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Roadkill on vertebrates in Brazil: seasonal variation and road type comparison

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Abstract. The construction of major Brazilian highways dates back to the 1940's and 1950's. During this time, ecological concepts were not considered during the construction of highways. Consequently, roads are one of the main causes of environmental fragmentation. The goals of this study were to assess the diversity of vertebrates that are killed on and near highway BR MG 265, to analyze the seasonal variation of these road-kills, to compare the rate of road kills on the paved and unpaved sections of the road, and to suggest conservation practices. The roads were monitored twice a day on seven days during six consecutive months. The species, date, and location (for georeferencing) was recorded for each road kill. Overall, 48 road kills were found that represented 18 species, of which 35.42% were birds, 41.66% were mammals, 14.53% were reptiles and 8.33% could not be identified. Tests indicated that differences occurred between rainy and dry periods, and that no significant differences occurred between the paved and unpaved roads. Critical points were identified that require the installation of physical speed bumps or automatic radars with signposts that indicate wildlife crossings.

Keywords: conservation, seasonality, paved road versus dirt road.

Introduction

The highways are arguably the largest economic bottlenecks in Brazil. Current road conditions increase the costs of consumer goods and merchandise export (Sandim 2014). The main Brazilian highways were constructed in the 1940's and 1950's (Rosa 2006, Pereira & Lessa 2011). At that time, ecological concepts related to wildlife protection and conservation were new, and roads were only built for product distribution (Pereira & Lessa 2011). Since their construction, the preservation and conservation of natural environments became known as essential for maintaining native biota. The ecological thought of preserving natural resources peaked at the United Nations Conference on Environment and Development in Rio de Janeiro, Brazil (Novaes 1992).

Beginning in the late 20th century, studies have been conducted that involve the processes and interaction patterns of roads and ecosystems. Since then, road ecology has been consolidated as a discipline (Rosa & Bager 2013), and attempts have been made to connect ecological principles with road construction and maintenance processes.

The highways fragment the environment and ecological communities. The growing pool of ecological research (Bagatini 2006, França et al. 2012, Pracucci et al. 2012, Rosa & Bager 2013) in this field continues to generate positive results. Consequently, Normative Instruction #13 was enacted on July 19, 2013 (IBAMA 2013) to require road ecology studies for highway projects.

However, Brazilian highways usually do not include fauna passages, speed bumps, or efficient signaling at critical sites in order to avoid accidents involving humans and other animals. This is the case of highway BR MG 265 that connects important regions as center of southeastern region and cities of great importance for the outflow of industrial production, tourism and leisure. This road presents an intensive traffic and it is surrounded by multiple fragments and forest corridors with rich and abundant animal biodiversity (Almeida & Louzada 2009, Lombardi et al. 2012, Machado et al. 2013). Presently no action driven to preserve the vertebrate fauna shows efficiency.

Thus, the goals of this study were the following: (1) to assess the diversity of vertebrates that were killed on BR MG 265 and in the surrounding areas, (2) to analyze the seasonal variations of road kills, (3) to compare the rates of road kills in paved and unpaved areas, and (4) to suggest conservation practices for the study area.

