Fast and furious: a look at the death of animals on the highway MS-080, Southwestern Brazil

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ABSTRACT. Several factors, such as hunting and the pet trade, are responsible for the worldwide decline of wildlife populations. In addition, fatal collisions with vehicles on highways have also taken one of the largest tolls. This study aimed to quantify the richness and abundance of vertebrate roadkill along highway MS-080 in Mato Grosso do Sul, Central-West Brazil. We compare the amount of roadkill to the distance between cities, moon phases and the flow of vehicles on the highway. Samples were collected weekly between March and September 2011, totaling 257 individuals, belonging to 32 families and 52 species, resulting in an index of 0.13 individuals hit/km. Birds were the most frequently hit taxa, followed by mammals. The most affected species was *Cariama cristata* (Cariamidae), followed by *Cerdocyon thous* (Canidae). The sections of highway closest to cities had the highest number of individual animals killed. Our observations indicate that the density of the vegetation next to the highway positively influences the amount of roadkill.

KEYWORDS. Conservation, roads, roadkill, urbanization, habitat fragmentation.

RESUMO. Velozes e furiosos: um olhar sobre a morte de animais na rodovia MS-080, centro-oeste do Brasil. Vários fatores são responsáveis pelo declínio da fauna mundial tais como a caça e comércio de animais selvagens. Mas a maior delas tem sido o atropelamento por veículos em rodovias. Este estudo teve como objetivo quantificar a riqueza e abundância de vertebrados atropelados ao longo da rodovia MS-080, em Mato Grosso do Sul, na região Centro-Oeste do Brasil. Além disso, nós relacionamos a quantidade de atropelamentos à distância entre as cidades, as fases da lua e o fluxo de veículos na rodovia. As amostras foram coletadas semanalmente, entre março e setembro de 2011, totalizando 257 animais atropelados, pertencentes a 32 famílias e 52 espécies, resultando em um índice de 0,13 indivíduos atropelados/km. As aves foram as mais frequentemente atropeladas, seguidas pelos mamíferos. As espécies mais afetadas foram *Cariama cristata* (Cariamidae) e *Cerdocyon thous* (Canidae). As seções da rodovia mais próximas das cidades apresentaram um maior número de animais mortos. As nossas observações indicam que a densidade da vegetação ao lado da estrada influencia positivamente na quantidade de animais mortos na estrada.

PALAVRAS-CHAVE. Conservação, rodovias, atropelamentos de fauna, urbanização, fragmentação de habitat.

Brazil has one of the greatest levels of biodiversity on the planet and is home to several important biodiversity hot spots, such as the Cerrado, Atlantic Forest and Pantanal (Brandon *et al*., 2005).

The vertebrate fauna of Brazil is currently comprised of 688 species of mammals (Reis *et al*., 2011), 1,832 birds (CRBO, 2010), 721 reptiles (SBH, 2010), 857 amphibians (SBH, 2010), and 3,000 species of fishes (Prado & Lewinsohn, 2000). According to the MMA (2008), there are many factors that threaten the existence of these species. Environmental degradation, which includes deforestation, fire, pollution, is one of the leading factors. Much of the cerrado (savanna) has been degraded and fragmented by cattle grazing, expansion of agricultural frontiers, the establishment of hydroelectric plants and the expansion of sugar cane cultivation. These anthropogenic changes have reduced the cerrado to approximately 35% of its original cover (Verdade *et al*., 2010).

Roads contribute directly to the fragmentation of habitat. Many roads, particularly those constructed without proper planning, compromise the quality of adjacent natural ecosystems and often function as geographic barriers for many species (Mader, 1984; Thurber *et al*., 1994).

Among the various threats to wildlife, collisions with vehicles on roads are becoming a major cause of mortality for a number of species (Bager & Rosa, 2010). Studies of roadkill conducted in the United States, Belgium, England, Germany, France and Spain have demonstrated that highways are definitely a threat to wildlife (PMVC, 2003). The quantity of dead animals on Brazilian highways continues to increase each year, particularly on roads with high traffic flows that cut through areas rich in flora and fauna (Brandon *et al*., 2005).

