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Vertebrate road kill survey on a highway in southern Brazil

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ABSTRACT. Highways are a major factor acting in the decline of several wildlife populations. Impact occurs due to the continuous flow of motor vehicles over tracks and collision with animals using the same area. This study aimed to list road killed wild vertebrates found in highways in the Pampa Biome, state of Rio Grande do Sul, over an entire year. The taxa found (amphibians, reptiles, birds and mammals) were identified to species level and their frequency of occurrence was seasonally registered. Along 2,160 km, we found 318 road killed individuals, totaling 65 species. This number represents an average of 0.147 road killed specimens by kilometer (that is, 1 individual each 7 km). Of these, seven species are under threat of extinction in the state of Rio Grande do Sul. We also found a seasonal pattern among road kills, in which the highest number of road killed animals was registered in the summer and spring months. These results contribute to increase knowledge about which species are most impacted by road kill on highways of the Pampa Biome. Such data can be used as an indicator for the implementation of measures by competent bodies to mitigate impacts of highways in the state of Rio Grande do Sul.

Keywords: mortality, wildlife, Rio Grande do Sul.

Levantamento de vertebrados atropelados em rodovias do sul do Brasil

RESUMO. As rodovias são um fator provocador de declínio populacional de diversas espécies da fauna silvestre. O impacto ocorre devido ao contínuo fluxo de veículos automotores sobre as pistas e a colisão dos mesmos com animais que também utilizam essa área. O presente estudo teve por finalidade listar os vertebrados silvestres encontrados atropelados em rodovias no bioma Pampa, no Estado do Rio Grande do Sul, ao longo de um ano. Os táxons encontrados (anfíbios, répteis, aves e mamíferos) foram identificados em nível específico e a sua frequência de ocorrência foi registrada de forma sazonal. Em 2.160 km de estrada percorridos, foram encontrados 318 indivíduos atropelados, totalizando 65 espécies. Essa quantia representa uma média de 0,147 espécimes atropelados por quilômetro (ou seja, 01 indivíduo atropelado a cada 07 Km). Destas, sete espécies estão sob ameaça de extinção no Estado do Rio Grande do Sul. Foram observados padrões sazonais nos atropelamentos, sendo que os meses de verão e da primavera apresentaram o maior número de animais atropelados. Os resultados do estudo contribuem para o conhecimento de quais espécies da fauna silvestre são mais impactadas por atropelamentos no bioma Pampa. Estes dados poderão ser utilizados como orientação na implantação de medidas por órgãos competentes, afim de mitigar o impacto de rodovias no Estado do Rio Grande do Sul.

Palavras-chave: mortandade, fauna silvestre, Rio Grande do Sul.

Introduction

Highways are considered a key element in society's economic development causing, in contrast, several environmental impacts (Fu, Liu, & Dong, 2010, Oliveira & Silva, 2012), which affect both terrestrial and aquatic ecosystems. Impacts start during road construction and remain through its utilization, sometimes causing irreversible damage to wildlife, such as biodiversity loss (Trombulak & Frissel, 2000). Due to collisions between vehicles and wild animals, highways are also considered one of the main causes of wildlife mortality (Trombulak & Frissel, 2000, Prado, Ferreira, & Guimarães, 2006, Bager & Rosa, 2011).

Such impacts on wildlife are reducing populations, especially those with low densities and/or under threat of extinction. Thus, efficient mitigation measures to reduce mortality and species isolation must be adopted (Bencke & Bencke, 1999, Cherem, Kammers, Ghizoni Jr, & Martins, 2007, Düpond & Lobo, 2012, Santos, Rosa, & Bager 2012, Teixeira et al., 2016). The implementation of speed reducers (Coelho, Kindel, & Coelho, 2008), traffic signs (Silva, Corrêa, Oliveira, & Cappellari, 2013) and the technique of road fencing (Clevenger, Chruszcz, & Gunson, 2001), along with the implementation of wildlife crossings are some of the measures used to reduce road kill. These measures must be applied in strategic sites that are usually used as crossing areas by animals and present high mortality rates. Environmental education activities in communities and schools, as a way to disseminate this issue to road users and raise awareness about the presence of wildlife in the tracks, are also essential to reduce road kill (Costa, 2011). To assess the diversity of impacted species in a highway is an important tool to define areas of greater vulnerability and thus, which require priority in the establishment of mitigation measures (Hengemühje & Cademartori, 2008, Silva et al., 2013, Cunha, Hartmann, & Hartmann, 2015, Steil, Düpont, & Lobo, 2016, Deffaci, Silva, Hartmann, & Hartmann, 2016). However, previous and post-monitoring of impacted species before the establishment of the measures is necessary to verify their efficiency (Cunha, Moreira, & Silva, 2010, Ferreira, Ribas, Casella, & Mendes, 2014).

