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Vertebrates road kills along a highway between two cities in the western Brazilian Amazon

Atropelamentos de vertebrados ao longo de uma rodovia entre duas cidades na Amazônia Ocidental Brasileira

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Abstract To better understand the importance of highways as conservation problems, during one year (March 2016 – 2017) we describe the terrestrial vertebrates road kills on an 11 km length of Brazilian highway, north Acre. We analyzed the influence of the type of environment around the highway and the rainfall on roakills. Also, we compared the results of this work with those recorded in a similar work done previously on the same site. We found 442 individual vertebrate road kills, comprising 58 morphospecies in the four vertebrate orders: Amphibia (245 individuals, 12 morphospecies), Reptilia (114, 27), Aves (48, 10) and Mammalia (28, 9). Seven samples were unidentifiable. There were most road kills where the road had open habitat and a and the higher road kill rate in this study compared to the previous study, when the environments around the highway were more preserved. Also, more road kills were found during the rainy season than in the dry season, Possibly because of the increased demand for partners, or new habitat, or food at this time. Thus, believe that the extensive deforestation and the rainiest period may have a strong influence on the assemblage of animals that are then killed as they cross the roads. We suggest that measures should be taken to permit animals to cross the highway without being killed and that continued monitoring need be carried out throughout the Amazon basin to better understand the importance of road kills in the conservation of fauna.

Keywords: Amazonia; Ecology; Mortality; Roads; Wild animals.

Resumo Estimamos os impactos do atropelamento de vertebrados em relação ao tipo de ambiente no entorno da rodovia e avaliamos a influência do regime de chuva nos atropelamentos. Também, comparamos os atropelamentos com aqueles registrados em um trabalho semelhante feito anteriormente no mesmo local. Encontramos 442 vertebrados mortos na estrada, pertencentes a 58 espécies/morfoespécies e quatro ordens de vertebrados: Amphibia (245 indivíduos / 12 espécies/morfoespécies); Reptilia (114/27), Aves (48/10) e Mammalia (28/9). Ainda, sete amostras de vertebrados não eram identificáveis. Houve mais atropelamentos onde, ao redor da rodovia, havia habitat aberto e houve maior número de atropelamentos neste estudo em relação ao estudo anterior, quando os ambientes do entorno da rodovia eram mais preservados. Também, mais atropelamentos ocorreram no período mais chuvoso em relação à estação seca, possivelmente pela maior procura por parceiros para reprodução, maior oferta de habitat ou de alimentos neste período. Assim, acreditamos que a desflorestação e o regime pluviométrico têm forte influência na variação espacial e temporal dos atropelamentos. Sugerimos que medidas poderiam ser tomadas para permitir que diferentes grupos animais atravessem a rodovia sem serem mortos e que um contínuo monitoramento precisa ser realizado em rodovias presentes na bacia Amazônica para melhor compreender a importância dos atropelamentos na conservação da fauna.

Palavras-chave: Amazônia; Ecologia; Mortalidade; Estradas; Animais selvagens.

Introduction

Highways and roads are inevitable consequences of human activities and necessary for development, but at the same time, are ever-increasing problems for wildlife (SPELLERBERG, 1998; TROMBULAK; FRISSEL, 2000). In some places roads can become the most important cause of mortality for a variety of threatened species (BANDEIRA; FIORIANO, 2004) and cause a much greater rate of interactions between humans and wildlife as well as facilitating the introduction of a variety of exotic species, both plant and animal (COFFIN, 2007).

Road-kills are a consequence of roads bisecting natural areas and may be exacerbated by the amount of fragmentation of habitat through which the road passes. Habitat fragmentation disrupts animal movement patterns and do may increase the likelihood of an animal crossing a road. Also, often food availability increases along roadways for a variety of reasons, and thus can attract animals as they search for food (FORMAN; ALEXANDER, 1998). When food abundance (seed and grain, fruits, herbaceous plants, etc.) is greater along or near the roadway a cascade effect can result. First, some animals come for the food, and then are hit by cars. Their cadavers then attract other animals, such as vultures, owls and mammalian predators (COFFIN, 2007). Road construction itself fragments habitat and results in long stretches of border effects along both sides of the road way (SAUNDERS, 2002), with resulting road kills occurring where once was continuous habitat (FERREIRA et al., 2004). Mortality due to roads can have an important impact on local populations of animals, especially if they are already endangered or if the road limits their access to resources. Also, some species tend to use roads simply due to their nature and some species may be slow moving and therefore vulnerable (COFFIN, 2007).