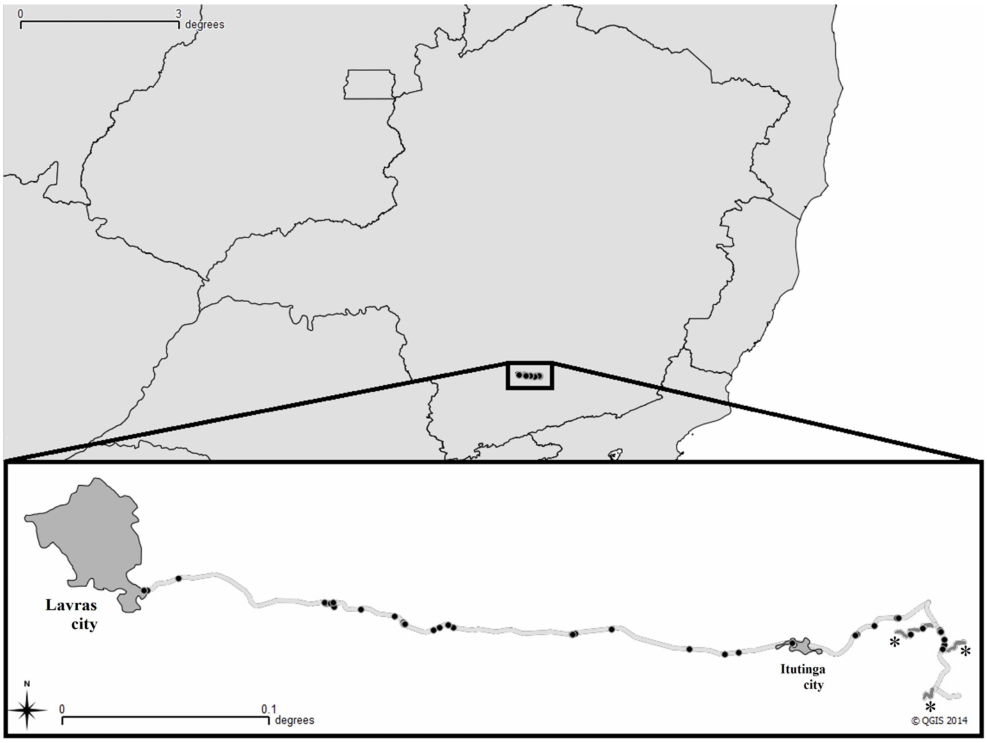

Figure 1. Study area and points roadkill of wildlife. The asterisk (*) represents the unpaved roads and points on the road represent records of trampling.

Material and methods

The study was conducted in five different areas (Fig. 1). The first area included a 45 km segment of highway BR MG 265 between the city of Lavras (21°27″S, 44°48″W) and the rural area of Nazareno City (21°16″S, 44°35″W). The second area included a 6.45 km segment of paved BR MG 265 access road that extended to the Camargo dam (21°18'55.17"S, 44°35'34.67"W). Finally, the reduced number of information related to unpaved roads in the neotropical region resulted in the selection of three unpaved roads for this study. Therefore, three unpaved roads were studied (21°19'18.67"S 44°36'5.17"W, 1.2 km; 21°17'46.25"S 44°35'4.08"W, 1.42 km; and 21°17'28.27"S 44°36'32.94"W, 2.67 km). The paved roads had an average width of 20 m and the unpaved roads had an average width of 15 m.

According to the Koppen classification system, the climate in the study area is Cwb (mesothermal, with mild summers and dry winters). The mean annual temperature is 19.6°C, with monthly means ranging from 16 to 21.8°C. In addition, the mean annual precipitation is 1517 mm, is concentrated between October and March, and varies from 19.2 to 2933 mm monthly (van der Berg & Oliveira-Filho 1999). The forest vegetation surrounding the highway is seasonal semi-deciduous forest lying in a lowland formation (IBGE 2004).

The roads were surveyed twice a day (8:00am and for 17:00pm) even days during six consecutive months (July-December 2013). A total of 4,766.16 km (888.72 km of unpaved road and 3,877.44 km of paved roads) were surveyed. From each carcass we recorded the coordinates and identification of material *in locu*. The roads were monitored with a motor vehicle, the study area was covered with a maximum speed of 50km/h and four observers analyzing both the center as the side areas of the road (escape area).

Information about endemicity and restricted distribution followed description of Paglia et al. (2012) for mammals, for reptiles and birds were used IUCN data (IUCN 2015) and information from Catalogue of Life (Catalogue 2015).

The recorded and estimated species richness where compared using the first-order jackknife procedure (Burnham & Overton 1978) in the EstimateS software (Colwell et al. 2012).

The road kill were grouped by month and season (dry and rainy) and compared using a chi-square test of equal distributions. In addition, a rarefaction curve was created to identify possible trends in road kill events between the dry and rainy seasons. The rarefaction curve data were randomized 1,000 times for each month and were plotted with the EstimateS software (Colwell et al. 2012).

Table 1. Diversity of road kills on highway BR MG 265, including the Class, Order, Species and the common name of the recorded species. The asterisk (*) represents the Domestic species. The letter "Y" means "Yes" and the letter "N" means "No" to "end." (endemicity) and dist (restricted distribution).