Road features, such as width, length and condition of the pavement, can directly affect the rate of collisions with animals. Paving roads without implementing physical mechanisms to control drivers' speed leads to higher vehicle speeds and hence, to an increase in roadkill (Oxley *et al*., 1974; Smith-Patten & Patten, 2008).

Seasonality may also influence the rate of roadkill. In northern Brazil, there is an increase in roadkill during the agricultural harvest (coinciding with the dry season) when more vehicles are on the road (Turci & Bernarde, 2009). However, in the country's Central-West region, most accidents occur in rainy season (Melo & Santos-Filho, 2007). Other studies also emphasize that the number of accidents with wildlife is higher on roads bordering reserves and protected areas (Clevenger *et al*., 2003; Coelho *et al*., 2008).

Several factors may motivate animals to cross roads, such as migration, seeking mates, foraging or to simply occupy their territories (Dias & Mikich, 2006). In Brazil, many projects focused on vertebrate conservation have addressed the issue of collisions with animals on highways (Hengemuhle & Cademartori, 2008; Gumier-Costa & Sperber, 2009; Meneguetti *et al.*, 2010).

In the state of Mato Grosso do Sul studies involving collisions with fauna have only been conducted in the low-lying wetlands (Cáceres *et al.*, 2010); there have been no studies in the plateau regions or grasslands. Many state highways in Mato Grosso do Sul are characterized by long, straight stretches (sometimes over 100 km), and a low linear slope, characteristics that promote increased speed among motorists, increasing the likelihood of fatal collisions with wildlife.

In order to contribute to our knowledge of the impact of fatal collisions on the fauna of the Cerrado in Mato Grosso do Sul, our study quantified the richness and abundance of vertebrate road kill on the highway MS-080, which connects the cities of Campo Grande and Rochedo. Our goal was to identify which areas had a higher incidence of roadkill and correlate this with the adjacent landscape features. We also used quantitative data to determine the relationship between the amount of roadkill and the lunar cycles and flow of vehicles traveling the highway.

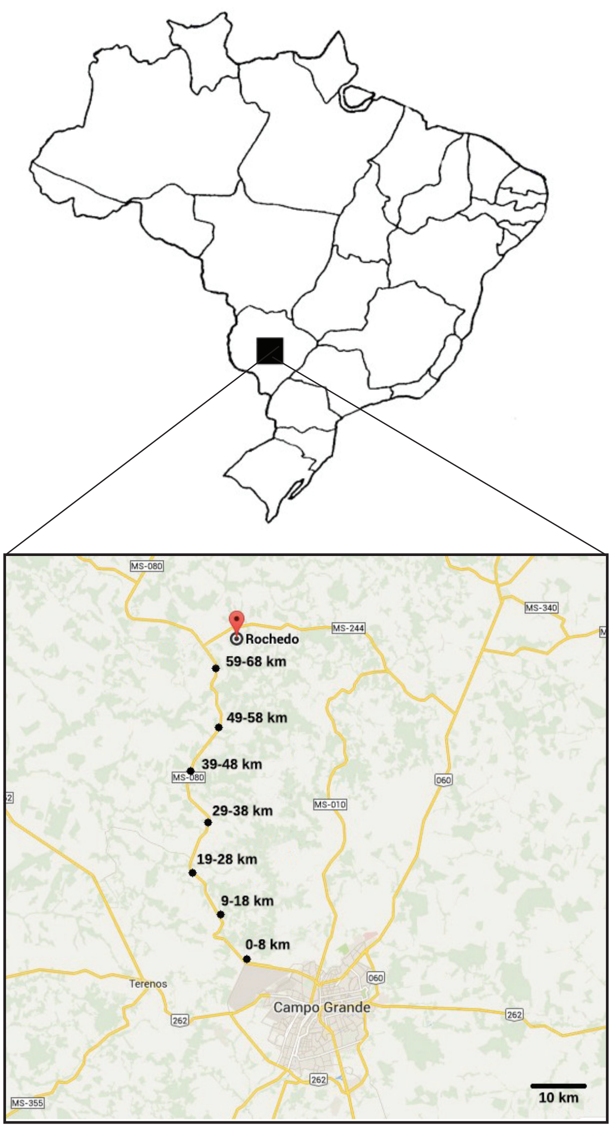


Fig. 1. Map of the study area, state of Mato Grosso do Sul, Brazil. The star indicates the city of Rochedo and the circle indicates the city of Campo Grande.

