Biota Neotropica 16(1): e0182, 2016
www.scielo.br/bn

biotaneotropica
ISSN 1676-0611 (online edition)
article

Wild vertebrate roadkill in the Chapada dos Veadeiros National Park, Central Brazil

Vívian da Silva Braz[1,3] & Frederico Gustavo Rodrigues França[2]

[1]Universidade de Brasília, Centro de Desenvolvimento Sustentável, Brasília, DF, Brazil.
[2]Universidade Federal da Paraíba, Departamento de Engenharia e Meio Ambiente, Rio Tinto, PB, Brazil.
[3]Corresponding author: Vívian da Braz, e-mail: vsbraz@gmail.com

BRAZ, V.S. FRANÇA, F.G.R. **Wild vertebrate roadkill in the Chapada dos Veadeiros National Park, Central Brazil.** Biota Neotropica. 16(1): e0182. http://dx.doi.org/10.1590/1676-0611-BN-2014-0182

Abstract: Chapada dos Veadeiros National Park is one of the most important protected areas of the Brazilian Cerrado and is inhabited by diverse species, but the area has seldom been studied. From 2006 to 2008, we studied the impact of roads on wild vertebrates by recording roadkill on the two main roads located in the vicinity of the park. Of 824 killed vertebrates belonging to 138 species that were recorded, the species that were found most often in each vertebrate group were the Schneider's toad (*Rhinella schneideri*), the grassland sparrow (*Ammodramus humeralis*), the yellow-toothed cavy (*Galea flavidens*), and the marbled lancehead (*Bothrops marmoratus*). The roadkill rate was 0.096 animals km^{-1}. Vertebrate mortality was significantly higher during the wet season. There is a significant relationship between habitat structure and the vertebrates that were found as roadkill: amphibians are associated with nearby forest and paved roads, birds with nearby pastures, reptiles with nearby grassland, and mammals with unpaved roads. Action should be taken such as highway fencing in combination with safe crossing opportunities for wildlife in order to decrease the number of animals killed on the roads.
Keywords: *road ecology, protected areas, conservation, cerrado.*

BRAZ, V.S. FRANÇA, F.G.R. **Impacto do atropelamento de vertebrados do Parque Nacional da Chapada dos Veadeiros no Brasil Central.** Biota Neotropica. 16(1): e0182. http://dx.doi.org/10.1590/1676-0611-BN-2014-0182

Resumo: O Parque Nacional da Chapada dos Veadeiros é uma das mais importantes Unidades de Conservação do Cerrado brasileiro e, apesar de abrigar uma enorme biodiversidade, ainda são escassos os estudos na área. Entre 2006 e 2008 foi estudado o impacto das duas principais rodovias que margeiam o Parque sobre os vertebrados silvestres utilizando os registros de atropelamento. Foram registrados 824 vertebrados atropelados pertencentes a 138 espécies, sendo as mais encontradas o sapo-cururu (*Rhinella schneideri*), o tico-tico-do-campo (*Ammodramus humeralis*), o preá (*Galea flavidens*) e a jararaca (*Bothrops marmoratus*). A taxa de atropelamento foi de 0.096 animais km^{-1}, com uma mortalidade significativamente maior durante a estação chuvosa. Foi encontrada uma relação significativa entre a estrutura do habitat e as classes de vertebrados atropelados nas rodovias, sendo o grupo dos anfíbios associados a fragmentos florestais e trechos pavimentadas das rodovias, o das aves associado com pastagens circundantes, répteis com campos e mamíferos com trechos não pavimentados das rodovias. Medidas como barreiras que impeçam a movimentação dos animais nas estradas, bem como passagens seguras são indicadas para a redução do número de animais mortos nas rodovias na região do Parque.
Palavras-chave: *ecologia de estradas, áreas protegidas, conservação, cerrado.*

Introduction

Roads have recently been recognized as an important cause of habitat fragmentation and wildlife decline around the world (Coffin 2007). The construction of a new road or highway across a preserved landscape has direct and indirect impacts on local wildlife (Sherewood et al. 2002). Roads may induce direct mortality to wildlife through collisions with vehicles, create barriers to animal movement and consequently isolate populations, produce edge effects, alter animal behavior and reproductive ability, disrupt water supplies to and from wetlands, or intensify the toxic contamination and pollution of habitats alongside roads (Andrews 1990, Spelleberg 1998, Lodé 2000, Trombulak & Frissel 2000). In addition, the creation or enlargement of roads may damage natural environments by creating new road cuttings and embankments that scar the landscape, increase traffic noise, and increase road lighting (Sherewood et al. 2002; Forman et al. 2003).

Because of these threats, a number of recent studies on road ecology have been conducted, especially in Europe, the United States, and Australia (Coffin 2007). These studies have emphasized the need to plan road systems and have indicated that conservation should be a major goal of road planning (Forman et al. 2003). In spite of the great influence of roads on the dynamics of wildlife populations, most studies examined their effects only on specific groups, such as amphibians (Hels & Buchwald 2001), birds (Reijnen et al. 1995), mammals (Meunier et al. 1999), or reptiles (Hartmann et al. 2011), or even individual species, such as the Iberian lynx (*Felis pardina*) (Ferreras et al. 1992), the eastern barred bandicoot (*Perameles gunnii*) (Mallick et al. 1998) or the Mediterranean snake (*Hierophis viridiflavus*) (Capula et al. 2014). A few studies have dealt with the impact of roads on the local vertebrate community, describing the species that are susceptible to road mortality and identifying those whose conservation status may be threatened by roads (Yanes et al. 1995, Lodé 2000, Dodd et al. 2004, Boitet & Mead, 2014).

The effects of roads may be more severe in protected areas (Coelho et al. 2008). A protected area is defined as an area of land that is especially dedicated to the protection and maintenance of biological diversity and that is designated and managed to achieve specific conservation goals. The effectiveness of a protected area depends on conservation of biodiversity not only within the park or reserve but also in its vicinity (Chape et al. 2005, West et al. 2006). In Brazil, most protected areas are crossed by roads or highways, or have transportation infrastructure at or close to their borders, such as Iguaçu National Park (Paraná State, 185.262,20 ha), Emas National Park (Goiás State, 131.800 ha), and Águas Emendadas Ecological Station (Distrito Federal, 10,400 ha), so they experience the previously described effects of roads (Cândido Jr. et al. 2002, Rodrigues et al. 2002, Lima & Obara 2004, Coelho et al. 2008). Brazil's road network extends over 1,713,885 km and is expected to increase due to new government incentives (PAC II – Brasil 2010). New studies should be conducted to determine the impact of these new roads on the Brazilian fauna, particularly in protected areas. In this article we investigate roads as a cause of vertebrate mortality in the Chapada dos Veadeiros National Park, located in Central Brazil, and address the composition, seasonal patterns, and influence of environment on wildlife mortality due to roads.

Materials and Methods

1. The study area

The study was conducted in Central Brazil, in the state of Goiás (GO), on two roads that border the Chapada dos Veadeiros National Park (CVNP) (13°51'S to 14°10'S, and 47°25'W to 47°42'W). The main road, GO 239, runs between Alto Paraíso and Colinas and comprises 72 km (22 km of paved and 50 km of unpaved road). It provides the main access to the official gate of the CVNP, located in São Jorge village (Figure 1). Additional data was obtained from highway BR 010, which runs between Alto Paraíso and Teresina de Goiás and includes 64 km of paved road. The CVPN covers approximately 65,512 ha of relatively undisturbed Cerrado. It is located in a mountainous region, the Planalto Central Goiano (Felfili et al. 2007), which has altitudes ranging between approximately 620 m and 1,700 m and includes Central Brazil's highest peak (Pouso Alto, 1,784 m). The climate is type Aw in the Köppen classification, receiving annually 1500–1750 mm of a highly predictable and strongly seasonal precipitation, restricted almost entirely to October–March (Nimer 1989). Long-term climatic data from the Chapada dos Veadeiros region are summarized in Figure 2. Average temperatures vary between 20°C and 26°C (Silva et al. 2001). The vegetation is characterized by a predominance of gallery forest formations at low elevations and Cerrado with montane savannas at high elevations (Felfili et al. 2007).

