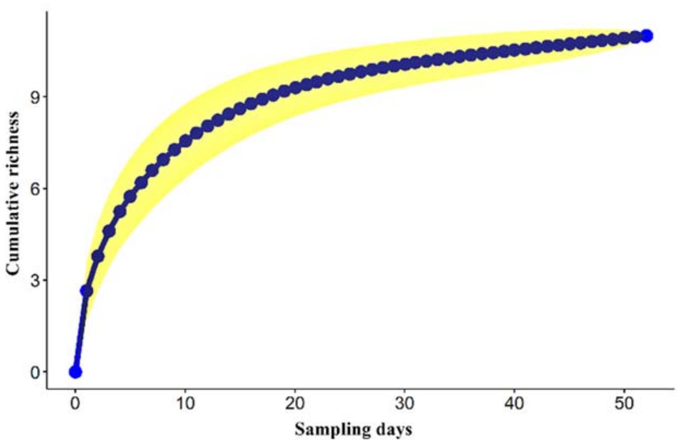

Figure 3. Observed species accumulation curve (blue line) with the 95% confidence interval (area in yellow) for the wild mammal community affected by roadkill on the BR427, RN118, RN288, and PB323 highways in the Caatinga of the Seridó region of Rio Grande do Norte, northeastern Brazil, between 2013 and 2017.

Roadkill was significantly more frequent during the rainy season (Figure 4A) for mammals in general (n = 104, df = 1, H = 12.07, $p < 0.05$). Similar patterns were observed in *P. cancrivorus* (n = 32, df = 1, H = 3.01, $p < 0.05$; Figure 4B) and *E. sexcinctus* (n = 30, df = 1, H = 5.58, $p < 0.05$; Figure 4C).

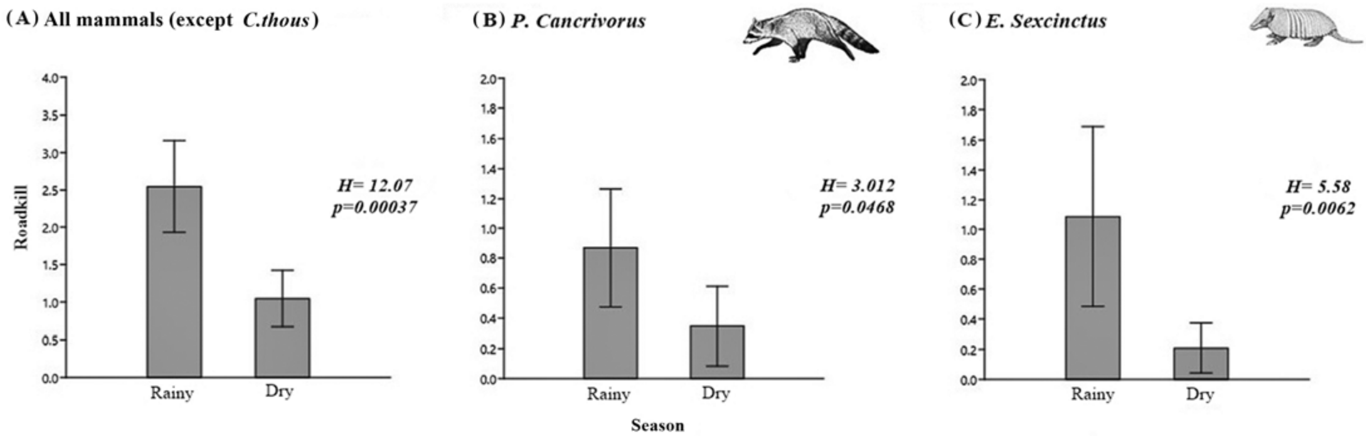

Figure 4. Results of the Kruskal–Wallis test, mean ± standard deviation of the records of wild mammals found killed on the study highways in the Caatinga of the Seridó region of Rio Grande do Norte, northeastern Brazil, during the rainy and dry seasons between 2014 and 2017. (**A**) All mammals (except *Cerdocyon thous*), (**B**) *Procyon cancrivorus*, and (**C**) *Euphractus sexcinctus*.

3.3. Roadkill Aggregations and Identification of Hotspots

The 2D HotSpot tests indicated aggregations of roadkills (hotspots) on several sections of the study highways. Mammals in general presented hotspots on the BR427, PB323, and RN288 highways, but none on the RN118. *Cerdocyon thous* was the only species to have roadkill hotspots on all the study highways. Most of the *P. cancrivorus* roadkill hotspots were on the BR427 highway, with only one on the RN288, while the *E. sexcinctus* hotspots were along the BR427 highway. The overall analysis established that the principal roadkill hotspots were located on the BR427 highway (Figure 5), although significant hotspots were also identified on the RN288 and the PB323 (intense red shading in Figure 5).

3.4. Landscape Variables Associated with Roadkill

Based on the AICc (ΔAICc and wAICc), systematic relationships were found between roadkill patterns and the landscape for mammals in general and each of the three species analyzed, i.e., *C. thous*, *P. cancrivorus*, and *E. sexcinctus*. The models selected by the AICc indicated that roadkill, in general, was associated negatively with urban infrastructure and positively with areas of dense or sparse vegetation (Table 3).

The model which best explains the variation in the frequency of roadkill of all mammals includes a positive effect of dense vegetation ($\beta = 2.77 \times 10^{-2}$), a positive but non-significant effect of urban infrastructure ($\beta = 7.87 \times 10^{-2}$), and the interaction between these two variables ($\beta = -2.36 \times 10^{-2}$), which had a negative effect, indicating that the effect of dense vegetation on the roadkill pattern is reduced when there is more urban infrastructure in the landscape. In addition to these landscape variables, the model also includes a negative effect of the dry season ($\beta = -9.51 \times 10^{-1}$), which means that there are fewer roadkill events during the dry season in comparison with the rainy season, and a positive effect for the distance from the protected area ($\beta = 6.39 \times 10^{-5}$), which indicates an increase in roadkill with increasing distance from the ESEC-Seridó (Figure 6).

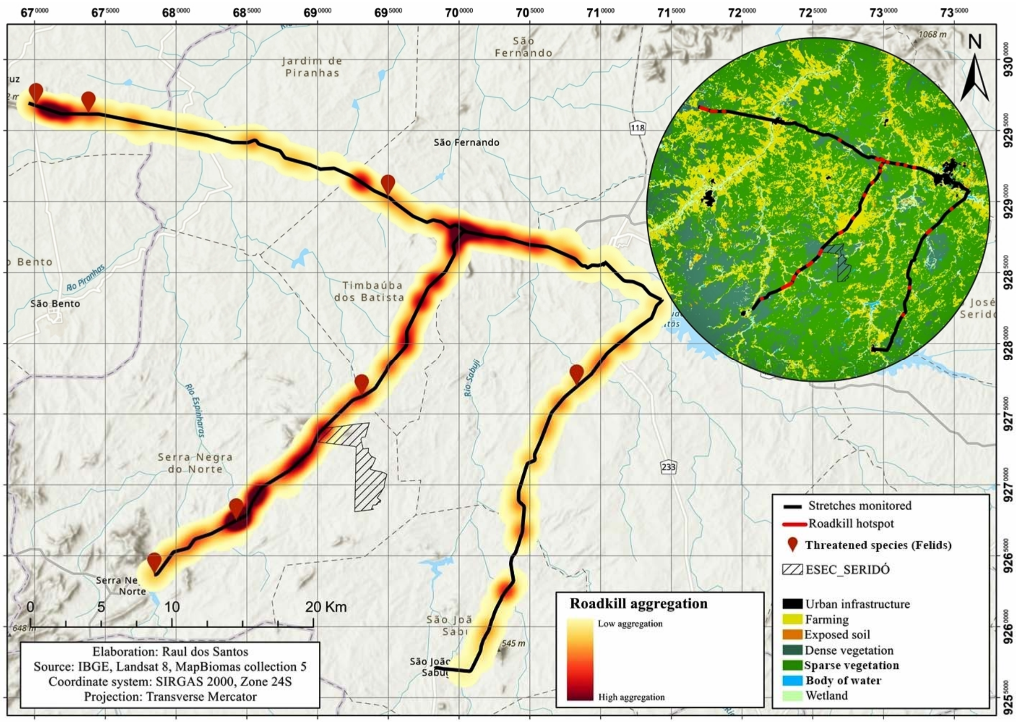

Figure 5. Principal roadkill hotspots for wild mammals in the Caatinga of the Seridó region of Rio Grande do Norte, northeastern Brazil, between 2014 and 2017. Information derived from the 2D HotSpot test.