MATERIAL AND METHODS

Study site. Our study was conducted on state Highway MS-080, which connects the city of Campo Grande to Rochedo, a distance of approximately 70 km (Fig. 1). This highway is characterized by a single lane, with few shoulder areas and no signs alerting drivers to the presence of wild animals.

The landscape along the highway is characterized by pasture and Cerrado (Brazilian savanna) vegetation: small and medium-sized trees and shrubs ranging from 1 to 10 m tall. Four rivers that drain into the Aquidauna River cross the highway. Once a year, during the dry season (June-July) the Departamento Nacional de Infraestrutura de Transportes (National Department of Transportation Infrastructure, DNIT), trims the marginal vegetation marginal along the highway.

Data sampling. From March to September 2011, the stretch of MS-080 between Campo Grande and Rochedo was driven once a week, totaling 28 sampling days. Each sampling trip totaled 140 km. The route was driven during the day between 07:30 and 16:00, at a constant speed between 50 and 60 km/h.

When a carcass was sighted, the vehicle was pulled over onto the shoulder of the highway and the following data were recorded: the date and time, distance from Campo Grande, the number of individuals, the species, sex (when possible), and the approximate age (juvenile or adult). Then the animal was photographed with a digital camera to help experts identify it later.

Whenever possible, dead animals were identified to the species level, based on existing literature (Develey & Endrigo, 2004; Marques *et al.*, 2005; Reis *et al.*, 2009) and by consulting researchers at the Universidade Federal de Mato Grosso do Sul (UFMS) who are experts in different classes of tetrapods.

To test the influence of vehicle flow on the amount of roadkill, we used an index of monthly fatal collisions expressed by animal/vehicle/hour. The vehicular traffic was recorded weekly as follows: in a given stretch of highway, we counted the number of vehicles passing the observer in a one hour period (Coelho *et al.*, 2008). Using the data from each week of observation, we calculated the average number of vehicles on the highway per month. In order to compare our data with other studies in the literature, we used a quantitative index of roadkill per kilometer traveled (roadkill/km).

To calculate the total amount of animal biomass removed from the population of each species, we multiplied the number of records of each species by the average weight of the species, which was obtained from data available in the literature (Marques *et al*., 2005; Dunnig, 2008; Reis *et al*., 2009).

We used the Pearson Correlation test to correlate the amount of roadkill and the highway traffic flow. The Chi-square test was used to compare the number of roadkill during the different lunar phases. All statistical tests were performed in the program BioEstat 5.0.

RESULTS

During the study period, we recorded 257 vertebrate killed in collisions with vehicles (9.3 animals/day). These animals consisted of 52 species and 32 families (Tab. I).

Birds represent the largest amount of roadkill (41%) followed by mammals (32%), reptiles (18%) and amphibians (9%). Among the animals registered, 8.5% could not be identified beyond the level of family, because the carcasses were too fragmented or decomposed to be identified accurately. These records were not included in statistical analyses.