2. Impact of roads

Roads as a cause of vertebrate mortality were investigated through surveys of animals killed by vehicles and by recording dead vertebrates observed on both roads on non-consecutive days, between November 2006 to April 2008. Road surveys were undertaken once every three days. The surveys were conducted by driving at 25–50 km h^{-1} along GO 239 and at 60–80 km h^{-1} along BR 010. When a dead animal was spotted, we stopped the car for closer inspection, identified the animal

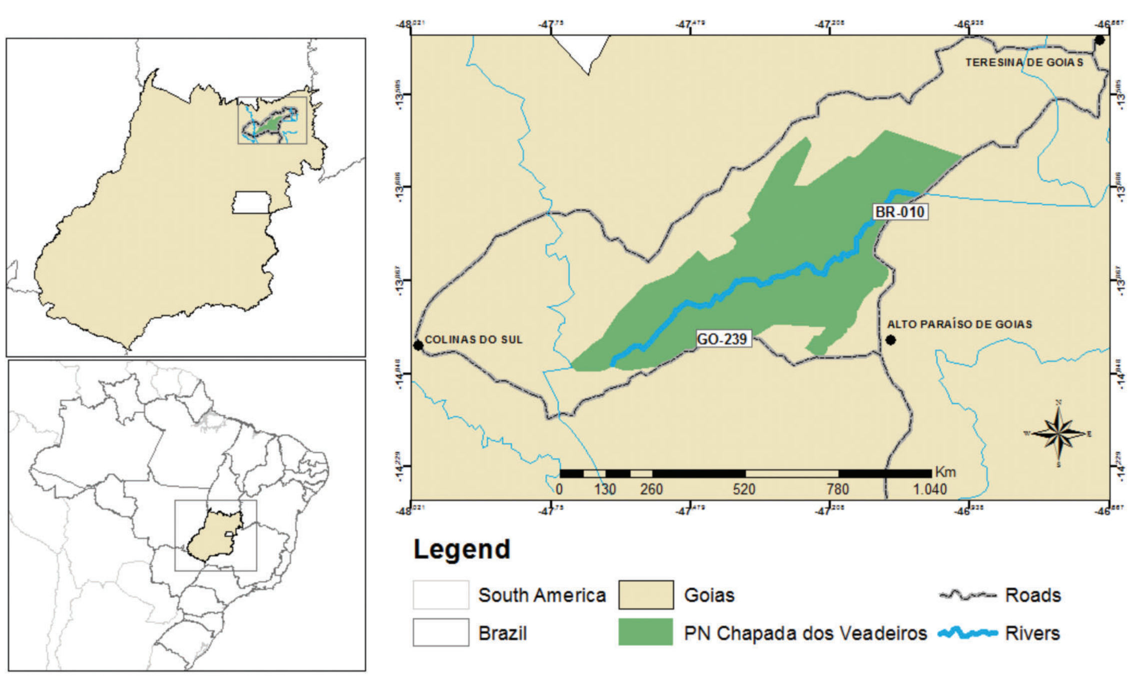

Figure 1. Study area showing the Central Brazil with Chapada dos Veadeiros National Park and the roads GO 239 and BR 010.

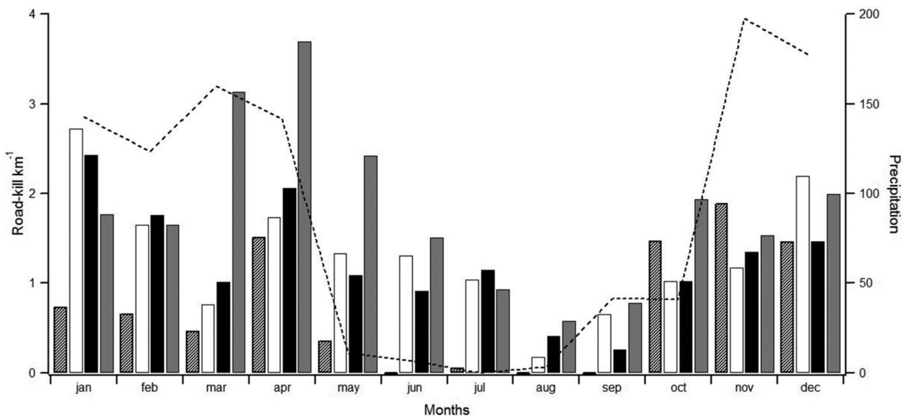

Figure 2. Monthly data of precipitation mean and road mortality rates of vertebrate classes of Chapada dos Veadeiros National Park during 2006 -2008. Bars indicate vertebrate groups: Amphibians: Grey bars with the black board; Birds: White bars; Mammals: Black bars; Reptile: Grey bars.

to the lowest taxonomic level possible, recorded the location with GPS, and removed the carcass from the road. Carcasses in good condition were preserved and added to the vertebrate collections of Universidade de Brasília.

The frequency of roadkill was calculated by dividing the number of individuals killed by the number of kilometers covered. The average frequencies of animals and species killed were compared between the dry season (April to September) and the rainy season (October to March). A paired t-test was used to evaluate the difference between dry and rainy seasons. Multiple regression was used to evaluate whether an association existed among roadkill, precipitation, and the structure of nearby vegetation.

3. Estimates

We constructed a species accumulation curve for all road-killed species and for each taxonomic class found on the road, using the individual-based rarefaction method (with the nonparametric Mao Tau estimator and with 95% confidence intervals) (Gotelli & Colwell 2001). The function of richness (Mao Tau) was computed as the accumulation function of individuals of each species. Species richness estimators were computed using nonparametric incidence-based estimators (Bootstrap, Chao 2, ICE, Jacknife 1 and 2) and abundance-based estimators (ACE and Chao 1) (Colwell & Coddington 1994, Colwell 2011). Both species accumulation curve and species richness estimators were performed to evaluate the sampling effort, allowing a better comparison among the groups of vertebrates found and pointing out which groups are underestimated through the method. Species rarefaction and richness estimators were performed with Estimates 8.2.0 software.

4. Correlation of landscape with roadkill

The attributes of landscapes near roads were assessed at 1 km intervals along the entire extent of the roads, both in the preserve and in the adjacent environment, using a 1:25000 topographic map. Landscape categories were assigned according to the proportions of environmental variables contained within 50 m on both sides of the the road shoulders on each kilometer. The categories included cerrado, grassland, forest, and pasture. In addition, the presence or absence of watercourses and the presence of paved or unpaved roads surfaces were recorded at the same intervals.

To examine the relationship between road-killed vertebrates and the road landscape, we performed a Canonical Correspondence Analysis (CCA; Ter Braak 1986), associating variation in one matrix (vertebrate abundance as the dependent variable) with variation in another matrix (landscape characteristics as the independent variable). In this analysis, we investigated whether a connection existed between specific habitat characteristics and the abundance of particular vertebrate groups. CCA was performed with CANOCO 4.5 (Ter Braak & Smilauer 1998), using the following options: focus scaling set on symmetric, biplot scaling type, downweighting of rare species, Monte Carlo test with 1,000 permutations of the reduced model, and unrestricted permutations.