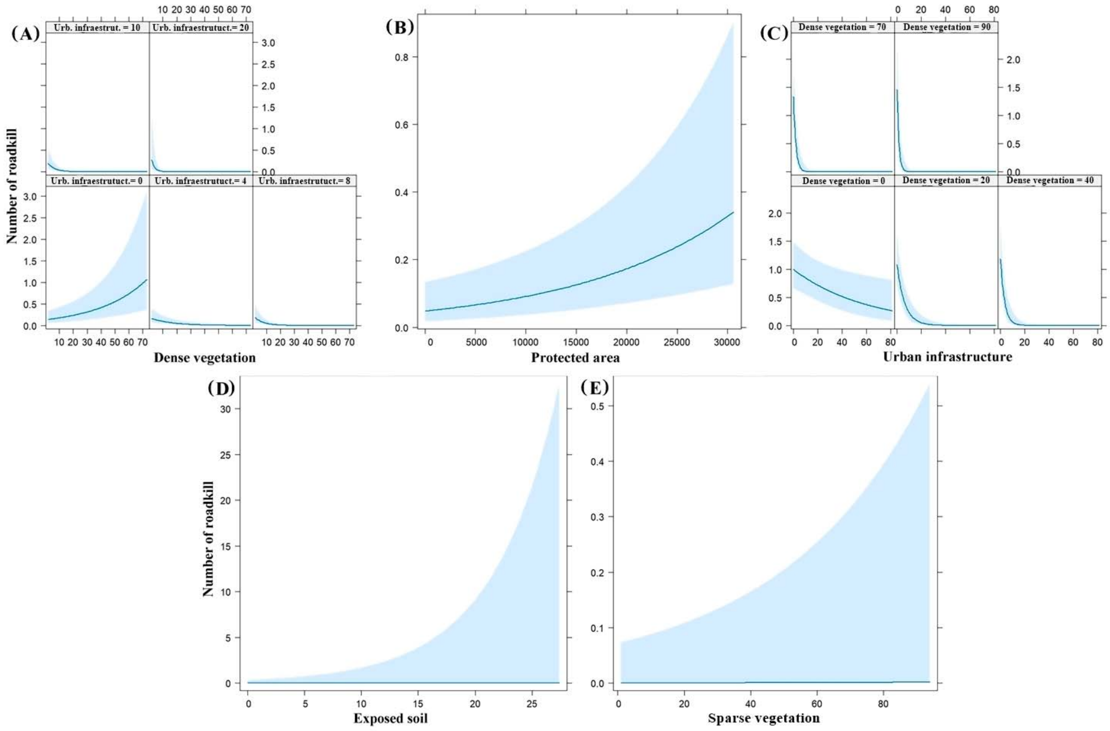

Figure 6. Linear regressions of the variables selected by the best AICc model ($p \leq 0.05$). (**A**,**B**) all mammals, (**C**) *Cerdocyon thous*, (**D**) *Procyon cancrivorus*, and (**E**) *Euphractus sexcinctus*. Data from the Caatinga of the Seridó region of Rio Grande do Norte, northeastern Brazil, collected between 2014 and 2017.

Table 3. Roadkill models selected using the Akaike criterion as a function of landscape features, in the Caatinga of the Seridó region of Rio Grande do Norte, northeastern Brazil, between 2014 and 2017. ΔAICc = the AIC distance; df = degrees of freedom; β = the regression coefficient; wAICc = the explanatory power of the model in comparison with all the others. Only models for which ΔAICc ≤ 2 are included here. The positive or negative sign before an independent variable indicates the direction of the effect.

Roadkill	Buffer	Variables Selected in the Model	B (Standard Error)	p	df	ΔAICc	wAICc
All mammals (Except *C. thous*)	5 km	Dense vegetation	2.77×10^{-2} (6.30×10^{-3})	1.08×10^{-5} *	9	0.0	0.9984
		Urban infrastructure	7.87×10^{-2} (4.14×10^{-2})	5.7×10^{-2}			
		Interaction	-2.36×10^{-2} (4.79×10^{-3})	8.35×10^{-7} *			
		Period (dry)	-9.51×10^{-1} (1.30×10^{-1})	3.14×10^{-13} *			
		Protected areas	6.39×10^{-5} (1.56×10^{-5})	4.21×10^{-5} *			
C. thous	1 km	Dense vegetation	4.20×10^{-3} (2.23×10^{-3})	5.9×10^{-2}	9	0.0	0.7813
		Urban infrastructure	-1.66×10^{-2} (6.77×10^{-3})	1.40×10^{-2} *			
		Interaction	-6.88×10^{-3} (1.78×10^{-3})	1.14×10^{-4} *			
		Period (dry)	8.30×10^{-2} (5.91×10^{-2})	1.60×10^{-1}			
		Protected areas	-3.96×10^{-6} (9.38×10^{-6})	6.73×10^{-1}			
P. cancrivorus	1 km	Exposed soil	1.55×10^{-1} (3.00×10^{-2})	2.28×10^{-7} *	8	0.0	0.5792
		Urban infrastructure	-1.12 (8.05×10^{-1})	1.64×10^{-1}			
		Period (dry)	-1.36 (2.65×10^{-1})	2.79×10^{-7} *			
		Protected areas	1.19×10^{-5} (2.33×10^{-5})	6.09×10^{-1}			
		Exposed soil	1.59×10^{-1} (3.01×10^{-2})	1.23×10^{-7} *	9	1.2	0.3166
		Urban infrastructure	-2.92×10^{-1} (1.07)	7.85×10^{-1}			
		Interaction	-2.76×10^{-1} (3.90×10^{-1})	4.80×10^{-1}			
		Period (dry)	-1.36 (2.65×10^{-1})	2.67×10^{-7} *			
		Protected areas	1.17×10^{-5} (2.33×10^{-5})	6.14×10^{-1}			
E. sexcinctus	1 km	Sparse vegetation	2.09×10^{-2} (6.16×10^{-3})	6.98×10^{-4} *	8	0.0	0.5092
		Urban infrastructure	-6.24×10^{-1} (5.21×10^{-1})	2.30×10^{-1}			
		Period (dry)	-1.59 (2.65×10^{-1})	2.20×10^{-9} *			
		Protected areas	2.53×10^{-5} (2.04×10^{-5})	2.16×10^{-1}			
		Sparse vegetation	1.93×10^{-2} (6.24×10^{-3})	2×10^{-3} *	9	0.4	0.4200
		Urban infrastructure	-2.95 (2.86)	3.01×10^{-1}			
		Interaction	4.44×10^{-2} (4.41×10^{-2})	3.14×10^{-1}			
		Period (dry)	-1.60 (2.66×10^{-1})	1.70×10^{-9} *			
		Protected areas	2.57×10^{-5} (2.03×10^{-5})	2.06×10^{-1}			

In the specific case of *C. thous*, the best model again included a negative effect of urban infrastructure (β = -1.66×10^{-2}) and a positive but non-significant effect of dense vegetation (β = 4.20×10^{-3}), with a negative interaction between these two variables (β = -6.88×10^{-3}), which indicates that the effect of urban infrastructure is reduced when there is more dense vegetation in the landscape (Figure 6C). This model also includes effects of the dry season (β = 8.30×10^{-2}) and the distance from the protected area (β = -3.69×10^{-6}), although these effects were non-significant in both cases.

The best model for *P. cancrivorus* (Figure 6D) includes a positive effect of bare soil (β = 1.55×10^{-1}) and a negative but non-significant effect of urban infrastructure (β = −1.12). This model also includes a negative effect of the dry season (β = −1.36) and a non-significant effect of the distance from the ESEC-Seridó (β = 1.19×10^{-5}), which implies that, in this species, roadkill patterns were unrelated to the proximity of the protected area. In the case of *E. sexcinctus,* the selected model includes a positive effect of sparse vegetation (β = 2.09×10^{-2}) and a negative but non-significant effect of urban infrastructure (β = -6.24×10^{-1}), indicating that the species is more susceptible to traffic in landscapes with sparse vegetation (Figure 6D). As for *P. cancrivorus*, the best model also shows a negative effect of the dry season (β = −1.59) and a non-significant effect of the proximity to protected areas (β = 2.53×10^{-5}).