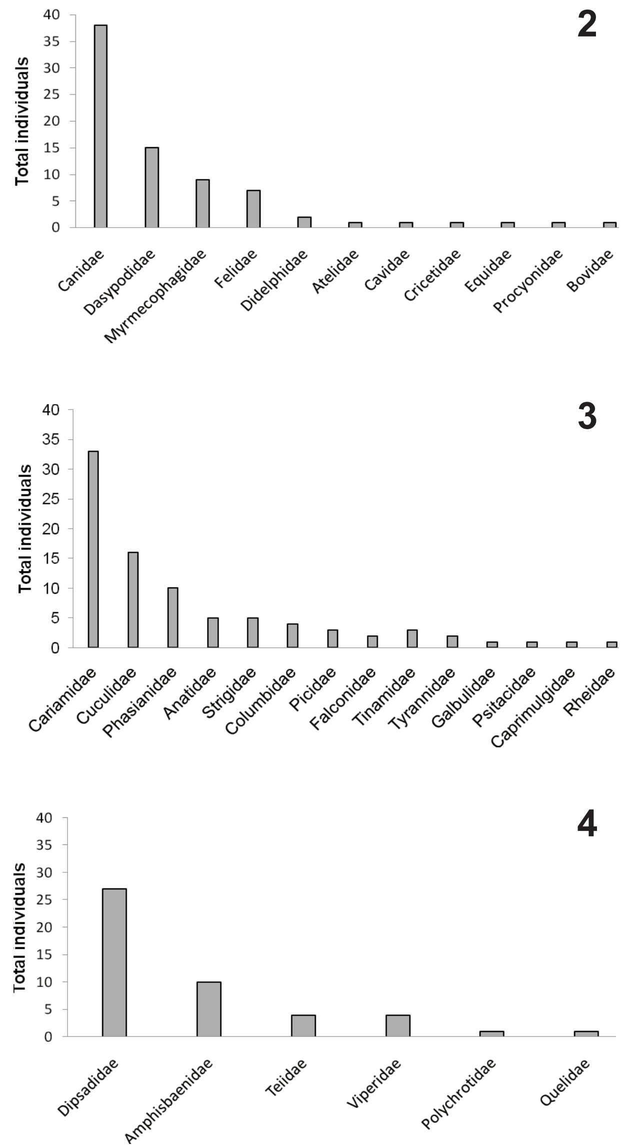
In a breakdown by families of vertebrates, the most common groups were: Canidae (Mammalia) (n = 38, 14.78%), Cariamidae (Aves) (n = 33, 12.84%), Dipsadidae (Reptilia) (n = 25; 9.72%) and Bufonidae (Amphibia) (n = 24; 9.33%) (Figs 2-4).

The most frequently identified species were the red-legged seriema (*Cariama cristata*) with 33 individuals (12.84%), the crab-eating fox (*Cerdocyon thous*) with 21 individuals (8.17%), the domestic dog (*Canis familiaris*) with 15 individuals (5.83%) and the yellow armadillo (*Euphractus sexcinctus*) with 12 individuals (4.66%) (Tab. I).

Within the class Mammalia, the crab-eating fox was the most frequently encountered species, with 27.27% of the total roadkill. In the class Aves, the red-legged seriema was the most abundant, with 40.2% of the occurrences. In the class Reptilia, red-worm lizard (*Amphisbaena alba*) represented 25.6% of roadkill. Within the class Amphibia, the cururu toad (*Rhinella schneideri*) was the only species recorded.

Considering the animal biomass, the giant anteater (*Myrmecophaga tridactyla*), the horse (*Equus caballus*), the crab eating fox, domestic dogs and sheep (*Ovis aries*) represented 77% of all biomass (Tab. I). The classes that had the greatest losses of biomass were (in descending order): Mammalia (1289.9 kg), Aves (102.1 kg), Reptilia (14.22 kg) and Amphibia (6.3 kg). Classified by the feeding niche occupied by each species, carnivores incurred a loss of 48.17%, insectivores 40.44%, herbivores 10.07%, frugivores 1.09% and scavengers 0.21%.

Among the seven sections of the highway evaluated, the initial stretch near the Campo Grande (0-8 km) had the highest incidence of roadkill, with 66 carcasses ($F = 3.131$, $p = 0.006$). The final section (59-68 km), near Rochedo, was the second most fatal, with 37 records (Fig. 5). There was no



Figs. 2-4. Total records of vertebrate roadkill on the highway of MS-080, state of Mato Grosso do Sul, Brazil: 2, Mammalia; 3, Aves; 4, Reptilia.

significant difference between any of the remaining sections covered ($F = 0.233$, $p = 0.918$).