Results

A total of 260 surveys of road-killed animals were conducted in 10,658 km: 212 on GO 239 (covering 7,463 km) and 48 on BR 010 (covering 3,195 km). In all, 824 vertebrates of 138 species were recorded along the two roads (Table 1). The most commonly road-killed species for each group of vertebrates were the yellow-toothed cavy (*Galea flavidens*) (10.2% of total vertebrate casualties), the marbled lancehead (*Bothrops marmoratus*) (7.5%), the Schneider's toad (*Rhinella schneideri*) (5.2%), and the grassland sparrow (*Ammodramus humeralis*) (3.0%). Six species that are nationally listed as threatened (MMA 2008) were found: black-masked finch (*Coryphaspiza melanotis*, n = 1,0.12% of total vertebrate casualties), sharp-tailed tyrant (*Culicivora caudacuta*, n = 1, 0.12%), maned wolf (*Chrysocyon brachyurus*, n = 7, 0.84%), cougar (*Puma concolor*, n = 1, 0.12%), ocelot (*Leopardus pardalis*, n = 3, 0.36%), and giant anteater (*Myrmecophaga tridactyla*, n = 1, 0.12%). The overall number of road-killed vertebrates in relation to road length was 0.096 animals km^{-1}; the overall roadkill incidence-interval was 10.42 km per roadkill. Reptiles were the most frequently killed group on both roads, followed by birds, mammals, and amphibians (Table 2).

Vertebrate mortality was significantly higher during the wet season than during the dry season (paired t-test, $t = 4.935$, $df = 285$, $P < 0.000$) and mortality differed between the two seasons for all taxonomic groups: amphibians (paired t-test, $t = -2.576$, $df = 23$, $P = 0.017$), birds (paired t-test, $t = -3.184$, $df = 125$, $P = 0.002$), mammals (paired t-test, $t = -2.854$, $df = 45$, $P = 0.007$) and reptiles (paired t-test, $t = -2.141$, $df = 89$,

Table 1. Vertebrate species killed during dry and rainy seasons on highways GO-239 and BR-010 in Chapada dos Veadeiros National Park, Central Brazil.

Species	Common name	GO 239		BR 010	
		Dry	Rainy	Dry	Rainy
Amphibians					
Rhinella granulosus	Common Lesser Toad	0	2	0	0
Rhinella rubescens	Toad	1	10	0	0
Rhinella schineideri	Schneider's Toad	2	40	0	1
Bufonidae NI		0	3	0	7
Hypsiboas albopunctatus	Spotted Treefrog	1	10	0	0
Hypsiboas lundii	Usina Treefrog	0	3	0	0
Leptodactylidae NI		0	5	0	0
Leptodactylus fuscus	Whistling Frog	1	6	0	0
Leptodactylus labirinthicus	Pepper Frog	0	2	0	0
Leptodactylus ocellatus	Llanos Toad-frog	0	1	0	0
Physalaemus cuvieri	Cuvier's Frog	0	1	0	0
Siphonops paulensis	Boettger's Caecilian	0	1	0	0
Birds					
Alipiopsitta xanthops	Yellow-faced Amazon	0	0	0	1
Ammodramus humeralis	Grassland Sparrow	15	10	0	0
Anumbius annumbi	Firewood-gatherer	0	1	0	0
Eupsittula aurea	Peach-fronted Parakeet	1	8	0	0
Athene cunicularia	Burrowing Owl	0	0	0	1
Brotogeris chiriri	Yellow-chevroned Parakeet	3	1	0	0
Hydropsalis longirostris	Band-winged Nightjar	0	3	0	0
Antrostomus parvulus	Little Nightjar	1	2	0	0
Antrostomus rufus	Rufous Nightjar	2	0	0	0
Caracara plancus	Crested Caracara	0	1	0	1
Cariama cristata	Red-legged Seriema	7	7	0	1
Chordeiles pusillus	Least Nighthawk	2	4	0	0
Colaptes campestris	Campo Flicker	0	2	0	0
Colaptes melanochloros	Green-barred Woodpecker	1	0	0	0
Colibri serrirostris	White-vented Violet-ear	1	0	0	0
Patagioenas cayennensis	Pale-vented Pigeon	0	1	0	0
Patagioenas plumbea	Plumbeous Pigeon	0	1	0	0
Columbina talpacoti	Ruddy Ground-dove	0	1	0	0
Coryphaspiza melanotis	Black-masked Finch	1	0	0	0
Crotophaga ani	Smooth-billed Ani	0	1	0	0
Crypturellus parvirostris	Small-billed Tinamou	2	2	0	1
Crypturellus undulatus	Undulated Tinamou	0	1	0	0
Culicivora caudacuta	Sharp-tailed Tyrant	1	0	0	0
Cypsnagra hirundinacea	White-rumped Tanager	1	0	0	0
Elaenia cristata	Plain-crested Elaenia	1	3	0	0
Elaenia NI		0	4	0	0
Emberizidae NI		0	2	0	0
Emberizoides herbicola	Wedge-tailed Grass-finch	0	3	0	0
Gallinago undulata	Giant Snipe	0	0	0	1
Geothlypis aequinoctialis	Masked Yellowthroat	1	1	0	0
Guira guira	Guira Cuckoo	0	1	0	0
Gnorimopsar chopi	Chopi Blackbird	0	1	0	0
Gubernetes yetapa	Streamer-tailed Tyrant	1	1	0	0
Hydropsalis torquata	Scissor-tailed Nightjar	0	1	0	0
Melanerpes candidus	White Woodpecker	1	0	0	0
Mimus saturninus	Chalk-browed Mockingbird	1	3	0	2
Myiarchus tyrannulus	Brown-crested Flycatcher	1	0	0	0
Myiophobus fasciatus	Bran-coloured Flycatcher	1	0	0	0
Nothura maculosa	Spotted Nothura	8	13	1	1
Nyctibius griseus	Common Potoo	0	1	0	0

Continued on next page

Table 1. Continued.