4. Discussion

The surveys conducted during the present study recorded 20% of the wild mammal species known to occur in the Caatinga biome [46]. The two most speciose orders recorded here, the Carnivora and Cingulata, were also found to be most susceptible to roadkill in previous studies in the Caatinga [64], Cerrado–Atlantic Forest ecotone [2,65], Amazonia–Cerrado ecotone [17], Cerrado [7], and the Atlantic Forest–Pampa ecotone [66]. These findings further reinforce the existing data on the overall vulnerability of the species of these two orders to roadkill, in any biome [7,17,64–66]. One limitation of the present study was that it did not consider detectability and carcass removal rates, which may mean that roadkill rates were underestimated [67,68].

When compared with the results of Cezar et al.'s [64] study in the Caatinga, the roadkill rate recorded in the present study (≅31 ind/km/year) was 85.2% higher, with a rate of only ≅4.59 ind/km/year being recorded in the previous study. This previous study surveyed a 134 km stretch of state and federal highways, although there were no protected areas along this route. The route was surveyed once a week by car at a constant speed of 80 km/h over a 12-month period, with a much higher frequency of monitoring than that of the present study.

The species most affected in the present study (*C. thous*, *P. cancrivorus*, and *E. sexcinctus*) are known to be relatively abundant in the Caatinga [46,69–74] and have also been recorded relatively frequently in other roadkill studies in the Caatinga [64,75] and other Brazilian biomes, that is, the Atlantic Forest, Cerrado, and Pampa [65,76–78]. The vulnerability of these three species in different regions may be related to their ample geographic distributions [79], abundance [46,69–74], foraging characteristics, and generalist habits [71,79]. In addition, *C. thous* and *P. cancrivorus* have crepuscular and nocturnal habits [79,80] and relatively ample home ranges of 12.8 km^2 and 6.95 km^2, respectively [81,82]. This activity pattern coincides with the period of least visibility on the roads, which renders these mammals relatively more vulnerable to collisions [15,27]. In the specific case of *E. sexcinctus*, home ranges are smaller—up to 1.32 km^2 [83]—but the species is tolerant of human presence [77] and occurs in anthropogenic habitats [84]. In fact, the edge of the highway is attractive to this armadillo, given the availability of food, such as carcasses [83,84], increasing its susceptibility to roadkill.

As they have been recorded in many other roadkill studies [9,23,85–88], the absence of records of *Subulo gouazoubira* [85], *Dasypus novemcinctus*, and *Galictis cuja* [18] in the present study may indicate either that these species avoid roads or are rare in the study area, given that they are known to be present in other areas of the Caatinga in Rio Grande do Norte [18,69]. In the specific case of the felines, *L. emiliae* was recorded more frequently than *H. yagouaroundi*, which may be consistent with their local population densities [69,71]. However, demographic and ecological studies of wild mammals in the region are still scarce [70], which hampers the reliable understanding of the real impact of roadkill on the local mammal populations.

As in the present study, *C. thous* appears to be the mammal most affected by roadkill in all Brazilian biomes [28,64,65,76]. The universal impact on this species reinforces the need for further research on the status and perspectives of its populations. While the species is not listed as threatened [46,47], local populations may be endangered by roads, which act as population sinks. Further data on population dynamics, genetic diversity, and the impacts of roads on *C. thous* will be fundamental to the understanding of the persistence of its populations and the development of more effective strategies for the conservation of the ecosystems it inhabits.

The results of the K-Statistics 2D test showed hotspots of 100 m for mammals in general, as well as for both *C. thous* and *P. cancrivorus* on the federal and state highways. Despite being one of the most vulnerable species, hotspots of *E. sexcinctus* roadkill were only observed on the federal highway, even though the species was also widely impacted on the state highways. This difference may be related to the more homogeneous distribution of *E. sexcinctus* in the landscape close to the highways [23], where sparse vegetation and farmland predominate. In fact, the 2D HotSpot did not identify any overlap between the *E. sexcinctus* roadkill hotspots and those of the other species analyzed, which is consistent with previous observations on the lack of hotspot overlap between the species of distinct guilds [16], even though they may occur at wider spatial scales. Teixeira et al. [16] concluded that the aggregation of roadkill hotspots between different guilds and vertebrate groups is dependent on the spatial scale, so that hotspot overlap tends to increase when the spatial scale increases. This relationship has been observed in reptiles, birds, and mammals.

In the models selected by the AICc, roadkill is, in general, negatively associated with areas of greater anthropic interference, such as urban infrastructure, which indicates that the species are sensitive to this type of land use. The best model for the mammals as a whole indicated that, in an analysis of the 5 km buffer, there is a positive relationship between roadkill and areas of dense vegetation. This indicates that mammals, in general, are more vulnerable to roads that traverse areas of dense vegetation, which are extremely important components of the ecology of most mammals in this arid landscape [73], providing resources, such as shelter, food, and water, as well as greater thermal comfort (shade), in comparison with more open areas, such as sparse vegetation or pasture.

The model selected for *C. thous* shows a negative relationship between roadkill and urban infrastructure, even though this species is capable of adapting to altered habitats and is often found in anthropogenic areas [28]. Previous studies indicate that *C. thous* is vulnerable to roads that cut through areas of dense vegetation [79,89–91] and environments with a predominance of farmland [28,92,93]. However, the presence of *C. thous* on farmland depends on the type of crop being cultivated. This species has been reported in melon, pineapple, and sugarcane, given that it can feed on fruit [73], as well as eucalypt plantations, and in pasture [94]. In the Cerrado, roadkill of *C. thous* was associated with the proximity of riparian forests and reduced vegetation cover [95]. Even though *C. thous* occurs in many disturbed environments [96], which would render it potentially more vulnerable to roadkill, it appears to avoid urban areas [79], reducing the potential for collisions in these environments.

In the present study, perhaps surprisingly, the best model for *P. cancrivorus* included a positive effect of exposed soil, which indicates that the species frequents these highly impacted environments, although this relationship was found primarily in the rainy season. While the ecology of the species is not well documented in arid and semi-arid regions such as the Caatinga, data from other regions and for *Procyon lotor* [97–99] indicate that reproduction occurs predominantly in the rainy season. This would imply that roadkill patterns are related to reproductive phenomena, such as the search for breeding partners and territorial defense, which may intensify dispersal, in particular across open areas, and increase contact with roads. In the rainy season, the species' activity pattern may also shift as the animals seek thermal comfort [100] and become more active during the early hours of the night, which is when nighttime traffic is most intense [101] and visibility is worst [101,102]. Dispersal through open areas would not be a problem for this semi-arboreal species, although it remains enigmatic that roadkill increases in open areas during the season when resources are most available. A number of studies in other Brazilian biomes have revealed the vulnerability of this species to roads that traverse areas of more humid habitat, in the Cerrado [86], Atlantic Forest–Cerrado ecotones [68], and the Atlantic Forest [65].

Euphractus sexcinctus presented a positive relationship with sparse vegetation, reflecting its vulnerability to roads that cut through open areas. This species is known to inhabit open areas [84] close to roads [31], where resources may often be relatively scarce, forcing the animals to forage more actively in search of widely dispersed resources, which may bring them into more frequent contact with roads [28]. This armadillo is easily obfuscated by headlights when crossing a road due to its slow movements and poor vision, which favors the formation of roadkill hotspots in open environments [22]. This species is known to occur in habitats ranging from farmland [23,28] to denser vegetation [65] and, while it is considered to be tolerant of anthropogenic impacts [78,84], it is sensitive to urban areas.