Several studies, such as those performed by Camargo, Mazim, and Garcias, (2011), Hartmann, Hartmann, and Martins (2011), Coelho, Teixeira, Colombo, Coelho, and Kindel (2012), Santana (2012), Carvalho, Bordignon, and Shapiro (2014), Secco, Ratton, Castro, Lucas, and Bager (2014) and Deffaci et al. (2016) highlight the issue of wildlife road kill in Brazil, reporting which taxa present higher mortality rates. This wide range of publications works both as a warning to authorities and as a source of information for decision-making in the construction and adaptation of highways in Brazil (Teixeira et al., 2016). Nevertheless, impacts of highways on some groups of vertebrates, such as amphibians, may still be underestimated. This is mainly due to their small size and to difficulties in sighting such small specimens (Teixeira, Coelho, Esperandio, & Kindel, 2013).

The aim of this study was to list road killed wild vertebrates found in a region of the Pampa Biome, in the state of Rio Grande do Sul, Brazil.

Material and methods

Study area

This study was carried out in a stretch of BR-392 and BR-290 highways. BR-392 crosses São Sepé city and connects with BR-290 towards Vila Nova do Sul. This stretch was considered as continuous in this study (Figure 1). The study area is located in the Pampa Biome in the central portion of the state of Rio Grande do Sul. The area presents a mischaracterization of its physiognomy due to the expansion of agriculture, extensive cattle ranching, monoculture (Instituto Brasileiro de Geografia e Estatística [IBGE], 2016) and to hunting pressure, still common in the region (Corrêa, Silva, Pazinato, & Mello, 2013). Such impacts on the biome contribute to the decline and isolation of wild populations, which in some cases are already under threat of extinction (Fontana, Bencke, & Reis, 2003, Corrêa, Silva, & Cappellari, 2010, Corrêa et al., 2013).

Data sampling

From February 2012 to January 2013, a 45 km stretch of a highway between São Sepé and Vila Nova do Sul was weekly sampled, totaling 2,160 km traveled in 48 surveys. Sampling was performed during the morning by two people aboard a motorcycle or a car, in an average speed of 50 km $hour^{-1}$ (Souza & Miranda, 2010). Road killed vertebrates were identified and registered by season in a spreadsheet (Silva et al., 2013). Specimens that were difficult to identify due to decomposition or degradation were photographed and subsequently identified (Costa, 2011). Carcasses of domestic animals were not considered as part of the samples (Hengemühle & Cademartori, 2008).

Data analysis

In order to compare results of this survey with other lists available in the literature, we used a quantitative index of road kill vertebrates by traveled kilometer (Carvalho et al., 2014). In order to check for any seasonal differences in the abundance of road killed vertebrate specimens, a Kruskal-Wallis test followed by Dunn's post hoc test was run using BioEstat 5.0 software. Segalla et al. (2016), Bérnils and Costa (2015), Piacentini et al. (2015) and Paglia et al. (2012) were used as reference for amphibian, reptile, bird and mammal nomenclature, respectively. Even though *Lepus europaeus* (Silva, 1994) is an introduced species in Brazil, it was considered in our records due to its large and established distribution in the state of Rio Grande Sul. Conservation status of species at the regional level followed the List of Threatened Wildlife Species in Rio Grande do Sul (Fontana et al., 2003, Fundação Zoobotânica do Rio Grande do Sul [FZB], 2014).