Species	Common name	GO 239		BR 010	
		Dry	Rainy	Dry	Rainy
Nyctidromus albicollis	Pauraque	1	2	0	0
Nystalus chacuru	White-eared Puffbird	0	4	0	0
Passeriforme NI		1	14	1	0
Penelope superciliaris	Rusty-margined Guan	0	1	0	0
Piaya cayana	Piaya cayana	1	0	0	0
Rhea americana	Greater Rhea	1	2	0	0
Rhynchotus rufescens	Red-winged Tinamou	2	2	2	0
Saltattricula atricollis	Black-throated Saltator	0	2	0	0
Sicalis citrina	Stripe-tailed Yellow-finch	1	2	0	0
Sicalis flaveola	Saffron Finch	1	0	0	0
Sporophila plumbea	Plumbeous Seedeater	1	2	0	0
Sporophila NI		1	1	0	0
Suiriri suiriri	Suiriri Flycatcher	1	1	0	0
Synallaxis albescens	Pale-breasted Spinetail	1	0	0	0
Synallaxis frontalis	Sooty-fronted Spinetail	1	1	0	0
Tangara palmarum	Palm Tanager	1	0	0	0
Troglodytes musculus	Southern House Wren	0	1	0	0
Turdus leucomelas	Pale-breasted Thrush	0	1	0	0
Tyranidae NI		0	3	0	0
Tyto furcata	Common Barn-owl	0	0	1	0
Vanellus chilensis	Southern Lapwing	0	0	0	1
Volatinia jacarina	Blue-black Grassquit	2	8	0	0
Zonotrichia capensis	Rufous-collared Sparrow	0	2	0	0
Mammals					
Alouatta caraya	Black Howler	0	2	0	0
Callithrix penicillata	Black-pencilled Marmoset	0	1	0	0
Caluromys lanatus	Brown-eared Woolly Opossum	2	1	0	0
Cerdocyon thous	Crab-eating Fox	0	2	0	0
Chrysocyon brachyurus	Maned Wolf	2	3	1	1
Conepatus semistriatus	Striped Hog-nosed Skunk	8	9	2	1
Didelphis albiventris	White-eared Opossum	0	2	0	0
Puma concolor	Cougar	0	1	0	0
Galea flavidens	Yellow-toothed Cavy	29	50	0	5
Gracilinanus agilis	Agile Gracile Opossum	0	1	0	0
Leopardus pardalis	Ocelot	0	2	0	0
Lycalopex vetulus	Hoary Fox	7	16	2	13
Mazama gouazoupira	Gray Brocket	0	0	0	1
Mimon bennettii	Golden Bat	0	2	0	0
Myrmecophaga tridactyla	Giant Anteater	0	1	0	0
Nasua nasua	South American Coati	0	2	0	0
Ozotoceros bezoarticus	Pampas Deer	0	1	0	0
Procyon cancrivorus	Crab-eating Raccoon	0	1	0	2
rodent NI		7	7	0	0
Sylvilagus brasiliensis	Tapeti	1	0	0	0
Tamandua tetradactyla	Southern Tamandua	0	1	0	2
armadillo NI		0	1	1	1
Tapirus terrestris	South American Tapir	0	1	0	0
Reptiles					
Ameiva ameiva	Giant Ameiva	0	1	0	0
Amphisbaena alba	White Worm-lizard	0	2	0	1
Amphisbaena mensae	Worm-lizard	0	1	0	0
Amphisbaena NI		0	1	0	0
Apostolepis ammodytes	Red Burrowing Snake	0	1	0	0
Boa constrictor	Boa Constrictor	0	1	0	3
Bothrops moojeni	Brazilian Lancehead	5	17	0	2

Continued on next page

Table 1. Continued.

Species	Common name	GO 239		BR 010	
		Dry	Rainy	Dry	Rainy
Bothrops marmoratus	Marbled lancehead	9	43	5	5
Chironius flavolineatus	Boettger's Sipo	3	1	0	0
Chironius exoletus	Linnaeus' Sipo	0	0	1	0
Chironius quadricarinatus	Central Sipo	0	1	0	0
Crotalus durissus	South American Rattlesnake	8	16	2	4
Taeniophallus occipitalis	Spotted Savanna Racer	0	1	0	0
Epicrates cenchria	Rainbow Boa	3	6	1	1
Erythrolamprus aesculapii	Aesculapian False Coral Snake	0	1	0	0
Leptodeira annulata	Banded Cat-eyed Snake	0	1	0	0
Erythrolamprus almadensis	Almada Legion Snake	1	2	0	2
Erythrolamprus maryellenae	Maryellen's Ground Snake	0	1	0	0
Erythrolamprus meridionalis	Lined Ground Snake	1	4	0	1
Erythrolamprus poecilogyrus	Trash Snake	1	0	2	0
Erythrolamprus reginae	Royal Ground Snake	0	1	0	0
Liotyphlops ternetzii	Ternetzi's Slender Blindsnake	1	0	0	0
Lystrophis nattereri	Hognose Snake	0	1	0	0
Mastigodryas bifossatus	Rio Tropical Racer	0	1	4	0
Ophiodes aff. striatus	Striped Worm Lizard	1	5	0	0
Oxybelis aeneus	Brown vinesnake	1	2	0	0
Oxyrhopus guibei	False Coral Snake	3	7	0	0
Oxyrhopus rhombifer	Amazon False Coral Snake	7	3	0	1
Oxyrhopus trigeminus	Brazilian False Coral Snake	9	12	4	0
Philodryas aestivus	Brazilian Green Tree Snake	2	2	2	0
Philodryas nattereri	Paraguay Green Racer	2	4	1	1
Philodryas olfersii	Southeastern Green Racer	1	1	0	1
Philodryas patagoniensis	Patagonian Savanna Racer	4	2	0	1
Phimophis guerini	Argentine Pampas Snake	3	1	0	1
Polycrus acutirostris	Brazilian Bush Anole	15	3	2	0
Pseudablabes agassizi	Burrowing Night Snake	0	3	0	1
Pseudoboa nigra	Black False Boa	1	1	0	0
Sibynomorphus mikanii	Brazilian Slug-eating snake	5	7	0	1
Tantilla melanocephala	Black-headed Snake	0	4	0	0
Thamnodynastes hypoconia	Argentine Large-eyed Snake	3	8	1	1
Thamnodynastes sp.	Large-eyed Snake	0	1	0	0
Tupinambis merianae	Black Tegu	0	1	0	0
Xenodon merremi	Merrem's False Pit Viper	1	3	1	1
Xenopholis undulatus	Jensen's Ground Snake	0	1	0	0
Phrynops vanderhaegei	Vanderhaege's toad-headed turtle	0	1	0	0

$P = 0.035$). In addition, a stepwise multiple regression analysis showed that there was no association between vertebrate roadkill and precipitation ($r = 0.489$; $F = 3.138$; $P = 0.107$).

Species rarefaction curves did not reach stability (Figure 3). The species richness estimators produced estimates greater than the actual recorded species richness for all taxonomic groups (Table 3). The major estimates with the major standard deviations were recorded with Chao 1 and 2 and the minor estimates were recorded with Bootstrap estimator (Table 3).

A summary of road and landscape attributes appears in Table 4. On the basis of 9,999 permutations of a Monte Carlo test and the first canonical axis, we found a significant relationship

Table 2. Road-kill frequencies and incidence-intervals of vertebrates on highways GO-239 and BR-010 in Central Brazil.

Vertebrates	GO 239 (7463 km)			BR 010 (3195 km)		
	N	Frequency (ind km^{-1})	Incidence-interval	N	Frequency (ind km^{-1})	Incidence-interval
All	716	0.096	10.41	108	0.033	30.30
Amphibian	89	0.012	83.33	8	0.002	500.0
Bird	198	0.026	38.46	15	0.005	200.0
Mammal	163	0.022	45.45	32	0.010	100.0
Reptiles	266	0.036	27.78	53	0.017	58.82

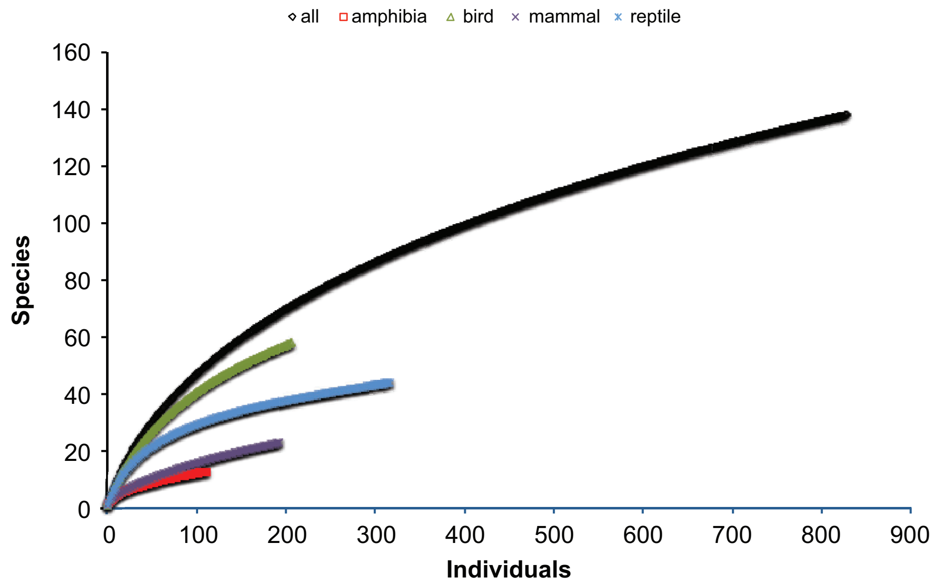

Figure 3. Individual-based rarefaction curves of roadkilled amphibians, birds, reptiles and mammals of Chapada dos Veadeiros National Park.

between habitat structure within arrays and vertebrate groups found there (eigenvalue = 0.146, $F_{4,35} = 14.958$, $P < 0.001$). In addition, all canonical axes were significant (trace = 0.205, $F_{4,35} = 4.444$, $P < 0.001$). Amphibians were associated with nearby forest and paved roads, birds were associated with nearby pasture, reptiles were associated with nearby grassland, and mammals were associated with unpaved road (Figure 4).