Most previous studies have associated higher roadkill rates in wild species with roads that cut through protected areas and noted that rates decrease with increasing distance from these areas [58]. In the present study, general roadkill rates for all mammals increased with increasing distance from the ESEC-Seridó. One possible explanation is that the majority of the records were of more generalist species, such as *P. cancrivorus* and *E. sexcinctus*, which are better adapted to altered areas. By contrast, the much rarer and more vulnerable felines *L. emiliae* and *H. yagouaroundi* are more typical of the larger forest fragments and were recorded very rarely in the present study. The populations of these species also tend to be smaller than those of other mammals [20,69,103,104] and these animals may tend to avoid moving through open areas and anthropogenic or more degraded environments [73], which would reduce their exposure to roads. In this case, further, more detailed analyses in other areas of the Caatinga will be needed to better understand the relationship between roadkill, in particular of threatened species, and the proximity to protected areas. One other relevant point here is the size of the protected area and the resources it contains. Many mammals, such as carnivores [104], have relatively large home ranges, which may often be incompatible with the size of protected areas, which demands special consideration [105]. In the case of semi-arid environments, the availability of water and vegetation cover may be crucial to the success of conservation initiatives [105], by reducing the exposure of animals foraging outside the protected area. Water management in protected areas, including the presence of natural springs, can be an efficient conservation tool in these environments [106–108]. However, the establishment of protected areas does not necessarily guarantee that animals will remain in these areas, especially species with large home ranges [109], whose dispersal patterns need to be better understood.

Roadkill events were significantly more frequent in the rainy season in all the mammal species, except *C. thous* (Figure 4). The seasonal effect observed here contrasts with the findings of studies of mammals in other biomes [27,31,88,110,111]. In the present study, the seasonal effect may be related to the predominance of generalist species that have an enormous capacity to adapt to shifts in the environment, thus exploiting different types of resource over the course of the year [24]. The vulnerability of *E. sexcinctus* and *P. cancrivorus* to roadkill in the rainy season may be associated with the greater activity of individuals in this period, driven by the increased availability of food resources, the search for breeding partners, or even the less extreme climatic conditions [23,24]. Previous studies have indicated that cingulate species are more vulnerable to roadkill during the rainy season in the Cerrado [23], however, which is consistent with the findings of the present study.

The present study raises a number of points of concern with regard to the implementation of measures to mitigate roadkill in the study region [23]. As the effectiveness of mitigation measures depends on an adequate alignment of actions, considering the specific characteristics of the target group or species [43,112], the measures outlined below were designed specifically for the species with the highest roadkill rates, i.e., *C. thous*, *P. cancrivorus*, and *E. sexcinctus*:

I The erection of signposts, showing color images of the species most vulnerable to roadkill, together with instructions for the driver on the need to reduce speed to increase their reaction time when confronted with an animal on the road. Signposts should be installed at at least six of the principal hotspots identified in the present study, including four of which are located on the federal highway (684543W, 9267232S; 693296W, 9276207S; 697918W, 9283630S, and 700332W, 9287730S) and two on state highways (672244W, 9296095S and 693573W, 9290888S). These hotspots were selected because, in addition to their relevance for the three principal species, they are also important for threatened species, such as *L. emiliae* and *H. yagouaroundi*. It is important to note that each hotspot must have two signposts at an interval of approximately 1 km, to warn drivers approaching from both directions.

II Installation of speed-reducing devices (in accordance with the national traffic legislation), such as electronic monitoring systems or physical structures, such as speed bumps or studs. These devices should be installed after the signposts and within the area of the hotspot, to provide a backup mechanism that contributes to the effectiveness of the signposts.
III The excavation of tunnels under the road as a complementary, but relatively costly measure, which may be more or less viable, depending on the size of the target species and the topography of the region (the need to avoiding flooding in the rainy season).
IV Installation of containment (guide) fences in the vicinity of crossing points, to divert animals and oblige them to cross the road near the speed-reducing devices or in more appropriate stretches of the road.

5. Conclusions

The data collected in the present study are extremely relevant to the conservation of mammals in the Caatinga. In addition to closing part of the information gap on the impact of roads in semi-arid environments, these results provide a fundamental baseline for the development of further research. The data may be extrapolated to other areas with similar conditions, as well as contributing to the development of effective public policies and conservation measures.

The high roadkill mortality rates recorded in the present study, especially in the three most impacted species, *C. thous*, *P. cancrivorus*, and *E. sexcinctus*, and the presence of threatened species *L. emiliae* and *H. yagouaroundi*, is preoccupying. These findings reinforce the urgent need for more detailed studies on the populations of these species, in particular *C. thous*, which accounted for more than 80% of all the records of mortality. The order Carnivora, which was both the most speciose and the most impacted, and includes threatened felines [47,48], deserves special attention here.

Although protected areas can contribute to the persistence of species, the dispersal routes of large mammals need to be better understood at a larger geographic scale. Expanding the research to other areas of the Caatinga will be necessary to better understand the relationship between roadkill in these species and both the proximity of protected areas and different types of landscape. Future studies can evaluate the role of more conserved areas and the presence of bodies of water in the reduction in the dispersal of mammals and their contact with roads.

On the other hand, the landscape analysis identified factors associated with the susceptibility of species to roadkill. Understanding these factors, together with the identification of roadkill hotspots, will be essential to the development of more effective mitigation measures [43,112]. It is extremely important that these measures be designed to satisfy the characteristics of a target species or group [112] and consider the spatial characteristics of the area in which they are to be implemented. To better understand the impacts of roadkill on the wildlife of the Caatinga, research that involves the removal of carcasses and the analysis of specific mitigation measures will be fundamental, in addition to expanding the study area and the sampling effort, to seek a better understanding of how the landscape influences the roadkill rates of threatened species.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/d15060780/s1, Table S1: Results obtained from the analysis of the K-Ripley 2D estatistic and 2D Hotspots tests, for the general class of wild mammals and for the species *Cerdocyon thous, Procyon cancrivorus* and *Euphractus sexcinctus*, considering the temporal scale (the entire sampling period, annually and dry and rainy period) and spatially (BR427, RN118 and RN288).; Table S2: Monthly precipitation (in mm) from the meteorological station called "Açude Mundo Novo" of *Empresa de Pesquisa Agropecuária do Rio Grande do Norte* (EMPARN), Caicó, Seridó-Rio Grande do Norte, Brazil.; Table S3: Data obtained from satellite images used in the research to develop classified analyzes of land use and occupation. Due to the location of the study area, it was necessary to obtain four satellite images to develop the spatial analysis in each corresponding season and year.; Table S4: Summary of model selection statistics from GLMMs selected by species according to Akaike criteria as a function of landscape features. ΔAICc represents the AIC distance; df represents degrees of freedom; β: Regression coefficient; wAICc represents how much the model explain de variables related to all other models.

Author Contributions: R.S. performed the analysis, interpreted the data, and wrote the study; A.S. and I.T. acquired the data; C.C. designed the study and supervised data analysis; A.L.-C. contributed to statistical analysis, interpretation of data, and critical revision; S.R.F. supervised data analysis and critical revision; R.M. designed the study. All authors contributed equally to this work and discussed the results and implications and commented on the manuscript at all stages. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by PROPPG/UFERSA through the PPP 16/2013, 2nd Edition, and to Fundação de Apoio à Pesquisa do Estado do Rio Grande do Norte through project number 06/2020—FAPERN, 1st Edition.

Institutional Review Board Statement: Not applicable.

Data Availability Statement: All data can be found within the manuscript.