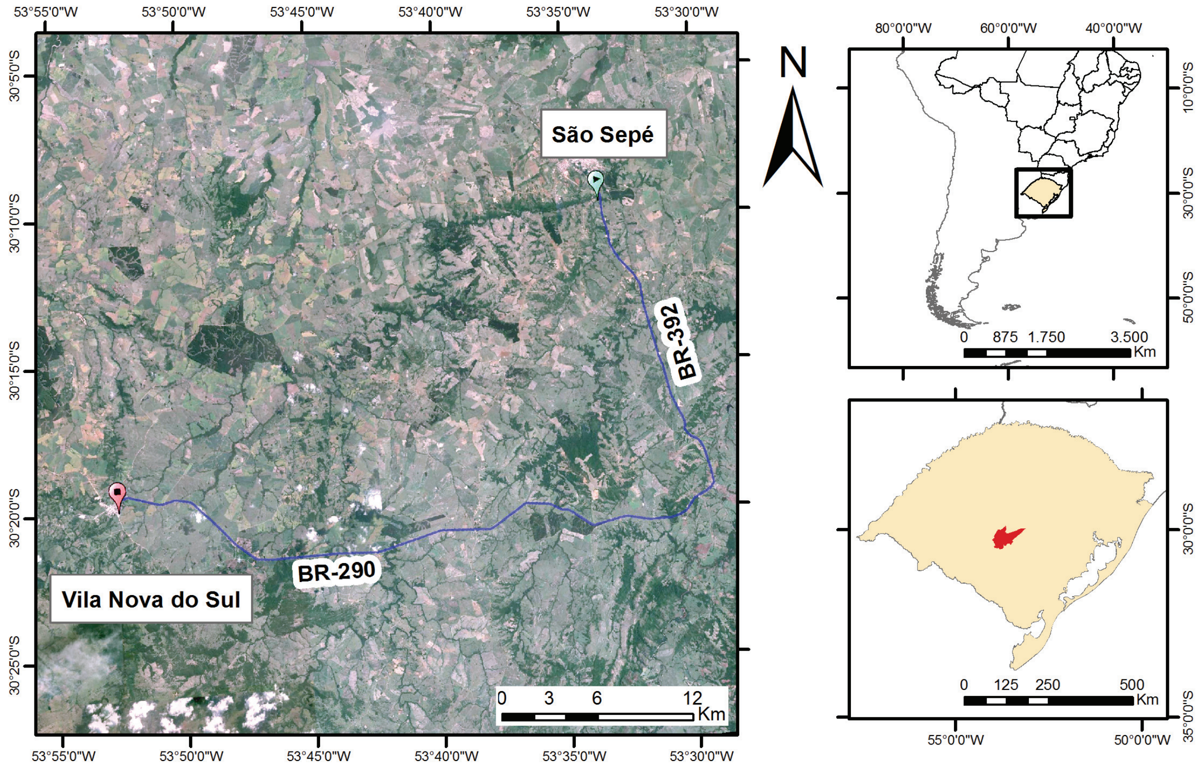

Figure 1. Study area: a stretch of the highway traveled between the cities of São Sepé and Vila Nova do Sul, Central Region, state of Rio Grande do Sul, Brazil.

Results and discussion

Along a year, 318 road killed vertebrates belonging to 65 species were registered. Of these, 38 species were birds, 20 were mammals, six were reptiles and one was anuran (Table 1). Vertebrates showed a mortality rate of 0.147 specimens per traveled kilometer, (i.e., an individual each seven kilometers). This rate was similar to those in other studies (Table 2). The most abundant species were *Cavia aperea* (10.4%), *Conepatus chinga* (9.5%), *Didelphis albiventris* (6.3%), *Nothura maculosa* (5.7%) and *Salvator merianae* (5.1%).

Among the records of this study, *Leopardus geoffroyi*, *Leopardus wiedii*, *Puma yagouaroundi*, *Alouatta guariba*, *Nasua nasua* and *Tamandua tetradactyla* are under the 'Vulnerable' threat category in the state of Rio Grande do Sul (Fontana et al., 2003, FZB, 2014). In relation to seasonality of abundance, the pairwise comparison showed that spring and summer were the seasons with greater occurrence of road killed animals (Figure 2; Table 3).