Discussion

The high number of road-killed vertebrates in CVNP indicates that the roads surrounding the park may significantly affect the wild vertebrates populations. The species richness found in our study (138 species) was greater than that reported by other long-term studies of Brazilian roads or motorways. Coelho et al. (2008) recorded 92 species on two roads in the northern coastal plain of Rio Grande do Sul; Rodrigues et al. (2002) found 100 species on four roads that delimit Águas Emendadas Ecological Station, in Distrito Federal; and Prada (2004) found 83 species on six roads in northeastern São Paulo. Fisher et al. (2003) recorded 140 species of vertebrates on BR 262, in the Pantanal wetlands of Mato Grosso do Sul, over the course of an 8-year-long study. The road mortality around CVNP is also high in comparison with other areas worldwide, such as Australia (Taylor & Goldingay 2004, n = 53), Europe (Lodé 2000, n = 97), and North America (Ashley and Robinson 1996, n = 100). However, the overall number of 0.096 road-killed vertebrates per kilometer was similar to that of other studies in Brazil, ranging from 0.078 animals km^{-1} on BR-383, in Rondônia (Turci & Bernarde 2009), to 0.138 on BR-307, in Acre (Pinheiro & Turci 2013).

Despite the high number of vertebrates found during our surveys, the results are still an underestimate of total roadkill. The survey method of the present study (searches by car) allows the record of many roadkills, but due to the car speed it may overlook small animals, such as small amphibians and birds (Coelho et al. 2008). Besides, by not searching the roads constantly (more than twice a day, for example), some animals are not recorded because they quickly disappear. For instance, scavenging predators could have removed numerous small dead animals from the roads (Antworth et al. 2005). In addition, some animals may have been thrown away from the road by the collision or may have been only wounded by the collision and died far from the road (Slater 2002). Nevertheless, the method of search by car permits the inspection of a great road extension in a short amount of time and it is comparable to similar surveys. Rarefaction curves for all groups do not reach stability, a common trend in roadkill studies (Santana 2009, Pinheiro & Turci 2013). Estimates also show that a high number of species for all groups are affected by the roads in CVNP. For example, at least 47 species of snake inhabit the park (França & Braz 2013), of which we found only 37 on the

Table 3. Richness estimators of road-killed vertebrates on Chapada dos Veadeiros roads.

Estimators	All (143)	Amphibians (12)	Birds (63)	Mammals (23)	Reptiles (45)
ACE	216.46 ± 1.19	21.51 ± 3.13	86.72 ± 1.36	49.34 ± 2.0	59.42 ± 0.71
ICE	216.27 ± 1.19	20.8 ± 3.06	86.63 ± 1.35	48.89 ± 1.97	59.3 ± 0.71
Chao 1	243.88 ± 38.89	18.0 ± 5.54	90.5 ± 17.22	65.25 ± 38.52	72.13 ± 20.9
Chao 2	243.88 ± 38.89	17.95 ± 5.5	90.34 ± 17.14	65.25 ± 38.52	72.13 ± 20.9
Jack 1	197.93 ± 7.46	18.95 ± 2.37	83.87 ± 4.76	35.93 ± 3.47	58.95 ± 3.77
Jack 2	240.84 ± 1.01	22.89 ± 0.9	100.75 ± 1.37	46.83 ± 0.97	69.9 ± 0.84
Bootstrap	163.35 ± 0.32	15.51 ± 0.3	69.25 ± 0.52	28.23 ± 0.36	50.32 ± 0.31

Table 4. Means for landscape characteristics of 35 quadrats of roads in the Chapada dos Veadeiros National Park.

Landscape	**Mean ± SD**
Pasture	2.06 ± 0.41
Grassland	6.38 ± 0.48
Savanna	3.32 ± 0.47
Forest	5.35 ± 0.77
Water	2.20 ± 0.41
Paved road	6.38 ± 0.48
Unpaved road	3.61 ± 0.48

roads. Some species that are common in the Cerrado and that have been found in previous studies are the brown-banded water snake (*Helicops angulatus*), the southern crested caracara (*Caracara plancus*), the American black vulture (*Coragyps atratus*), the greater grison (*Galictis vittata*), and the nine-banded armadillo (*Dasypus novemcinctus*). These species will probably appear in future surveys of roads around the CVNP.

Among the four vertebrate classes found as roadkill, the impact on amphibians is most likely to have been underestimated, due to their small size, their thin skin, and the slow locomotion of many amphibian species. The carcasses do not last as long on roads as those of other vertebrates because scavengers eat them rapidly or they are run over many times and are rapidly obliterated by vehicles (Hels & Buchwald 2001). Also, due to their activity patterns, seasonal reproduction, population structure, and selected habitats, amphibians are commonly more vulnerable to being hit by vehicles than other species (Hels & Buchwald 2001). Most data regarding road-killed amphibians are for large toads and frogs of the Bufonidae and Leptodactylidae families, the carcasses of which remain longer on the roads (Fahrig et al. 1995). The most commonly found amphibian in our surveys, the Schneider's toad (*Rhinella schneideri*), is a very common species in the Brazilian Cerrado, and individuals belonging to the genus *Rhinella* are often found as roadkill in different regions, such as Amazonia and the Atlantic Forest (Silva et al. 2007, Turci & Bernarde 2009).

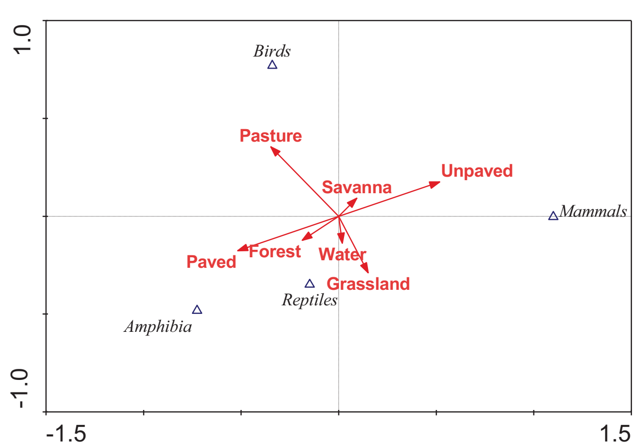

Figure 4. Plot of Canonical Correspondence Analysis comparing matrices of structural habitat characteristics with roadkill vertebrates sampling data. The plot shows the position of each vertebrate class among arrays on first two canonical axes. Lengths of environmental vectors indicate significance strength and points of arrows represent centroids of impact of environmental variables on each vertebrate class' distributions among arrays.