Acknowledgments: We thank H. S. de Oliveira, A. M. Dantas, L. R. L. Sá, C. Sombra, S. Paiva, and L. R. Silva for their valuable assistance in the field. We are also grateful to the Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio) for logistic support in the ESEC-Seridó and for authorizing specimen collection through license number 40620. A. Shimabokuro thanks Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for a Master's scholarship. R. Santos and I. Taili thank CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior) for Master's scholarships. We are also grateful to PROPPG/UFERSA for funding this project through the PPP 16/2013, 2nd Edition, and to Fundação de Apoio à Pesquisa do Estado do Rio Grande do Norte for funding part of this project through project number 06/2020—FAPERN, 1st Edition.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Trombulak, S.C.; Frissell, C.A. Review of Ecological Effects of Roads on Terrestrial and Aquatic Communities. *Conserv. Biol.* **2000**, *14*, 18–30. [CrossRef]
2. Bager, A.; Da, P.; Lucas, S.; Bourscheit, A.; Kuczach, A.; Maia, B. Os Caminhos Da Conservação Da Biodiversidade Brasileira Frente Aos Impactos Da Infraestrutura Viária. *Biodivers. Bras. BioBrasil* **2016**, *6*, 75–86.
3. Morelli, F.; Benedetti, Y.; Delgado, J.D. A Forecasting Map of Avian Roadkill-Risk in Europe: A Tool to Identify Potential Hotspots. *Biol. Conserv.* **2020**, *249*, 108729. [CrossRef]
4. Grilo, C.; Borda-de-Água, L.; Beja, P.; Goolsby, E.; Soanes, K.; le Roux, A.; Koroleva, E.; Ferreira, F.Z.; Gagné, S.A.; Wang, Y.; et al. Conservation Threats from Roadkill in the Global Road Network. *Glob. Ecol. Biogeogr.* **2021**, *30*, 2200–2210. [CrossRef]
5. Pinto, F.A.S.; Clevenger, A.P.; Grilo, C. Effects of Roads on Terrestrial Vertebrate Species in Latin America. *Environ. Impact Assess. Rev.* **2020**, *81*, 106337. [CrossRef]
6. CBEE. Centro Brasileiro De Estudos Em Ecologia De Estradas Brasil: Atropelamentos de Fauna Selvagem. Available online: https://sistemaurubu.com.br/dados/ (accessed on 18 March 2023).
7. Dornas, R.A.P.; Kindel, A.; Bager, A.; Freitas, S.R. Avaliação Da Mortalidade de Vertebrados Em Rodovias No Brasil. In *Ecologia de Estradas: Tendências e Pesquisas*; Bager, A., Ed.; UFLA: Lavras, Brazil, 2012; Volume 1, pp. 139–152. ISBN 978-85-903770-3-0.
8. González-Suárez, M.; Zanchetta Ferreira, F.; Grilo, C. Spatial and Species-Level Predictions of Road Mortality Risk Using Trait Data. *Glob. Ecol. Biogeogr.* **2018**, *27*, 1093–1105. [CrossRef]
9. Pinto, F.A.S.; Cirino, D.W.; Cerqueira, R.C.; Rosa, C.; Freitas, S.R. How Many Mammals Are Killed on Brazilian Roads? Assessing Impacts and Conservation Implications. *Diversity* **2022**, *14*, 835. [CrossRef]
10. Dean, W.R.J.; Seymour, C.L.; Joseph, G.S.; Foord, S.H. A Review of the Impacts of Roads on Wildlife in Semi-Arid Regions. *Diversity* **2019**, *11*, 81. [CrossRef]
11. Garda, A.A.G.; Lion, M.B.; Lima, S.M.D.Q.; Mesquita, D.O.; Araujo, H.F.P.D.; Napoli, M.F. Os Animais Vertebrados Do Bioma Caatinga. *Cienc. Cult.* **2018**, *70*, 29–34. [CrossRef]
12. Lee, E.; Croft, D.B.; Achiron-Frumkin, T. Roads in the Arid Lands: Issues, Challenges and Potential Solutions. In *Handbook of Road Ecology*; van der Ree, R., Smith, D.J., Grilo, C., Eds.; John Wiley & Sons, Ltd.: Hoboken, NJ, USA, 2015; pp. 382–390. ISBN 9781118568170.
13. Dixon, J.D.; Oli, M.K.; Wooten, M.C.; Eason, T.H.; Cown, J.W.M.C.; Paetkau, D. Two Florida Black Bear Populations. *Conserv. Biol.* **2006**, *20*, 155–162. [CrossRef]
14. Forman, R.T.T.; Deblinger, R.D. The Ecological Road-Effect Zone of a Massachusetts (U.S.A.) Suburban Highway. *Conserv. Biol.* **2000**, *14*, 36–46. [CrossRef]

15. Laurance, W.F.; Goosem, M.; Laurance, S.G.W. Impacts of Roads and Linear Clearings on Tropical Forests. *Trends Ecol. Evol.* **2009**, *24*, 659–669. [CrossRef] [PubMed]
16. Teixeira, F.Z.; Coelho, I.P.; Esperandio, I.B.; Rosa Oliveira, N.; Porto Peter, F.; Dornelles, S.S.; Rosa Delazeri, N.; Tavares, M.; Borges Martins, M.; Kindel, A. Os Hotsposts de Atropelamentos Nas Estradas São Coincidentes Entre Diferentes Grupos de Vertebrados? *Oecologia Aust.* **2013**, *17*, 36–47. [CrossRef]
17. Santos, E.; Cordova, M.; Rosa, C.; Rodrigues, D. Hotspots and Season Related to Wildlife Roadkill in the Amazonia–Cerrado Transition. *Diversity* **2022**, *14*, 657. [CrossRef]
18. Shimabukuro, A.R.; Santos, R.; Taili, I.; Lima, A.; Freitas, K.; Guimarães, T.; Morlanes, V.; Calabuig, C. Novos Registros e Considerações Sobre a Distribuição Geográfica de Galictis Cuja (Carnivora: Mustelidae) No Rio Grande Do Norte, Brasil. *Bol. Do Mus. Para. Emílio Goeldi Ciências Nat.* **2022**, *17*, 545–555. [CrossRef]
19. Perrino, E.V.; Musarella, C.M.; Magazzini, P. Management of Grazing Italian River Buffalo to Preserve Habitats Defined by Directive 92/43/EEC in a Protected Wetland Area on the Mediterranean Coast: Palude Frattarolo, Apulia, Italy. *Euro-Mediterr. J. Environ. Integr.* **2021**, *6*, 32. [CrossRef]
20. Grilo, C. A Rede Viária e a Fauna: Impactos, Mitigação e Implicações Para a Conservação Das Espécies Em Portugal. In *Ecologia de Estradas: Tendências e Pesquisas*; Bager, A., Ed.; UFLA: Lavras, Brazil, 2012; Volume 1, pp. 35–58. ISBN 978-85-903770-3-0.
21. Abra, F.D.; Granziera, B.M.; Huijser, M.P.; de Barros Ferraz, K.M.P.M.; Haddad, C.M.; Paolino, R.M. Pay or Prevent? Human Safety, Costs to Society and Legal Perspectives on Animal-Vehicle Collisions in São Paulo State, Brazil. *PLoS ONE* **2019**, *14*, e0215152. [CrossRef]
22. Melo, E.S.; Santos-Filho, M. Efeitos Da BR-070 Na Província Serrana de Cáceres, Mato Grosso, Sobre a Comunidade de Vertebrados Silvestres. *Rev. Bras. Zoociências* **2007**, *9*, 185–192.
23. Cáceres, N.C.; Casella, J.; Goulart, C.D.S. Variação Espacial e Sazonal Atropelamentos de Mamíferos No Bioma Cerrado, Rodovia BR 262, Sudoeste Do Brasil. *Mastozool. Neotrop.* **2012**, *19*, 21–33.
24. Caires, H.S.; Souza, C.R.; Lobato, D.N.C.; Fernandes, M.N.S.; Damasceno, J.S. Roadkilled Mammals in the Northern Amazon Region and Comparisons with Roadways in Other Regions of Brazil. *Iheringia. Ser Zool* **2019**, *109*, 1–9. [CrossRef]
25. Caro, T.M.; Shargel, J.A.; Stoner, C.J. Frequency of Medium-Sized Mammal Road Kills in an Agricultural Landscape in California. *Am. Midl. Nat.* **2000**, *144*, 362–369. [CrossRef]
26. Caceres, N.C. Biological Characteristics Influence Mammal Road Kill in an Atlantic Forest-Cerrado Interface in South-Western Brazil. *Ital. J. Zool.* **2011**, *78*, 379–389. [CrossRef]
27. Orlandin, E.; Piovesan, M.; Favretto, M.A.; D'Agostini, F.M. Mamíferos de Médio e Grande Porte Atropelados No Oeste de Santa Catarina, Brasil. *Biota Amaz.* **2015**, *5*, 125–130. [CrossRef]
28. Cirino, D.W.; Lupinetti-Cunha, A.; Freitas, C.H.; de Freitas, S.R. Do the Roadkills of Different Mammal Species Respond the Same Way to Habitat and Matrix? *Nat. Conserv.* **2022**, *47*, 65–85. [CrossRef]
29. Moore, L.J.; Petrovan, S.O.; Bates, A.J.; Hicks, H.L.; Baker, P.J.; Perkins, S.E.; Yarnell, R.W. Demographic Effects of Road Mortality on Mammalian Populations: A Systematic Review. In *Biological Reviews*; Wiley Online Library: Hoboken, NJ, USA, 2023. [CrossRef]
30. LaRue, M.A.; Nielsen, C.K. Modelling Potential Dispersal Corridors for Cougars in Midwestern North America Using Least-Cost Path Methods. *Ecol. Modell.* **2008**, *212*, 372–381. [CrossRef]
31. Carvalho, C.F.; Custódio, A.E.I.; Júnior, O.M. Agregações de Atropelamentos de Vertebrados Silvestres Na Rodovia Br-050, Minas Gerais, Brasil. *Biosci. J.* **2015**, *31*, 951–959. [CrossRef]
32. Aresco, M.J. Mitigation Measures To Reduce Highway Mortality of Turtles and Other Herpetofauna At a North Florida Lake. *J. Wildl. Manag.* **2005**, *69*, 549–560. [CrossRef]
33. Bager, A.; Piedras, S.R.N.; Tainana, M.S.; Hóbus, Q. Fauna Selvagem e Atropelamento. -Diagnóstico Do Conhecimento Brasileiro. In *Áreas Protegidas—Repensando as Escalas de Atuação*; Bager, A., Ed.; Bager, Alex: Porto Alegre, Brazil, 2007; Volume 1, pp. 49–62.
34. Fabrizio, M.; di Febbraro, M.; D'Amico, M.; Frate, L.; Roscioni, F.; Loy, A. Habitat Suitability vs Landscape Connectivity Determining Roadkill Risk at a Regional Scale: A Case Study on European Badger (*Meles meles*). *Eur. J. Wildl. Res.* **2019**, *65*, 7. [CrossRef]
35. Filius, J.; van der Hoek, Y.; Jarrín-V, P.; van Hooft, P. Wildlife Roadkill Patterns in a Fragmented Landscape of the Western Amazon. *Ecol. Evol.* **2020**, *10*, 6623–6635. [CrossRef]
36. Grilo, C.; Ascensão, F.; Santos-Reis, M.; Bissonette, J.A. Do Well-Connected Landscapes Promote Road-Related Mortality? *Eur. J. Wildl. Res.* **2011**, *57*, 707–716. [CrossRef]
37. Seo, C.; Thorne, J.H.; Choi, T.; Kwon, H.; Park, C.H. Disentangling Roadkill: The Influence of Landscape and Season on Cumulative Vertebrate Mortality in South Korea. *Landsc. Ecol. Eng.* **2015**, *11*, 87–99. [CrossRef]
38. Cândido, J.F., Jr.; Brocardo, C.R. Persistência de Mamíferos de Médio e Grande Porte Em Fragmento de Floresta Ombrófila Mista No Estado Do Paraná, Brasil. *Rev. Árvore* **2012**, *36*, 301–310.
39. Clevenger, A.P.; Chruszcz, B.; Gunson, K.E. Spatial Patterns and Factors Influencing Small Vertebrate Fauna Road-Kill Aggregations. *Biol. Conserv.* **2003**, *109*, 15–26. [CrossRef]
40. Davies, J.M.; Roper, T.J.; Shepherdson, D.D.J. Seasonal Distribution of Road Kills in the European Badger (*Meles meles*). *J. Zool* **1987**, *211*, 525–529. [CrossRef]