Class / Order / Species	Common name	End.	Distr.
Reptile			
Squamata			
Crotalus durissus (Linnaeus, 1758)	South American rattlesnake	N	N
Xenodon merremii Wagler, 1824	Wagler's snake	N	N
Tubinambis merineae Linnaeus, 1758	Argentine black and white tegu	N	N
Testudinata			
Trachemys sp.	Slider	N	N
Birds			
Columbina sp.	Ground dove	N	N
Coragyps atratus Bechstein, 1793	Common vulture	N	N
Passer sp.	True sparrows	N	N
Polyborus plancus Miller, 1777	Crested caracara	N	N
Ramphastos toco Müller, 1776	Toucan	N	N
Mammal			
Primates			
Callithrix penicillata (É. Geoffroy, 1812)	Black tufted-ear marmoset	Y	N
Carnivora			
Canis lupus familiaris Linnaeus, 1758*	Domestic dog	-	-
Conepatus semistriatus Boddaert, 1785	Striped hog-nosed skunk	N	N
Felis catus (Linnaeus, 1758)*	Domestic cat	-	-
Cerdocyon thous Linnaeus, 1766	Crab-eating fox	N	N
Cingulata			
Dasypus novemcinctus Linnaeus, 1758	Nine-banded armadillo	N	N
Didelphimorphia			
Didelphis aurita Wied-Neuwied, 1826	Big-eared opossum	N	N
Didelphis sp.	Opossum	N	N

Road kill rates (individual/km/day) (Pracucci et al. 2012) were calculated to compare the effects of road kills on different types of roads and to standardize the different surveyed distances between the treatments. Monthly road kill rates were compared using a G test. The Bioestat 5.0 (Ayres et al. 2007) software was used for the chi-square and G tests with a 5% significance level. The road kill locations were georeferenced and mapped to indicate the critical sites of the study area and to enable suggestions for mitigating or minimizing road kills.

Results and discussion

A total of 48 road kills were found, which included 18 species (Table 1).

From the 48 road kills, 17 were birds (35.42%), 20 mammals (41.66%), 7 reptiles (14.53%), and 4 unidentified animals (8.33%) due to the high degree of carcass deterioration. The observed species richness value was below the value that was estimated by the first-order jackknife richness estimator (26.83 species). Thus, only 74.24% of the road kill diversity was recorded by the estimator. Some of the recorded road kills are shown in Fig. 2. Most events that were recorded in this study occurred on the paved road segments with high-speed curves (Fig. 1).

The chi-square test indicated that no significant differences (X^2=9.25, df=5, p=0.0995) occurred between the studied months. However, a significant difference was observed between the dry and wet months when they were grouped (X^2=6.75, df=1, p=0.0141). In addition, no significant difference was observed between the paved and unpaved roads (test G=0.0292, df=1, p=0.8644).

The rarefaction curve indicated species accumulation during the early sampling months. An average of 2.63 species were added each month, with a maximum of 4.24 species added between July and August and minimum of 1.67 species added between November and December (Fig. 3).

High proportion of roadkill consists of species considered common with wide distribution in Brazil (94.4%). Only *C. penicillata* is endemic in Brazil (Paglia et al. 2012). The number of species and roadkill is low compared to other studies, however is similar when comparing the relation between species by kilometers studied (sp. / km)

Figure 2. Animals get hit recorded in the study area.
(A) *Conepatus semistriatus*, (B) *Felis catus*, (C) *Xenodon merremii* and (D) *Crotalus durissus*.

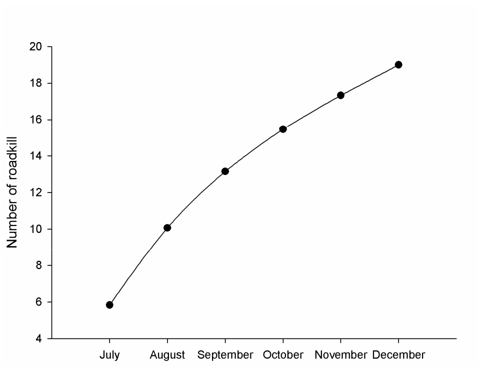

Figure 3. Rarefaction curve to number of roadkill during the six months.

and number of roadkills by kilometers studied (ind. / km). Pracucci et al. (2012) for a stretch of highway MG 354, a region adjacent to the study area, with 28 species in 46 roadkill and 468km studied (0.06 sp./km and 0.1 ind./km); Glista et al. (2007) in four highways in the United States found 69 species in 1488 roadkill and 10515km studied (0.007 sp./km and 0.1 ind./km); Hobday & Minstrell (2008) on some highways in Australia found 54 species in 5691 roadkill and 15281km studied (0.003 esp./km and 0.4 ind./km).