Birds are also likely underestimated, particularly small passerines. Usually birds are hit while they are in flight and are thrown off the roads by the impact (Erritzoe et al. 2003). Many hawks and buzzards are hit while scavenging roadkill (Antworth et al. 2005). In addition, the type of habitat near roads can attract birds to the roads and increase their risk of becoming roadkill. For example, many small birds move and forage in the vegetation along the roads (Orłowski 2005). In natural landscapes crossed by roads, the roadside vegetation serves as a corridor and ecotone used by insects and birds, facilitating movement and feeding along the border of an area, but birds that spend time in this area are at higher risk of being hit by vehicles (Orłowski 2008, Rosa & Badger 2012). Most road-killed birds in the CVNP were species that use road borders frequently, such as the grassland sparrow (*Ammodramus humeralis*) and the blue-black grassquit (*Volatinia jacarina*). Although some authors have described roadkill as having low influence on the population dynamics of birds (Reijnen et al. 1995), these impacts can be proportionally greater in threatened species, such as certain grassland birds in the Cerrado, like the black-masked finch (*Coryphaspiza melanotis*). This species should receive special attention and mitigation programs, because it is nationally threatened species in Brazil (Brazilian National list of endangered species Portaria MMA no 444/2014).

Mammals are usually affected by roads when they have wide home ranges and terrestrial habits, which make them use roads as corridors for movement (Smith-Patten & Patten 2008). Also, many mammals are nocturnal and/or are scavengers. At night, they are targets for vehicles because they can become blind and immobilized on roads when cars' headlights shine on them (Barthelmess & Brooks 2010). Both the hoary fox (*Lycalopex vetulus*) and the crab-eating fox (*Cerdocyon thous*) are commonly hit by cars for this reason. These omnivorous, nocturnal and generalist foxes have ample distributions in South America and abundant populations (Wozencraft 2005) and are frequently found on various roads (Vieira 1996, Silveira 1999, Coelho 2003, Prada 2004). Another small mammal that was frequently found on CVNP roads was the yellow-toothed cavy (*Galea flavidens*). Despite its high abundance in the CVPN, this species is not common, as it is endemic to Brazil and restricted to the montane savanna habitat (Bonvincino et al. 2005, Weksler & Bonvicino 2008). Finally, other mammals that require special conservation attention are the giant anteater (*Myrmecophaga tridactyla*), the cougar (*Puma concolor*), and the maned wolf (*Chrysocyon brachyurus*). These are Brazilian threatened species and their populations are low in Central Brazil (Brazilian National list of endangered species Portaria MMA no 444/2014).

Snakes are the reptiles that are most likely to be hit on roads, due to their characteristic long body morphology and their habit of frequently using roads as thermoregulation sites (Bernardino & Dalrymple 1992, Bonnet et al. 1999). Most reptiles found on CVPN roads were snakes or long-bodied lizards, such as *Ophiodes aff. striatus*. Terrestrial and sit-and-wait genera, such as *Bothrops*, *Crotalus*, and *Oxyrhopus*, and slow-moving reptiles, such as *Polychrus acutirostris* and the worm lizards of the genus *Amphisbaena,* are commonly hit by vehicles. No reptile species are listed as threatened in Central Brazil. However, species with life histories characterized by low reproductive rates and low adult mortality, such as the Vanderhaege's toad-headed turtle (*Phrynops vanderhaegei*), and huge snakes and vipers, are more vulnerable to the demographic consequences of road mortality (Forman et al. 2003, Shepard 2009).

The species richness of roadkill and the roadkill rates are influenced by seasonality as well as by type of nearby habitat (Trombulak & Frissell 2000, Rosa & Bager 2012). There are two well-defined seasons in Central Brazil, the wet or rainy season, characterized by high precipitation, and the dry season, during which almost no rain falls (Nimer 1989). Vertebrate mortality on CVNP roads was significantly higher during the wet season, as reported by previous studies in Central Brazil (Rodrigues et al. 2002). Studies show that more Brazilian mammals (Cáceres et al. 2012) and anurans (Coelho et al. 2012) are killed on roads during the rainy season. The Cerrado of Central Brazil shows high seasonality and the activity of vertebrates becomes more intense after the first rainfalls (Oliveira & Marquis 2002). Even for plants, the rainy season is a more active time; although fructification of anemochorous and autochorous species occurs during the dry season, the fructification of zoochorous species is dispersed throughout the rainy season (Batalha & Mantovani 2000). Also, many animal species of Cerrado show dispersion and migratory movements and reproductive activities during the rainy season, when roads become barriers to their intense locomotion.

Amphibians were associated with patches of paved road with nearby forest habitat. In the Cerrado, gallery forests are always associated with streams and rivers, suitable environments for amphibians (Colli et al. 2002). These animals are at increased risk of being hit on high-speed paved roads and are killed mainly during the reproductive season. In contrast, there were more road-killed birds along roads next to pasture habitats. Despite their preference for forest habitats, birds that live in rural landscapes are usually associated with roads that are bordered by native vegetation. These roads can be attractive habitat and potentially a population sink, and offer a higher abundance of insects than other areas, attracting birds (Orłowski 2008).

In contrast with amphibians and birds, most of the reptiles and small mammals of the Cerrado are associated with open areas, and the majority of snakes found in the CVNP are found in grasslands or open savanna environments (França & Braz 2013). Roadkilled mammals were strongly associated with unpaved road. In spite of the fact that mammals inhabit mainly forest habitats in the Cerrado (Johnson et al. 1999), most species have wide home ranges and may traverse the entire Cerrado. Compared with paved roads, unpaved roads appear to be more suitable and less exposed environments that enable the movements of CVNP mammals.

Due to the importance of the CVNP as a protected area that harbors and maintains the biodiversity of the Cerrado, it is important to remain monitoring the impact of the park's roads on wild vertebrates. Further studies may use recent indices and analyses to measure the impact of roads on the fauna of the CVNP and to establish priorities for mitigation programs (Coelho et al. 2008, Bager & Rosa 2011). Some mitigation actions are urgently needed, such as highway fencing in combination with safe crossing opportunities for wildlife (Clevenger et al. 2001).

Acknowledgments

The authors are grateful to Daniel Rios de Magalhães Borges and ICMbio for collection permits in the Chapada dos Veadeiros National Park (IBAMA license 051/2007 and SISBIO license 15325-1). We thank Santos Balbino, Davi Pantoja, and Iubatã Farias for their generous help during fieldwork, Rafaela França for the map of CVNP, and José Augusto Drummond, Marcel Bursztyn, Marília Machado and Rebeca Roysen for their suggestions to improve the manuscript. We also thank the National Counsel of Technological and Scientific Development (CNPq) for a graduate scholarship and the Fundação O Boticário de Proteção à Natureza for financial support (0754_20072).

References

ANDREWS, A. 1990. Fragmentation of habitat by roads and utility corridor: A review. Aust. Zool. 26:130–141, http://dx.doi.org/10.7882/AZ.1990.005.

ANTWORTH, R.L., PIKE, D.A. & STEVENS, E.E. 2005. Hit and Run: Effects of Scavenging on Estimates of Roadkilled Vertebrates. Southeast. Nat. 4(4):647–656, http://dx.doi.org/10.1656/1528-7092(2005)004[0647:HAREOS]2.0.CO;2.

ASHLEY, E.P. & ROBINSON, J.T. 1996. Road mortality of amphibians, reptiles and other wildlife on the Long Point causeway, Lake Erie, Ontario. Can. Field Nat. 110:403–412.

BARTHELMESS, E.L. & BROOKS, M.S. 2010. The influence of body-size and diet on road-kill trends in mammals. Biodivers. Conserv. 19:1611–1629, http://dx.doi.org/10.1007/s10531-010-9791-3.