41. Medinas, D.; Marques, J.T.; Mira, A. Assessing Road Effects on Bats: The Role of Landscape, Road Features, and Bat Activity on Road-Kills. *Ecol. Res.* **2013**, *28*, 227–237. [CrossRef]
42. Bastos, D.F.D.O.; Souza, R.A.T.; Zina, J.; da Rosa, C.A. Seasonal and Spatial Variation of Road-Killed Vertebrates on Br-330, Southwest Bahia, Brazil. *Oecologia Aust.* **2019**, *23*, 388–402. [CrossRef]
43. Bager, A.; Alves Da Rosa, C. Priority Ranking of Road Sites for Mitigating Wildlife Roadkill. *Biota. Neotrop.* **2010**, *10*, 149–153. [CrossRef]
44. MMA. Ministério do Meio Ambiente Plano de Manejo ESEC Seridó. Available online: https://www.gov.br/icmbio/ptbr/assuntos/biodiversidade/unidade-de-conservacao/unidades-de-biomas/caatinga/lista-de-ucs/esec-do-serido (accessed on 18 March 2023).
45. Quintela, F.M.; DA ROSA, C.A.; Feijó, A. Updated and Annotated Checklist of Recent Mammals from Brazil. *An. Acad. Bras. Ciências* **2020**, *92*, 1–57. [CrossRef]
46. Carmignotto, A.P.; Astúa, D. Mammals of the Caatinga: Diversity, Ecology, Biogeography, and Conservation. In *Caatinga: The Largest Tropical Dry Forest Region in South America*; Silva, J.M.C.D., Leal, I.R., Tabarelli, M., Eds.; Springer International Publishing: Berlin/Heidelberg, Germany, 2018; pp. 211–254. ISBN 9783319683393.
47. Bonvicino, C.R.; Bezerra, A.M.R.; Percequillo, A.R.; D'Andrea, P.S. Instituto Chico Mendes de Conservação da Biodiversidade. In *Livro Vermelho da Fauna Brasileira Ameaçada de Extinção: Volume II—Mamíferos*; ICMBio, Ed.; Instituto Chico Mendes de Conservação da Biodiversidade: Brasília, Brazil, 2018; Volume II.
48. IUCN. The IUCN Red List of Threatened Species. Available online: http://www.iucnredlist.org (accessed on 18 March 2023).
49. MMA—Ministério do Meio Ambiente Salve: Risco de Extinção Da Fauna Brasileira. Available online: https://salve.icmbio.gov.br/#/ (accessed on 18 March 2023).
50. MapBiomas—Collection 5 of the Annual Coverage and Land Use Maps Series of the Brazil. Available online: https://mapbiomas.org (accessed on 13 April 2021).
51. Queiroz, L.P.; Cardoso, D.; Fernandes, M.F.; Moro, M.F. Diversity and Evolution of Flowering Plants of the Caatinga Domain. In *Caatinga: The Largest Tropical Dry Forest Region in South America*; Silva, J.M.C.D., Leal, I.R., Tabarelli, M., Eds.; Springer International Publishing: Cham, Switzerland, 2017; pp. 23–63. ISBN 978-3-319-68339-3.
52. Coelho, A.V.P.; Coelho, I.P.; Kindel, A.; Teixeira, F.Z. *Siriema: Road Mortality Software*; NERF, UFRGS: Porto Allegre, Brazil, 2014; Volume 2.0.
53. Bolker, B.M. *Ecological Models and Data in R*; Princeton University Press: Princeton, NJ, USA, 2008; ISBN 9781400840908.
54. Burnham, K.P.; Anderson, D.R.; Burnham, K.P. *Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach*; Springer: New York, NY, USA, 2002; Volume 1, ISBN 0387953647.
55. Muriel, R.; Ferrer, M.; Balbontín, J.; Cabrera, L.; Calabuig, C.P. Disentangling the Effect of Parental Care, Food Supply, and Offspring Decisions on the Duration of the Postfledging Period. *Behav. Ecol.* **2015**, *26*, 1587–1596. [CrossRef]
56. Grueber, C.E.; Nakagawa, S.; Laws, R.J.; Jamieson, I.G. Multimodel Inference in Ecology and Evolution: Challenges and Solutions. *J. Evol. Biol.* **2011**, *24*, 699–711. [CrossRef] [PubMed]
57. Bolker, B.; Giné-Vázquez, I.; R Core Team. *Bbmle: Tools for General Maximum Likelihood Estimation*, R package version 0.9; R Core Team: Vienna, Austria, 2010.
58. Bates, D.; Mächler, M.; Bolker, B.M.; Walker, S.C. Fitting Linear Mixed-Effects Models Using Lme4. *J. Stat. Softw.* **2015**, *67*, 1–48. [CrossRef]
59. Venables, W.N.; Ripley, B.D. *Modern Applied Statistics with S*, 4th ed.; Springer: New York, NY, USA, 2002; ISBN 0-387-95457-0.
60. Fox, J.; Weisberg, S. *An {R} Companion to Applied Regression*, 3rd ed.; Published online: Thousand Oaks, CA, USA, 2019.
61. Wickham, H. *Ggplot2: Elegant Graphics for Data Analysis*; Springer: Cham, Switzerland; New York, NY, USA, 2016; ISBN 978-3-319-24277-4.
62. Fox, J.; Weisberg, S. Visualizing Fit and Lack of Fit in Complex Regression Models with Predictor Effect Plots and Partial Residuals. *J. Stat. Softw.* **2018**, *87*, 1–27. [CrossRef]
63. Landis, J.R.; Koch, G.G. The Measurement of Observer Agreement for Categorical Data. *Biometrics* **1977**, *33*, 159–174. [CrossRef] [PubMed]
64. Cezar, H.R.D.A.; Abrantes, S.H.F.; Lima, J.P.R.D.; Medeiros, J.B.D.; Abrantes, M.M.R.; Carreiro, A.D.N.; Barbosa, J.P.D.L. Mamíferos Silvestres Atropelados Em Estradas Da Paraíba, Nordeste Do Brasil. *Braz. J. Dev.* **2021**, *7*, 48037–48049. [CrossRef]
65. Araujo, L.A.D.F.; Hannibal, W.; Costa, R.R.G.F.; Rossi, R.F.; Claro, H.W.P. Effects of Landscape on Roadkill of Medium and Large-Sized Mammals in Southern Goiás, Brazil. *Oecologia Aust.* **2020**, *24*, 164–172. [CrossRef]
66. Oliveira, D.D.S.; Silva, V.M.D. Vertebrados Silvestres Atropelados Na BR 158, RS, Brasil. *Biotemas* **2012**, *25*, 229–235. [CrossRef]
67. Teixeira, F.Z.; Rytwinski, T.; Fahrig, L. Inference in Road Ecology Research: What We Know versus What We Think We Know. *Biol. Lett.* **2020**, *16*, 20200140. [CrossRef]
68. Teixeira, F.Z.; Coelho, A.V.P.; Esperandio, I.B.; Kindel, A. Vertebrate Road Mortality Estimates: Effects of Sampling Methods and Carcass Removal. *Biol. Conserv.* **2013**, *157*, 317–323. [CrossRef]
69. Marinho, P.H.; Bezerra, D.; Antongiovanni, M.; Fonseca, C.R.; Venticinque, E.M. Mamíferos de Médio e Grande Porte Da Caatinga Do Rio Grande Do Norte, Nordeste Do Brasil. *Mastozool. Neotrop.* **2018**, *25*, 345–362. [CrossRef]
70. Alves, R.R.N.; Feijó, A.; Barboza, R.R.D.; Souto, W.M.S.; Fernandes-Ferreira, H.; Cordeiro-Estrela, P.; Langguth, A. Game Mammals of the Caatinga Biome. *Ethnobiol. Conserv.* **2016**, *5*, 1–51. [CrossRef]