Among road killed vertebrates, mammals were the group with greater predominance (44%; N = 140 ind.), followed by birds (41.5%; N = 132 ind.) and in a smaller percentage, reptiles (11%; N = 35 ind.) and amphibians (3.5%; N = 11 ind.). Nonetheless, the number of road killed specimens belonging to specific taxa might still be underestimated (Teixeira et al., 2013), since, when hit by a car, several individuals are thrown to the side of the road and/or move themselves out of the tracks (Slater, 2002).

Amphibians are one of the most underestimated taxa in road kill surveys (Teixeira et al., 2013, Braz & França, 2016). In the present survey, it was possible to identify only one individual of *Rhinella* sp., due to its outstanding size. Accordingly, to Corrêa et al. (2013), other species of smaller amphibians occur in the region and most likely, the number of road killed frogs was probably once again underestimated (Teixeira et al., 2013, Braz & França, 2016).

Amphibian behavior can be driven by temperature and rainfall volume, thus certain weather conditions increase the risk of collisions. In order to reduce sample bias in this group, we suggest that two people should cover short stretches of the highway on foot. Surveys should be performed in the morning period, in both sides of the track (Coelho et al., 2012). However, the reduced number and/or absence of amphibians and small rodents might also be associated with predation by scavengers, such as birds and mammals.

Table 1. List of road killed species recorded in highways between the cities of São Sepé and Vila Nova do Sul, Rio Grande do Sul. (N) Number of individuals; (%) Percentage of road kill, per species.

Taxa	N	%
Amphibians		
Rhinella sp	11	3.6
Reptiles		
Bothrops pubescens (Cope, 1870)	01	0.3
Erythrolamprus sp.	01	0.3
Mastigodryas bifossatus (Raddi, 1820)	05	1.6
Philodryas patagoniensis (Girard, 1858)	03	0.9
Salvator merianae (Duméril & Bibron, 1839)	16	5.1
Trachemys dorbigni (Duméril & Bibron, 1835)	09	2.9
Birds		
Agelaioides badius (Vieillot, 1819)	03	0.9
Anumbius annumbi (Vieillot, 1817)	02	0.6
Aramides ypecaha (Vieillot, 1819)	03	0.9
Bubo virginianus (Gmelin, 1788)	01	0.3
Cariama cristata (Linnaeus, 1766)	02	0.6
Colaptes campestris (Vieillot, 1818)	01	0.3
Colaptes melanochloros (Gmelin, 1788)	02	0.6
Columbina picui (Temminck, 1813)	05	1.6
Columbina talpacoti (Temminck, 1811)	01	0.3
Coryphospingus cucullatus (Statius Muller, 1776)	05	1.6
Crotophaga ani Linnaeus, 1758	01	0.3
Cyanoloxia brissonii (Lichtenstein, 1823)	01	0.3
Cyanoloxia glaucocaerulea (D'Orbigny & Lafresnaye,1837)	01	0.3
Falco sparverius Linnaeus, 1758	02	0.6
Furnarius rufus (Gmelin, 1788)	07	2.2
Glaucidium brasilianum (Gmelin, 1788)	01	0.3
Guira guira (Gmelin, 1788)	06	1.9
Machetornis rixosa (Vieillot, 1819)	03	0.9
Mackenziaena leachii (Such, 1825)	01	0.3
Megascops choliba (Vieillot, 1817)	01	0.3
Mimus triurus (Vieillot, 1818)	01	0.3
Molothrus bonariensis (Gmelin, 1789)	07	2.2
Nothura maculosa (Temminck, 1815)	18	5.7
Pachyramphus polychopterus (Vieillot, 1818)	01	0.3
Paroaria coronata (Miller, 1776)	07	2.2
Penelope obscura Temminck, 1815	04	1.3
Piaya cayana (Linnaeus, 1766)	02	0.6
Pitangus sulphuratus (Linnaeus, 1766)	02	0.6
Pyrrhura frontalis (Vieillot, 1817)	03	0.9
Rhynchotus rufescens (Temminck, 1815)	02	0.6
Saltator similis D'Orbigny & Lafresnaye, 1837	03	0.9
Sicalis flaveola (Linnaeus, 1766)	04	1.3
Tapera naevia (Linnaeus, 1766)	01	0.3
Thamnophilus ruficapillus Vieillot, 1816	01	0.3
Turdus rufiventris Vieillot, 1818	01	0.3
Tyrannus savana Vieillot, 1808	05	1.6
Zenaida auriculata (Des Murs, 1847)	12	3.8
Zonotrichia capensis (Statius Muller, 1776)	09	2.9
Mammals		
Alouatta guariba (Humboldt, 1812)	01	0.3
Cavia aperea Erxleben, 1777	33	10.4
Cerdocyon thous (Linnaeus, 1766)	08	2.6
Conepatus chinga (Molina, 1782)	30	9.5
Dasypus hybridus (Desmarest, 1804)	03	0.9
Dasypus novemcinctus Linnaeus, 1758	07	2.2
Didelphis albiventris Lund, 1840	20	6.3
Euphractus sexcinctus (Linnaeus, 1758)	02	0.6
Galictis cuja (Molina, 1782)	02	0.6
Hydrochoerus hydrochaeris (Linnaeus, 1766)	02	0.6
Leopardus geoffroyi (D'Orbigny & Gervais, 1844)	02	0.6
Leopardus wiedii (Schinz, 1821)	01	0.3
Lepus europaeus Pallas, 1778	05	1.6
Lontra longicaudis (Olfers, 1818)	01	0.3
Lycalopex gymnocercus (G. Fischer, 1814)	11	3.6
Mazama gouazoubira (G. Fischer, 1814)	02	0.6
Nasua nasua (Linnaeus, 1766)	01	0.3
Procyon cancrivorus (G. Cuvier, 1798)	06	1.9
Puma yagouaroundi (É. Geoffroy, 1803)	01	0.3
Tamandua tetradactyla (Linnaeus, 1758)	02	0.6
		100