BATALHA, M.A. & MANTOVANI, W. 2000. Reproductive phenological patterns of Cerrado plant species at the Pé-de-Gigante Reserve (Santa Rita do Passa Quatro, SP, Brazil): a comparison between the herbaceous and woody floras. Rev. Bras. Biol. 60(1): 129–145, http://dx.doi.org/10.1590/S0034-71082000000100016.

BAGER, A. & ROSA, C.A. 2010. Hierarquização de quilômetros prioritários à mitigação de atropelamentos de animais selvagens. Biota Neotropica 10(4): http://www.biotaneotropica.org.br/v10n4/pt/abstract?article + bn03010042010.

BERNARDINO JUNIOR, F.S. & DALRYMPLE, G.H. 1992. Seasonal activity and road mortality of the snakes of the pa-hay-okee wetlands of Everglades National Park, USA. Biol. Conserv. 62:71–75, http://dx.doi.org/10.1016/0006-3207(92)90928-G.

BOITET, E.R. & MEAD, A.J. 2014. Application of GIS to a Baseline Survey of Vertebrate Roadkills in Baldwin County, Georgia. Southeast. Nat. 13(1):176–190.

BONNET, X., NAULLEAU, G. & SHINE, R. 1999. The dangers of leaving home: dispersal and mortality in snakes. Biol. Conserv. 89:39–50, http://dx.doi.org/10.1016/S0006-3207(98)00140-2.

BONVICINO, C.R., LEMOS, B. & WEKSLER, M. 2005. Small mammals of Chapada dos Veadeiros National Park (Cerrado of central Brazil): ecology, karyologic, and taxonomic considerations. Braz. J. Biol. 65(3):1–12, http://dx.doi.org/10.1590/S1519-69842005000300004.

BRASIL 2010. Presidência da República; Ministério do Planejamento, Orçamento e Gestão. PAC: Programa de Aceleração do Crescimento. Brasília. https://www.pac.gov.br/.

CÁCERES, N.C., CASELLA, J.E.C. & GOULART, S. 2012. Variação Espacial e Sazonal de atropelamentos de mamíferos no Bioma Cerrado, Rodovia Br 262, Sudoeste do Brasil. Mastozool. Neotrop. 19(1): 21–33.

CÂNDIDO JUNIOR, J.F., MARGARIDO, V.P., PEGORARO, J.L., D'AMICO, A.R., MADEIRA, W.D., CASALE, V.C. & ANDRADE, L. 2002. Animais atropelados na rodovia que margeia o Parque Nacional do Iguaçu, Paraná, Brasil, e seu aproveitamento para estudos da biologia da conservação. In: III. Congresso Brasileiro de Unidades de Conservação (ed.) Anais do III congresso brasileiro de unidades de conservação. p 553.

CAPULA, M., RUGIERO, L., CAPIZZI, D., MILANA, G., VIGNOLI, L., FRANCO, D., PETROZZI, F. & LUISELLI, L. 2014. Long-term, climate change-related shifts in monthly patterns of roadkilled Mediterranean snakes (Hierophis viridiflavus). Herpetol. J. 24:97–102.

CHAPE, S., HARRISON, J., SPALDING, M. & LYSENKO, I. 2005. Measuring the extent and effectiveness of protected areas as an indicator for meeting global biodiversity targets. Philos. Trans.

R. Soc. Lond. B Biol. Sci. 360:443–55, http://dx.doi.org/10.1098/rstb.2004.1592.

CLEVENGER, A.P., CHRUSZCZ, B., GUNSON, K.E. 2001. Highway mitigation fencing reduces wildlife-vehicle collisions. Wildlife Soc. Bull. 29:646–653.

COELHO, I.P., KINDEL, A. & COELHO, A.V.P. 2008. Roadkills of vertebrate species on two highways through the Atlantic Forest Biosphere Reserve, southern Brazil. Eur. J. Wildlife Res. 54:689–699, http://dx.doi.org/10.1007/s10344-008-0197-4.

COELHO, I.P., TEIXEIRA, F.Z., COLOMBO, P., COELHO A.V.P. & KINDEL, A. 2012 Anuran road-kills neighboring a peri-urban reserve in the Atlantic Forest, Brazil. J. Environ. Manage. 112:17–26.

COFFIN, A.W. 2007. From roadkill to road ecology: A review of the ecological effects of roads. J. Transp. Geogr. 15:396–406, http://dx.doi.org/10.1016/j.jtrangeo.2006.11.006.

COLLI, G.R., BASTOS, R.P. & ARAÚJO, A.F.B. 2002. The character and dynamics of the Cerrado herpetofauna. In The Cerrados of Brazil: Ecology and Natural History of a Neotropical Savanna (P.S. Oliveira & R.J. Marquis, eds.). Columbia New York. University Press, p.223–241.

COLWELL, R.K. 2011. EstimateS. version 8.2.0: Statistical Estimation of Species Richness and Shared Species from Samples (Software and User's Guide). Freeware for Windows and Mac OS.

COLWELL, R.K. & CODDINGTON, J.A. 1994. Estimating terrestrial biodiversity through extrapolation. Philos. T. Roy. Soc. B. 345:101–118, http://dx.doi.org/10.1098/rstb.1994.0091.

DODD JUNIOR, C.K., BARICHIVICH, W.J. & SMITH, L.L. 2004. Effectiveness of a barrier wall and culverts in reducing wildlife mortality on a heavily traveled highway in Florida. Biol. Conserv. 118:619–631, http://dx.doi.org/10.1016/j.biocon.2003.10.011.

ERRITZOE, J., MAZGAJSKI, T. & REJT, Ł. 2003. Bird casualties on European roads—a review. Acta Ornithol. 38:77–93, http://dx.doi.org/10.3161/068.038.0204.

FAHRIG, L., PEDLAR, J.H., POPE, S.E., TAYLOR, P.D. & WEGNER, J.F. 1995. Effects of road traffic on amphibian density. Biol. Conserv. 73:177–182, http://dx.doi.org/10.1016/0006-3207(94)00102-V.

FELFILI, J.M., REZENDE, A.V. & SILVA JUNIOR, M.C. 2007. Biogeografia do Bioma Cerrado: Vegetação e Solos da Chapada dos Veadeiros. Editora Universidade de Brasília, Finatec, Brasília.

FERRERAS, P., ALDAMA, J.J., BELTRÁN, J.F. & DELIBES, M. 1992. Rates and causes of mortality in a fragmented population of Iberian lynx Felis pardina (Temminck). Biol. Conserv. 61:197–202, http://dx.doi.org/10.1016/0006-3207(92)91116-A.

FISCHER, W.A., RAMOS-NETO, M.B., SILVEIRA, L. & JACOMO, A.T. 2004. Human transportation network as ecological barrier for wildlife on Brazilian Pantanal-Cerrado corridors. In Proceedings of the 2003 International Conference on Ecology and Transportation (C.L. Irwin, P. Garrett, K.P. McDermott, eds). Center for Transportation and the Environment, North Carolina State University, p. 182–194.

FORMAN, R.T.T., SPERLING, D., BISSONETTE, J.A., CLEVENGER, A.P., CUTSHALL, C.D. & DALE, V.H. 2003. Road ecology: science and solutions. Island Press, Washington, DC.

FRANÇA, F.G.R. & BRAZ, V.S. 2013. Diversity, activity patterns, and habitat use of the snake fauna of Chapada dos Veadeiros National Park in Central Brazil. Biota Neotropica, 13(1): http://www.biotaneotropica.org.br/v13n1/pt/abstract?article+bn01313012013.

GOTELLI, N. & COLWELL, R.K. 2001. Quantifying biodiversity: Procedures and pitfalls in the measurement and comparison of species richness. Ecol. Lett. 4:379–391, http://dx.doi.org/10.1046/j.1461-0248.2001.00230.x.