The number of roadkill varied between months ($X^2 = 13.33$, $p = 0.038$). April had the highest number of records (n = 53), while the number of roadkill was lowest in August (n = 23).

The monthly rate of roadkill over the entire 70 km of highway MS-080 evaluated was 36.7 animals/month. This equates to 0.13 dead animals per km.

There was a positive correlation between the number of roadkill and the vehicle flow ($r^2 = 0.518$, $p = 0.004$) (Fig. 6). The roadkill index was highest in April (0.12 animals/vehicle/hour) and lowest in August (0.06 animals/vehicles/hour).

Nights with a new moon showed a greater number of roadkill when compared with first quarter moon or full moon nights ($X^2 = 10.65$; $p = 0.013$).

Tab. I. Number of records, frequency of occurrence, individual body mass, total biomass and percentage of total biomass of vertebrate roadkill on Highway MS-080, Central-West Brazil. The Class Amphibia was represented by only one species *Rhinella schneideri* Werner, 1894 with 24 individuals recorded and therefore has not been included in the table.

	N	%	Body mass (kg)	Biomass (kg)	%
AVES					
Cariamidae					
Cariama cristata Linnaeus,1766	33	40,2	1,4	46,2	45,4
Phasianidae					
Gallus gallus domesticus Linnaeus,1758	10	12,2	0,9	8,8	8,6
Cuculidae					
Guira guira Gmelin,1788	8	9,7	0,1	0,1	0,1
Crotophaga ani Linnaeus, 1758	6	7,3	0,1	0,6	0,6
Piaya cayana Linnaeus,1766	1	1,2	0,1	0,1	0,1
Tapera naevia Linnaeus,1766	1	1,2	0,1	0,1	0,1
Anatidae					
Dendrocygna bicolor Vieillot,1816	5	6,1	0,8	3,8	3,7
Picidae					
Colaptes campestris Vieillot,1818	3	3,7	0,2	0,5	0,5
Columbidae					
Geotrygon sp.	1	1,2	0,3	0,3	0,3
Columbina sp.	3	3,7	0,4	1,1	1,0
Strigidae					
Megascops choliba Vieillot,1817	1	1,2	0,1	0,1	0,1
Athene cunicularia Molina,1782	2	2,4	0,2	0,3	0,3
Falconidae					
Caracara plancus J. F. Miller, 1777	2	2,4	1,4	2,7	2,5
Tinamidae					
Nothura maculosa Temminck,1815	1	1,2	0,2	0,2	0,2
Crypturellus parvirostris Wagler, 1827	1	1,2	0,2	0,2	0,2
Rhynchotus rufescens Temminck, 1815	1	1,2	0,8	0,8	0,8
Galbulidae					
Galbula ruficauda Cuvier,1816	1	1,2	0,1	0,1	0,1
Tyrannidae					
Machetornis rixosa Vieillot,1819	1	1,2	0,1	0,1	0,1
Rheidae					
Rhea americana Linnaeus,1758	1	1,2	36,0	36,0	35,3
Total	82	100	43,3	102,1	100
REPTILIA					
Amphisbaenidae					
Amphisbaena alba Linnaeus,1758	10	25,6	0,13	1,25	8,8
Dipsadidae					
Oxyrhopus trigeminus Bibron & Duméril, 1854	8	20,5	0,13	1,0	7,0
Philodryas mattogrossensis Koslowsky, 1898	2	5,1	0,13	0,3	1,8
Boiruna maculata Boulenger, 1896	1	2,6	0,25	0,3	1,8
Clelia sp.	1	2,6	0,13	0,1	0,9
Erythrolamprus aesculapii Linnaeus,1766	1	2,6	0,13	0,1	0,9
Philodryas psammophidea Günther, 1872	1	2,6	0,13	0,5	3,5
Philodryas sp.	1	2,6	0,13	0,5	3,5
Pseudoboa nigra Duméril, Bibron & Duméril, 1854	1	2,6	0,25	0,3	1,8
Xenodon mattogrossensis Scrocchi & Cruz, 1993	1	2,6	0,13	0,13	0,9
Xenodon merremii Wagler, 1824	1	2,6	0,13	0,13	0,9
Polychrotidae					
Polychrus acutirostris Spix, 1825	1	2,6	0,3	0,3	2,1
Teiidae					
Ameiva ameiva Linnaeus,1758	4	10,3	0,7	2,8	19,7
Viperidae					
Bothrops moojeni Hoge,1966	4	10,3	0,13	0,5	3,5
Colubridae					
Chironius quadricarinatus Boie, 1827	1	2,6	0,13	0,13	0,9
Chelidae					
Mesoclemmys vanderhaegei Bour, 1973	1	2,6	6,0	6,0	42,2
Total	39	100	8,88	14,23	100
MAMMALIA					
Canidae					
Cerdocyon thous Linnaeus,1766	21	27,27	7,4	155,4	12
Canis familiaris Linnaeus, 1758	15	19,48	7,4	111	8,60
Lycalopex vetulus Lund,1842	2	2,59	3	6	0,46
Felidae					
Felis catus Linnaeus,1758	7	9,10	2,5	17,5	1,35
Procyonidae					
Nasua nasua Linnaeus,1766	1	1,30	8,35	8,35	0,70
Dasypodidae					
Euphractus sexcinctus Linnaeus,1758	12	15,58	5	60	4,65
Dasypus novemcinctus Linnaeus,1758	2	2,59	4,5	9	0,69
Cabassous unicinctus Linnaeus, 1758	1	1,30	3,5	3,5	0,27