When predators feed on road kill, they can carry carcasses out of the road (Silva et al., 2013). This behavior is also a risk to predators, which feed over the track, become vulnerable to collisions (Turci & Bernarde, 2009, Zandonadi, Brunaldi, Meneguelli, & Araújo, 2014). In this study, we found species that could have been killed in this manner, for instance *Cerdocyon thous* and *Lycalopex gymnocercus*. Finally, another bias factor is deterioration through the continuous passage of cars over carcasses (Souza & Miranda, 2010), making them hard to distinguish (Pinheiro & Turci, 2013). Therefore, it is clear that specific strategies to measure impact over each taxon need to be established in order to improve taxa records (Fey et al., 2015) and to become globally standardized, thus being suitable for large scale comparisons.

Table 2. Results of the present study in relation to other recent works that present average values of vertebrate road kill in Brazil. km = average number of road kill per traveled km and respective highways. Groups: 1 - amphibians; 2 - reptiles; 3 - birds; 4 - mammals.

km	Groups	Highway	State	Author (s)
0.15 ind.	1, 2, 3, 4	BR-290/BR-392	RS	Present study
0.21 ind.	2, 3, 4	RS-389	RS	Coelho et al. (2008)
0.46 ind.	2, 3, 4	BR-101	RS	Coelho et al. (2008)
0.169 ind.	2, 3, 4	BR-116	RS	Camargo et al. (2011)
0.104 ind.	2, 3, 4	BR-293	RS	Camargo et al. (2011)
0.175 ind.	2, 3, 4	BR-392	RS	Camargo et al. (2011)
0.1 ind.	3	BR-392	RS	Bager and Rosa (2012)
0.36 ind.	4	BR-230	PB	Souza and Miranda (2010)
0.10 ind.	2, 3, 4	BR-158	RS	Oliveira and Silva (2012)
0.098 ind.	1, 2, 3, 4	MG 354	MG	Santos et al. (2012)
0.14 ind.	1, 2, 3, 4	BR-392/RS-149	RS	Silva et al. (2013)
0.138 ind.	1, 2, 3, 4	BR-307	AC	Pinheiro and Turci (2013)
0.13 ind.	2, 3, 4	MS-080	MT	Carvalho et al. (2014)
0.077 ind.	4	ES-060	ES	Ferreira et al. (2014)
0,13 ind.	2, 3, 4	BR-290	RS	Cunha et al. (2015)
0.096 ind.	1, 2, 3, 4	GO-239/BR-010	GO	Braz and França (2016)
0,14 ind.	2, 3, 4	RS-331/RS-420	RS	Deffaci et al. (2016)
0.078 ind.	1, 2, 3, 4	BR-290	RS	Steil et al. (2016)