HARTMANN, P.A., HARTMANN, M.T. & MARTINS, M. 2011. Snake road mortality in a protected area in the Atlantic Forest of Southeastern Brazil. South Am. J. Herpetol. 6:35–42, http://dx.doi.org/10.2994/057.006.0105.

HELS, T. & BUCHWALD, E. 2001. The effect of road kills on amphibian populations. Biol. Conserv. 99:331–340, http://dx.doi.org/10.1016/S0006-3207(00)00215-9.

JOHNSON, M.A., SARAIVA, P.M. & COELHO, D. 1999. The role of gallery forests in the distribution of Cerrado mammals. Rev. Bras. Biol. 59(3):421–427.

LIMA, S.F. & OBARA, A.T. 2004. Levantamento de animais silvestres atropelados na br-277 às margens do Parque Nacional do Iguaçu: Subsídios ao programa multidisciplinar de proteção a fauna. In VII Semana de Artes, IV Mostra do Museu Dinâmico Interdisciplinar, II Mostra Integrada de Ensino, Pesquisa e Extensão e V Simpósio da APADEC, p. 1–7.

LODÉ, T. 2000. Effect of a motorway on mortality and isolation of wildlife populations. Ambio 29:163–166, http://dx.doi.org/10.1579/0044-7447-29.3.163.

MALLICK, S.A., HOCKING, G.J. & DRIESSEN, M.M. 1998. Road kills of the eastern barred bandicoot (Perameles gunnii) in Tasmania: an index of abun- dance. Wildlife Res. 25:139–145, http://dx.doi.org/10.1071/WR96119.

MEUNIER, F.D., CORBIN, J., VERHEYDEN, C. & OUVENTINP, J. 1999. Effects of landscape type and extensive management on use of motorway road sides by small mammals. Can. J. Zool. 77:108–117, http://dx.doi.org/10.1139/z98-203.

NIMER, E. 1989. Climatologia do Brasil. 2 ed. IBGE, Rio de Janeiro.

OLIVEIRA, P.S. & MARQUIS, R.J. 2002. The Cerrados of Brazil. Ecology and natural history of a neotropical savanna. Columbia University Press, New York.

ORLOWSKI, G. 2005. Factors affecting road mortality of barn swallow Hirundo rustica in farmland. Acta Ornithol. 40:117–125, http://dx.doi.org/10.3161/068.040.0207.

ORLOWSKI, G. 2008. Roadside hedgerows and trees as factors increasing road mortality of birds: Implications for management of roadside vegetation in rural landscapes. Landscape Urban Plan. 86:153–161, http://dx.doi.org/10.1016/j.landurbplan.2008.02.003.

PINHEIRO, B.F. & TURCI, L.C. 2013. Vertebrados atropelados na estrada da Variante (BR-307), Cruzeiro do Sul, Acre, Brasil. Natureza on line. 11(2):68–78.

PRADA, C.S. 2004. Atropelamento de vertebrados silvestres em uma região fragmentada no nordeste no estado de São Paulo: quantificação do impacto e análise de fatores envolvidos. Dissertação de mestrado, Universidade Federal de São Carlos, São Carlos.

REIJNEN, R., FOPPEN, R., BRAAK, C.T. & THISSEN, J. 1995. The effects of car traffic on breeding bird populations in woodland. III. Reduction of density in relation to the proximity of main roads. J. Appl. Ecol. 32:187–202.

RODRIGUES, F.H.G., HASS, A., REZENDE, L.M., PEREIRA, C.S., FIGUEIREDO, C.F., LEITE, B.F. & FRANÇA, F.G.R. 2002. Impacto de rodovias sobre a fauna da estação ecológica de águas emendadas. In III Congresso Brasileiro de Unidades de Conservação (ed.) Anais do III congresso brasileiro de unidades de conservação, p. 585.

ROSA, C.A. & BAGER, A. 2012. Seasonality and habitat types affect roadkill of neotropical birds. J. Environ. Manage. 97:1–5.

SANTANA, S.G. 2012. Fatores influentes sobre atropelamentos de vertebrados na região central do Rio Grande do Sul, Brasil. Neotrop. Biol. Conserv. 7:26–40, http://dx.doi.org/10.4013/nbc.2012.71.05.

SILVA, M.O., OLIVEIRA, I.S., CARDOSO, M.W. & GRAF, V. 2007. Impacto dos atropelamentos sobre a herpetofauna da Floresta Atlântica (PR-340, Antonina, Paraná). Acta Biol. Paran. 36:103–112, http://dx.doi.org/10.5380/abpr.v36i0.9668.

SILVA, S.R., SILVA, A.P., MUNHOZ, C.B., SILVA JUNIOR, M.C. & MEDEIROS, M.B. 2001. Guia de Plantas do Cerrado Utilizadas na Chapada dos Veadeiros. WWF-Brasil, Brasília.

SILVEIRA, L. 1999. Ecologia e conservação dos mamíferos carnívoros do Parque Nacional das Emas. Dissertação de mestrado, Universidade Federal de Goiás, Goiânia.

SLATER, F.M. 2002. An assessment of wildlife road casualties – the potential discrepancy between numbers counted and numbers killed. Web Ecol. 3:33–42, http://dx.doi.org/10.5194/we-3-33-2002.

SMITH-PATTEN, B.D. & PATTEN, M.A. 2008. Diversity, Seasonality, and Context of Mammalian Roadkills in the Southern Great Plains. Environ. Manage. 41(6):844–852.

SPELLERBERG, I.F. 1998. Ecological effects of roads and traffic: A literature review. Global Ecol. Biogeogr. 7:317–333, http://dx.doi.org/10.1046/j.1466-822x.1998.00308.x.

SHERWOOD, B., CUTLER, D. & BURTON, J. 2002. Wildlife and Roads: The Ecological Impact. Imperial College Press, London.

TAYLOR, B.D. & GOLDINGAY, R.L. 2004. Wildlife road-kills on three major roads in north-eastern New South Wales. Wildlife Res. 31(1):83–91, http://dx.doi.org/10.1071/WR01110.

TER BRAAK, C.J.F. 1986. Canonical correspondence analysis: a new eigenvector technique for multivariate direct gradient analysis. Ecology 67:1167–1179, http://dx.doi.org/10.2307/1938672.

TER BRAAK, C.J.F. & SMILAUER, P. 1998. CANOCO: Reference Manual and User's Guide to Canoco for Windows: Software for Canonical Community Ordination (version 4). Microcomputer Power, Ithaca, NY.

TROMBULAK, S.C. & FRISSELL, C.A. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conserv. Biol. 14:8–30, http://dx.doi.org/10.1046/j.1523-1739.2000.99084.x.

VIEIRA, E.M. 1996. Highway mortality of mammals in Central Brazil. Cienc. Cult. 48:270–272.

WEKSLER, M. & BONVICINO, C. 2008. Galea flavidens. In 2008 IUCN Red List of Threatened Species. www.iucnredlist.org.

WEST, P., IGOE, J. & BROCKINGTON, D. 2006. Parks and peoples: The social impact of protected areas. Annu. Rev. Anthropol. 35:251–277.

WOZENCRAFT, W.C. 2005. Order Carnivora. In Mammal Species of the World (D.E. Wilson & D.M. Reeder, eds.). 3 ed. Johns Hopkins University Press, Baltimore, p. 532–628.

YANES, M., VELASCO, J.M. & SUÁREZ, F. 1995. Permeability of roads and railways to vertebrates: The importance of culverts. Biol. Conserv. 71:217–222, http://dx.doi.org/10.1016/0006-3207(94)00028-O.

Received 02/12/2014
Revised 20/10/2015
Accepted 18/11/2015