Tab. I (cont.)

Myrmecophagidae					
Myrmecophaga tridactyla Linnaeus,1758	9	11,70	45	405	31,4
Didelphidae					
Didelphis albiventris Lund,1840	2	2,59	2	4	0,31
Atelidae					
Alouatta caraya Humboldt, 1812	1	1,30	5,5	5,5	0,43
Caviidae					
Cavia aperea Erxleben, 1777	1	1,30	0,65	0,65	0,05
Hydrochoerus hydrochaeris Linnaeus,1766	1	1,30	54	54	4,18
Equidae					
Equus caballus Linnaeus,1758	1	1,30	350	350	27,1
Bovidae					
Ovis aries Linnaeus,1758	1	1,30	100	100	7,75
Total	77	100	598,8	1289,9	100

Regarding the type of roadside vegetation, both open fields and dense forest were present along all the sections evaluated. However, within the first kilometers leaving the cities, where the number of roadkill was high, there was also a greater abundance of dense vegetation compared to other areas of the highway.

DISCUSSION

During the last three decades, death by vehicular collisions has surpassed hunting in the number of wildlife fatalities in Brazil, thus becoming the leading cause of direct, human-caused mortality among terrestrial vertebrates. Rates of mortality from collisions are especially significant for some species listed as threatened or endangered (Forman & Alexander, 1998).

In our study, we found a high rate of roadkill (0.13 roadkill/km), particularly when considering a distance of only 70 km between Campo Grande and Rochedo was analyzed.

Our results were similar to those of Melo & Santos-Filho (2007) in a study conducted on a 65 km stretch of Highway BR-070 between Cuiabá and Cáceres (Tab. II). However, that study was conducted within a more mountainous area whose topography is characterized by many winding curves and steep slopes.

Birds comprised the majority of fauna hit on Highway MS-080. This may be related to the abundance of landing sites and shelter provided by the shrubs and trees along the highway, as suggested by Rosa & Mauhs (2004) in another study conducted in southern Brazil.

As in other studies conducted in Brazil (Melo & Santos-Filho, 2007), the crab-eating fox was the mammal with the largest number of records of fatalities on highway MS-080. Souza & Miranda (2010) suggest that the mobility and large home range of this species may lead to increased road crossings and contribute to more fatalities. The crab-eating fox also has an opportunistic diet, often scavenging roadkill, which increases its own likelihood of being hit by a vehicle.