71. Feijó, A.; Langguth, A. Mamíferos de Médio e Grande Porte Do Nordeste Do Brasil: Distribuição e Taxonomia, Com Descrição de Novas Espécies. *Rev. Nord. Debiologia* **2013**, *22*, 3–225.
72. Dias, D.M.; Guedes, P.G.; Silva, S.S.P.; Sena, L.M.M. Diversidade de Mamíferos Não Voadores Em Uma Área de Caatinga Do Nordeste Do Brasil. *Neotrop. Biol. Conserv.* **2017**, *12*, 200–208. [CrossRef]
73. Dias, D.D.M.; Bocchiglieri, A. Riqueza e Uso Do Habitat Por Mamíferos de Médio e Grande Porte Na Caatinga, Nordeste Do Brasil. *Neotrop. Biol. Conserv.* **2016**, *11*, 38–46. [CrossRef]
74. Delciellos, A.C. Mammals of Four Caatinga Areas in Northeastern Brazil: Inventory, Species Biology, and Community Structure. *Check List* **2016**, *12*, 1916. [CrossRef]
75. Ramos-Abrantes, M.M.; Carreiro, A.D.N.; Araújo, D.V.F.D.; Souza, J.G.D.; Lima, J.P.R.D.; Cezar, H.R.D.A.; Leite, L.S.; Abrantes, S.H.F. Vertebrados Silvestres Atropelados Na Rodovia BR-230, Paraíba, Brasil. *Pubvet* **2018**, *12*, 139. [CrossRef]
76. Zocche, J.; Costa, S.; Zocche-de-Souza, P.; Viana, I.; Mattia, D.; Scussel, C.; Zocche, C.; Pereira, J.; Carvalho, F. Vertebrados Silvestres Atropelados Em Rodovias Do Sul de Santa Catarina, Brasil. In *Geoprocessamento na Análise Ambiental*; UNESCO: Paris, France, 2020; pp. 252–289.
77. Brum, T.R.; Santos-Filho, M.; Canale, G.R.; Ignácio, A.R.A. Efeitos Das Rodovias Mt 235 e 358 Sob a Diversidade de Vertebrados No Sudoeste de Mato Grosso. *Braz. J. Biol.* **2018**, *78*, 125–132. [CrossRef]
78. Hegel, C.G.Z.; Consalter, G.C.; Zanella, N. Mamíferos Silvestres Atropelados Na Rodovia RS-135, Norte Do Estado Do Rio Grande Do Sul. *Biotemas* **2012**, *25*, 165–170. [CrossRef]
79. Beisiegel, B.D.M.; Lemos, F.G.; Azevedo, F.C.D.; Queirolo, D.; Jorge, R.S.P. Avaliação Do Risco de Extinção Do Cachorro-Do-Mato Cerdocyon Thous (Linnaeus, 1766) No Brasil. *Biodivers. Bras.* **2013**, *1*, 138–145.
80. Lima, L.A.Q.; de Oliveira, T.M.A.; Maia, T.G.; Shimabukuro, A.; Taili, I.; dos Santos, R.; Calabuig, C. Predation of Boa Constrictor (Boidae) by Cerdocyon Thous (Canidae) in Caatinga in Brazil. *Pak. J. Zool* **2022**, *54*, 1935–1937. [CrossRef]
81. Cheida, C.C.; Guimarães, F.H.; Beisiegel, B.D.M. Avaliação Do Risco de Extinção Do Guaxinim Procyon Cancrivorus (Cuvier, 1798) No Brasil. *Biodivers. Bras.* **2013**, *1*, 283–290.
82. Macfadem Juarez, K.; Marinho-filho, J. Diet, Habitat Use, and Home Ranges of Sympatric Canids in Central Brazil. *J. Mammal.* **2002**, *83*, 925–933. [CrossRef]
83. Medri, Í.M.; Mourão, G.D.M.; Rodrigues, F.H.G. Ordem Cingulata. In *Mamíferos do Brasil*; Reis, N.R.D., Peracchi, A.L., Pedro, W.A., Lima, I.P.D., Eds.; Technical Books Editora: Londrina, Brazil, 2011; Volume 2, pp. 75–90. ISBN 978-85-906395-4-1.
84. Souza, J.L.; Anacleto, T.C.S. Levantamento de Mamíferos Atropelados Na Rodovia BR-158, Estado de Mato Grosso, Brasil. In *Ecologia de Estradas: Tendências e Pesquisas*; Bager, A., Ed.; UFLA: Lavras, Brazil, 2012; Volume 1, pp. 207–2022. ISBN 978-85-903770-3-0.
85. Bernegossi, A.M.; Borges, C.H.D.S.; Sandoval, E.D.P.; Cartes, J.L.; Cernohorska, H.; Kubickova, S.; Vozdova, M.; Caparroz, R.; González, S.; Duarte, J.M.B. Resurrection of the Genus Subulo Smith, 1827 for the Gray Brocket Deer, with Designation of a Neotype. *J. Mammal.* **2022**, *104*, 619–633. [CrossRef]
86. Cherem, J.J.; Kammers, M.; Ghizoni, I.R., Jr.; Martins, A. Mamíferos de Médio e Grande Porte Atropelados Em Rodovias Do Estado de Santa Catarina, Sul Do Brasil. *Biotemas* **2007**, *3*, 81–96.
87. Bueno, C.; José, P.; de Almeida, A.L. Sazonalidade de Atropelamentos e Os Padrões de Movimentos Em Mamíferos Na BR-040 (Rio de Janeiro-Juiz de Fora). *Rev. Bras. De Zoociências* **2010**, *12*, 219–226.
88. Bueno, C.; Sousa, C.O.M.; Freitas, S.R. Habitat Ou Matriz: Qual é Mais Relevante Para Prever Atropelamentos de Vertebrados? *Braz. J. Biol.* **2015**, *75*, S228–S238. [CrossRef]
89. Saranholi, B.H.; Bergel, M.M.; Ruffino, P.H.; Rodríguez-C, K.G.; Ramazzotto, L.A.; de Freitas, P.D.; Galetti, P.M., Jr. Roadkill Hotspots in a Protected Area of Cerrado in Brazil: Planning Actions to Conservation Zonas de Alto Impacto de Atropellamientos En Un Área Protegida de Cerrado (Brasil): Planeando Acciones Para La Conservación. *Rev. MVZ Córdoba* **2016**, *21*, 5441–5448. [CrossRef]
90. Rocha, V.J.; Agular, L.M.; Silva-Pereira, J.E.; Moro-Rios, R.F.; Passos, F.C. Feeding Habits of the Crab-Eating Fox, Cerdocyon Thous (Carnivora: Canidae), in a Mosaic Area with Native and Exotic Vegetation in Southern Brazil. *Rev. Bras. Zool.* **2008**, *25*, 594–600. [CrossRef]
91. Cheida, C.C.; Nakano-Oliveira, E.; Fusco-Costa, R.; Rocha-Mendes, F.; Quadros, J. Ordem Carnivora. In *Mamíferos do Brasil*; Reis, N.R.D., Peracchi, A.L., Pedro, W.A., Lima, I.P.D., Eds.; Technical Books Editora: Londrina, Brazil, 2011; Volume 1, pp. 235–288.
92. Barros Ferraz, K.M.P.M.; de Siqueira, M.F.; Martin, P.S.; Esteves, C.F.; do Couto, H.T.Z. Assessment of Cerdocyon Thous Distribution in an Agricultural Mosaic, Southeastern Brazil. *Mammalia* **2010**, *74*, 275–280. [CrossRef]
93. Freitas, S.R.D.; Oliveira, A.N.D.; Ciocheti, G.; Vieira, M.V.; Matos, D.M.D.S. How Landscape Features Influence Road-Kill of Three Species of Mammals in the Brazilian Savanna? *Oecologia Aust.* **2015**, *18*, 35–45. [CrossRef]
94. Courtenay, O.; Maffei, L. Crab-Eating Fox (Cerdocyon Thous). In *Canids: Foxes, Wolves, Jackals and Dogs. Status Survey and Conservation Action Plan*; Sillero-Zubiri, C., Hoffmann, M., Macdonald, D.W., Eds.; IUCN Publications: Gland, Switzerland; Cambridge, UK, 2004; pp. 32–38. ISBN 2-8317-0786-2.
95. Ascensão, F.; Desbiez, A.L.J.; Medici, E.P.; Bager, A. Spatial Patterns of Road Mortality of Medium-Large Mammals in Mato Grosso Do Sul, Brazil. *Wildl. Res.* **2017**, *44*, 135–146. [CrossRef]
96. Rocha, V.J.; Reis, N.R.D.; Sekiama, M.L. Dieta e Dispersão de Sementes Por Cerdocyon Thous (Linnaeus) (Carnívora, Canidae), Em Um Fragmento Florestal No Paraná, Brasil. *Rev. Bras. Zool.* **2004**, *21*, 871–876. [CrossRef]