Among the most injured species, *Cavia aperea* was frequently seen crossing the highway in the sampled stretches. Due to its foraging habits, it occupies marginal vegetation and thus becomes susceptible to collisions with vehicles (Deffaci et al., 2016). *Conepatus chinga* and *Didelphis albiventris* are abundant species that present crepuscular and nocturnal habits and a generalist diet (Silva, 1994). When they forage on the tracks during these periods, due to low visibility they can also be more susceptible to collisions. *Nothura maculosa*, a highly abundant species in the region, has a diet composed of seeds (Belton, 1994). Silva et al. (2013) reported that soybeans and rice grains lost by road transport are an attractive source of food for several granivorous species, which then use frequently highways as a foraging area. *Salvator meriane* was the most abundant road killed reptile. During this survey, individuals of the species were seen lying on the tracks, thermo regulating, thus also becoming an easy victim of running overs. All these frequently killed species were evenly distributed in sampled stretches and between seasons. Except for *S. merianae* records, which were uniform, but concentrated in spring and summer seasons, confirming the findings of Rosa and Mauhs (2004).

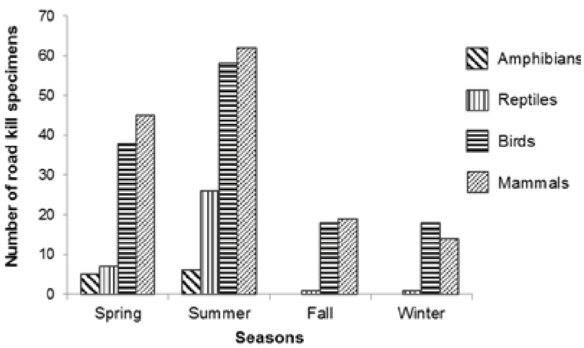

Figure 2. Seasonal abundance of road killed specimens per taxa between São Sepé and Vila Nova do Sul, state of Rio Grande do Sul.

Table 3. Seasonal comparison of road killed vertebrate abundance in highways between the cities of São Sepé and Vila Nova do Sul, state of Rio Grande do Sul. (N) Number of individuals, (V) difference values and (P) significance level. Differences were considered significant when $p < 0.05$. Non-significant (ns).

Seasons	N (individuals)	V	P
Spring x Summer	95 – 152	19.5769	ns
Spring x Fall	95 – 38	45.6846	$p < 0.05$
Spring x Winter	95 – 33	50.3538	$p < 0.05$
Summer x Fall	152 – 38	65.2615	$p < 0.05$
Summer x Winter	152 – 33	69.9308	$p < 0.05$
Fall x Winter	38 – 33	4.6692	ns

The seasonal comparison of road kill abundance revealed statistically significant differences in the number of dead individuals. Summer and spring months presented a greater number of carcasses, respectively. Months with milder temperatures (fall and winter) showed about 71% less road kills than warmer months. Accordingly, to Cerqueira (2005), climate variation influences primary productivity and consequently resource availability in the food chain. This increase in biomass raises individual abundance and therefore the risk of collisions during months with plentiful resources (summer and spring), when compared to months of restricted food intake (winter and fall). Vehicle flow also becomes more intense in the summer (Camargo et al., 2011), making collision risk even higher in this season.

Further studies should identify which stretches present a higher abundance of road kill records, correlating this data with landscape characteristics, cycles of the moon, temperature, car movement patterns (Carvalho et al., 2014) and rainfall rates (Braz & França, 2016). An approach involving landscape ecology and the Geographic Information System could help to explain and identify vulnerable areas in terms of collisions. Afterwards, it will be safe to infer causal relationships and to propose mitigation measures suitable to distinct risk profiles in stretches of highways (Clevenger, Chruszcz, & Gunson, 2003).

Conclusion

The high number of deaths by collisions emphasizes the fact that highways are a frequent source of direct and indirect impacts on wildlife. However, the reduced number of frogs and reptiles in our survey highlights the need of using new methodological approaches to assess impacts on these taxa. Finally, the presence of six threatened species in our list highlights the need of implementing mitigation measures in highways in order to minimize impacts and biodiversity loss.

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