Among the reptiles, the red-worm lizard was hit the most often. Features such as poor vision and slower speeds increase this species' risk of being hit (Turci & Bernarde, 2009). We note that many reptile and amphibian species were found only after erratic rainfall and on sections of the highway near water sources, such as rivers and lakes. The number of reptiles and amphibians killed on the highway was higher in the rainy season than the dry season, perhaps due to their generally higher activity during this period when temperatures are higher and food availability is

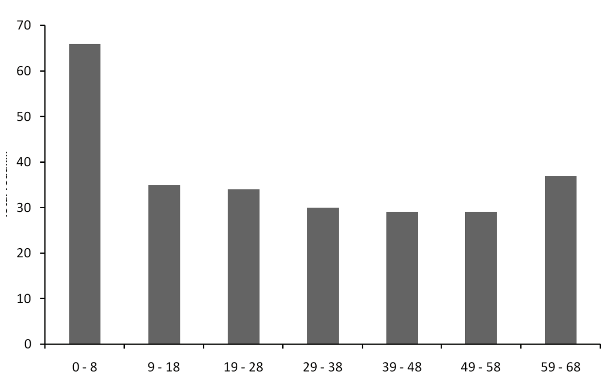


Fig. 5. Total records of roadkill in different parts of the highway MS-080, state of Mato Grosso do Sul, Brazil.

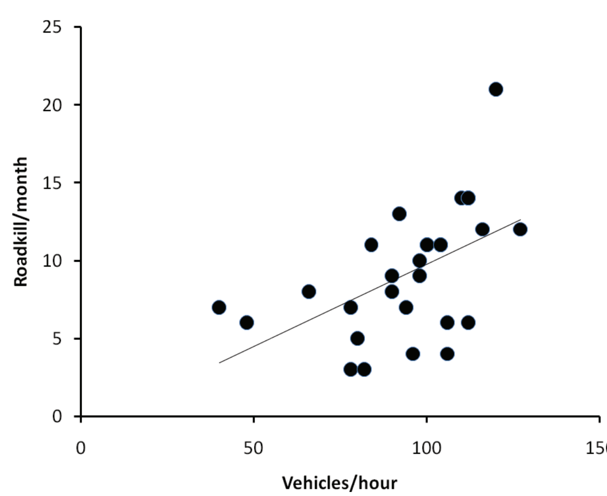


Fig. 6. Correlation between the amount of roadkill and traffic flow on the highway MS-080, state of Mato Grosso do Sul, Brazil during the period of study ($r^2 = 0.5183$; $p = 0.004$).

Tab. II. Comparison between different studies conducted in Brazil showing the rate of vertebrate roadkill (animals/km) (A) and mammal-only roadkill (animals/km) (B).

Authors	Highway	Location	Animals/km (A)
Present study	MS-080	Midwest	0.13
Rosa & Mauhs, 2004	RS-040	South	0.07
Melo & Santos-Filho, 2007	BR-070	North	0.13
Meneguetti *et al.*, 2010	Line 200	North	0.01
Gumier-Costa & Sperber, 2009	PA-275	North	0.01
Turci & Bernarde, 2009	RO-383	North	0.07
Authors	**Highway**	**Location**	**Mammals/km (B)**
Present study	MS-080	Midwest	0.030
Pereira *et al.*, 2006	PA-458	North	0.004
Cáceres *et al.*, 2010	BR-262	Midwest	0.030
Souza & Miranda, 2010	BR-230	Northeast	0.002

greater. Moreover, abundant rainfall may flood reptiles' burrows, compromising their thermal regulation and forcing them to seek new, more reliable places to bask, such as the hot asphalt on highways (Cáceres *et al*., 2010).

We found that greater lunar light reduced the number of roadkill. It is possible that on lighter evenings, drivers' visibility is greater, allowing them to better detect animals crossing the highway and avoid collisions.