97. Fritzell, E.K. Reproduction of Raccoons (*Procyon lotor*) in North Dakota. *Am. Midl. Nat.* **1978**, *100*, 253–256. [CrossRef]
98. Sanderson, G.C.; Nalbandov, A.V. The Reproductive Cycle of the Raccoon in Illinois. *Ill. Nat. Hist. Surv. Bull.* **1973**, *31*, 29–85. [CrossRef]
99. Stope, M.B. The Raccoon (*Procyon lotor*) as a Neozoon in Europe. *Animals* **2023**, *13*, 273. [CrossRef] [PubMed]
100. Marques, R.V.; Fábian, M.E. Daily Activity Patterns of Medium and Large Neotropical Mammals during Different Seasons in an Area of High Altitude Atlantic Rain Forest in the South of Brazil. *Rev. Bras. De Zoociências* **2018**, *19*, 38–64. [CrossRef]
101. Lagos, L.; Picos, J.; Valero, E. Temporal Pattern of Wild Ungulate-Related Traffic Accidents in Northwest Spain. *Eur. J. Wildl. Res.* **2012**, *58*, 661–668. [CrossRef]
102. Morelle, K.; Lehaire, F.; Lejeune, P. Spatio-Temporal Patterns of Wildlife-Vehicle Collisions in a Region with a High-Density Road Network. *Nat. Conserv.* **2013**, *5*, 53–73. [CrossRef]
103. Almeida, L.B.D.; Queirolo, D.; Beisiegel, B.D.M.; Oliveira, T.G. de Avaliação Do Estado de Conservação Do Gato-Mourisco Puma Yagouaroundi (É. Geoffroy Saint-Hilaire, 1803) No Brasil. *Biodivers. Bras.* **2013**, *1*, 99–106.
104. Marinho, P.H.; Bezerra, D.; Antongiovanni, M.; Fonseca, C.R.; Venticinque, E.M. Activity Patterns of the Threatened Northern Tiger Cat Leopardus Tigrinus and Its Potential Prey in a Brazilian Dry Tropical Forest. *Mamm. Biol.* **2018**, *89*, 30–36. [CrossRef]
105. Paolino, R.M.; Versiani, N.F.; Pasqualotto, N.; Rodrigues, T.F.; Krepschi, V.G.; Chiarello, A.G. Uso Da Zona de Amortecimento de Uma Unidade de Conservação de Cerrado Por Mamíferos. *Biota. Neotrop.* **2016**, *16*, 1–13. [CrossRef]
106. Astete, S.; Marinho-Filho, J.; Kajin, M.; Penido, G.; Zimbres, B.; Sollmann, R.; Jácomo, A.T.A.; Tôrres, N.M.; Silveira, L. Forced Neighbours: Coexistence between Jaguars and Pumas in a Harsh Environment. *J. Arid. Environ.* **2017**, *146*, 27–34. [CrossRef]
107. Montalvo, V.H.; Saénz-Bolanõs, C.; Alfaro, L.D.; Cruz, J.C.; Guimarães-Rodrigues, F.H.; Carrillo, E.; Sutherland, C.; Fuller, T.K. Seasonal Use of Waterholes and Pathways by Macrofauna in the Dry Forest of Costa Rica. *J. Trop. Ecol.* **2019**, *35*, 68–73. [CrossRef]
108. Najafi, J.; Farashi, A.; Pasha Zanoosi, A.A.; Yadreh, R. Water Resource Selection of Large Mammals for Water Resources Planning. *Eur. J. Wildl. Res.* **2019**, *65*, 82. [CrossRef]
109. Massara, L.R.; Paschoal, A.M.D.O.; Hirsch, A.; Chiarello, A.G. Diet and Habitat Use by Maned Wolf Outside Protected Areas in Eastern Brazil. *Trop. Conserv. Sci.* **2012**, *5*, 284–300. [CrossRef]
110. Costa, R.R.G.F.; Dias, L.A. Mortalidade de Vertebrados Por Atropelamento Em Trecho Da GO-164, No Sudoeste Goiano. *Rev. De Biotecnol. Ciência* **2013**, *2*, 58–74.
111. Evangelho Silva, D.; Liberato Costa Corrêa, L.; Vilges de Oliveira, S.; Helena Cappellari, L. Monitoramento de Vertebrados Atropelados Em Dois Trechos de Rodovias Na Região Central Do Rio Grande Do Sul, Brasil. *Rev. De Ciências Ambient.* **2013**, *7*, 26–36.
112. Glista, D.J.; DeVault, T.L.; DeWoody, J.A. A Review of Mitigation Measures for Reducing Wildlife Mortality on Roadways. *Landsc Urban Plan* **2009**, *91*, 1–7. [CrossRef]