Road ecology studies are relatively recent, with the first studies dating back to the 1990s (Rosa & Bager 2013). Thus, ecological concepts were not used during the construction of highways, consequently, these are one of the main causes of environmental and ecological fragmentation.

This fragmentation is linked to slow movements of some species, the use to thermoregulation, and behavior to avoid related to traffic disturbances (noise, lights, pollution, traffic motion) (Fahrig & Rytwinski 2009).

Ignoring the ecological aspects in a country with high animal diversity is extremely troubling. The main Brazilian highways are inserted in extremely threatened areas, such as the Atlantic Forest and Cerrado, which are known as biodiversity hotspots (Myers et al. 2000). Highway BR MG 265, which connects the cities of Nazareno and Lavras, is surrounded by a large number of fragments and forest corridors and by rich and abundant animal biodiversity (Silva & Passamani 2009, Machado et al. 2013). Thus, the results of this study are likely underestimates. Furthermore, Ratton et al. (2014) demonstrates that the permanence time of carcasses is short, a few hours, after road kill event.

In addition to the highway's impacts on biodiversity, it has a high traffic flow. This high flow could result in a reduced number of carcasses, especially small animal carcasses that can be crushed or carried away by scavengers (Bagatini 2006, Pracucci et al. 2012, Ratton et al. 2014), weather and traffic which act synergistically (Ratton et al. 2014). Locations on the road where bloodstains were observed were noted at the different sampling times. However, in addition to not having the carcasses for analysis, these stains potentially originated from road kill that was killed before the sampling period or from other road kill events in which the animals were able to move away from the road before dying (Bagatini 2006, Pracucci et al. 2012).

The absence of amphibians was not expected and does not corroborate Glista et al. (2007), but is in line with the arguments presented by Fahrig & Rytwinski (2009). These authors comment that amphibians are not attracted to the roads, but which favors the trampling is the difficulty in commuting and the imperative need to shift in reproductive periods. One factor that may have contributed to substantial reduction of the presence of amphibians during the study period was the severe drought of the southeastern Brazilian states in recent years. Increased temperature has left drier environments, with low relative humidity, low levels of the main and secondary reservoirs of water (see news in Kafruni 2015 and ONS 2015).

The difference between the dry and rainy months was confirmed by the statistical tests, with the highest number of road kills observed during the wet season. The rainy season includes months with higher primary productivity. The increase in primary production in the rainy season increases the availability of food resources for herbivores of the food web. These reserves are used commonly trigger for reproductive purposes, ie, to a greater amount of puppies and better adapted to periods of drought. This behavior is standard for rodents and marsupials, for example. Cerqueira (2005) indicated that the rainy season triggers strong increases in the body mass of rodents and small marsupials due to the presence of abundant resources. This increased body mass promotes early reproduction, which may occur up to two times in a single rainy season for some species. This behavior at the base of the food web generates a cascading effect to the other trophic levels. Thus, the number of displacements during the rainy season increases due to foraging and mating (as animals seek sexual partners) behaviors. Some studies have observed contrasting results, with a greater number of road kills during the dry season due to the larger number of reptiles being run over (Pracucci et al. 2012). Reptiles are poikilothermic; thus, they search for highway areas as a source of heat, which results in road kills. Furthermore, there are recent studies showing that drivers intentionally run over reptiles, especially snakes (Secco et al. 2014).

The relationships between the paved and unpaved roads correspond with the results of other studies (Bagatini 2006, Pracucci et al. 2012). Nevertheless, all of these studies agree that the conditions of unpaved roads make it difficult for drivers to increase their vehicle speed (Bagatini 2006), which reduces the number of road kills. In addition, another parameter that supports this observed pattern is the soil vibration. Some animals can sense vibrations from the road and immediately escape (Bagatini 2006).

The installation of mechanisms for wildlife protection in highways has been shown effective in reducing mortality from different taxonomic groups, but they are not completely efficient and require constant maintenance (Dodd Jr. et al. 2004). Nevertheless, several factors should be considered when analyzing the conservation aspects of study area. First, the road has critical sites that require specific approaches. Therefore, the installation of physical speed bumps or automatic radar is suggested in the following sections: km 330 (entrance to the town of Rosario), km 321 (entrance to the town of Macuco de Minas), km 313 (border between the towns of Itutinga and Macuco de Minas) and km 332. Moreover, wildlife crossing signs should be installed. Due to the small number of records in the dirt pavement, specific mitigation measures are not needed for the unpaved roads while their current traffic flow and paving characteristics are maintained.

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