Our data show that there was a greater number of fatal accidents with wildlife within the 10 km closest to the city of Campo Grande and the 10 km closest to Rochedo. This may be due to a variety of factors, including: the increased flow of vehicles leaving or coming into the cities, more stretches of highway with downhill slopes, or denser vegetation close to the shoulder (Fig. 5). According to Clevenger *et al*., 2003, the highest incidence of roadkill occurs on downhill stretches of roads, because this type of landscape is attractive to foraging animals while vehicles travel at high speeds, in addition to the higher flow of vehicles leaving or entering the cities.

Some species in our study could not be identified due to the high degree of degradation of their carcasses. This occurred in areas with high traffic flow, especially where many trucks pass, as the roadkill is often crushed multiple times by heavy vehicles, causing severe deformation and disintegration (Clevenger *et al*., 2003; Coelho *et al*., 2008).

Further, the recorded number of vertebrates in this study may be an underestimate, since some animals that are hit by vehicles fall off to the side of the road or are able to get off the highway but later die undetected. In addition, carcasses can be consumed by birds of prey and scavengers such as the southern crested caracara (*Caracara plancus*) or the black vulture (*Coragyps atratus*).

In Venezuela, Pinowski (2005) noted that roadkill are generally correlated to the type of surrounding vegetation, the climatic conditions, and the behavior of each species. In early June, the transportation authorities trimmed the marginal vegetation along highway MS-080, mainly in order to avoid fires, which are very common during this time of year. This may have also caused the decrease in the number of roadkill, because there is a greater tendency for fatal collisions on roads with dense riparian vegetation (Zaleski *et al*., 2009). There are generally less incidents in areas where there is no vegetation, or a greater distance to be crossed between margins, characteristics that may discourage the animals from crossing the highway (Hodson, 1962; Bellis & Graves, 1971).

Although it is not a species of wildlife, the single horse recorded in this study accounted for 15.84% of the total biomass lost in roadkill. This may give us insight into the impact of fatal collisions on the total biomass of the local fauna, especially when large mammals such as the tapir (*Tapirus terrestris*) or giant anteater (*Myrmecophaga tridactyla*) are hit.

In our study we found a positive correlation between the number of vehicles and amount of roadkill. Since we do not know the total size of the wildlife populations involved (Zaleski *et al*., 2009), we cannot measure the real impact of collisions on the local fauna. Nonetheless, our results can give us a glimpse of what this represents in a country as large and biodiverse as Brazil with a road network of more than 100,000 km.

Once we have definitively determined that roads are a threat to wildlife, the government should give special attention to developing actions and plans that will reduce the impact of collisions on Brazilian highways on wildlife.

There are few studies that seek to develop strategies that reduce the amount of roadkill on highways. Bager & Rosa (2010) developed an index that defines sections of highway BR-392 in southern Brazil as priority for implementing measures to reduce the number of collisions with wild animals. This index could be a useful tool for the Brazilian government to use for addressing the problem.

Indisputably, the implementation of strict speed limits in the areas with the highest number of roadkill would have a large effect. According to Orlowski & Nowak (2006), limiting the speed of vehicles to 40 to 50 km/h in critical areas can substantially reduce the number of roadkill.

Further, Bager & Rosa (2010) suggest the use of tunnels as one of the most effective tools to decreasing the impact of highways on wildlife. However the effect of such projects in Brazil remains undetermined. In this case, the implementation of such a system should consider the different needs and habits of each species of vertebrates.

Actions and conservation opportunities often arise when a crisis is apparent (Brandon *et al*., 1998). In conservation terms, Brazil has taken many positive steps, but now is an especially important time for strengthening the connection between science and government in developing conservation strategies (Brandon *et al*., 2005). Our study provides a glimpse into the impact of state highways on the wildlife of Mato Grosso do Sul. Our hope is that government authorities take effective measures to reduce the amount of roadkill at critical locations, using the data available in the literature or sponsoring further monitoring studies to inform their actions.

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