Understanding the dynamics of road kill is therefore important for determining how to manage the problem and reduce the effects of roads on the local wildlife. This issue is well-studied in North America, Australia and Europe (BENNET, 1991). In Brazil, while several studies have examined this issue (VALLADARES-PADUA et al., 1995; VIEIRA, 1996; CÂNDIDO-JR et al., 2002; ROSA; MAUHS, 2004; PEREIRA et al., 2006; CBEE, 2020), studies are still necessary because of the wide range of habitat types, regions and species being affected where roads are an increasing problem, especially in the Amazon basin (TURCI; BERNARDE, 2009; BAGER; ROSA, 2010; 2011).

Here, we examine the distribution of vertebrate species over time that were killed in a stretch of road connecting two small cities in the state of Acre in Amazonian Brazil. We wanted to better understand which species are most vulnerable, whether seasonality and climate influenced the chances of road kill, and the magnitude of the problem. Also, in 2012 a similar study was carried out in the same location using similar methodology. Thus, we compare our results with those of Pinheiro and Turci (2013) to better understand changing conditions over time and how those changes are associated with road kills.

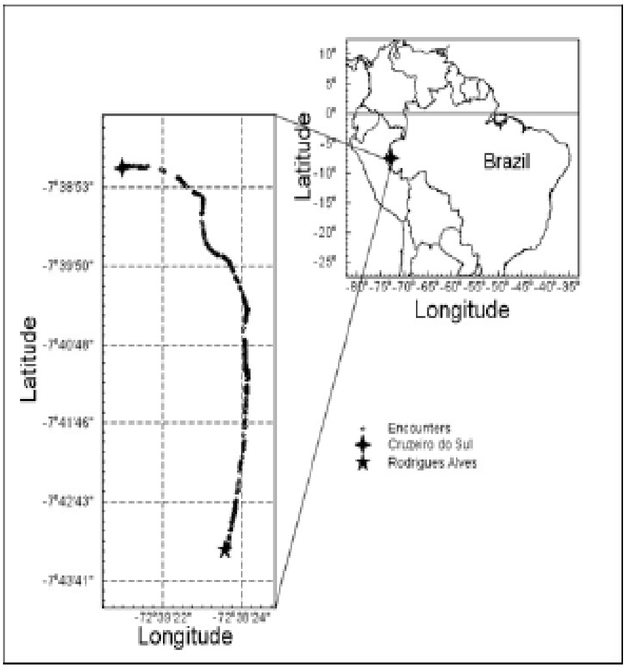
Material and Methods

Study area

We sampled all vertebrates found dead along an 11 km transect of Brazilian highway 307 (hereafter BR307) connecting the cities Cruzeiro do Sul and Rodrigues Alves in the western Brazilian state of Acre (-7.644°S, -72.664°W to -7.722°S, -72.643°W, Figure 1). The road is more or less parallel to the meandering Juruá River. The area adjacent to the road is a combination of relatively recently cleared agricultural lands interspersed with Amazonian forest and old dried meanders (oxbows) of the river, providing a rich matrix of different habitats, successional forests, marshes and fields along with areas of rapidly increasing anthropic impact. This landscape in the Juruá River watershed is described as open alluvial forest with palms (ACRE, 2006). Climate in this region is hot, wet tropical, with an average annual temperature of 24°C and ca. 2,200 mm of annual rainfall, with a drier season from May to October (RIBEIRO, 1977). Extreme deforestation has devastated the landscape (SILVA et al., 2014) and with deforestation, microclimate is also changing (DELGADO et al., 2012).

At each sampling point (where a roadkill was found) we noted the vegetation types on both sides of the road. We classified each side in a simple, but comprehensive way that clearly identified the vegetation types: “open” was when there was no forest or trees within 50 m of the road, “successional” was when the open area also had various trees of a variety of ages, but the aspect appeared more open than a forest with a dense understory, and “forest” when emergent tall trees and a developed understory reached the right of way of the road (Figure 2).

Figure 1. Map placing the study are in context. The larger map, with north at the top, shows the highway (BR 307) connecting the two cities, with markers indicating all locations were road kills were found. The inset shows the location of the study area in western Brazil



Field methods

We collected all vertebrates found dead along this section of road from March 2016 through March 2017 (13 months). Every weekend, during daylight hours, we drove slowly (30 - 40 km h-1) from Cruzeiro do Sul to Rodrigues Alves and then returned to Cruzeiro do Sul, following methods described in Turci and Bernarde (2009). At every vertebrate road kill encountered, we noted the species, condition of the carcass (following MILLI; PASSAMANI 2006), (PAES; POVALUK 2012), time of day and date, location, and vegetation type as described above. When possible, carcasses were collected and stored for identification in the Herpetology Laboratory of the Campus Floresta of the Universidade Federal do Acre.

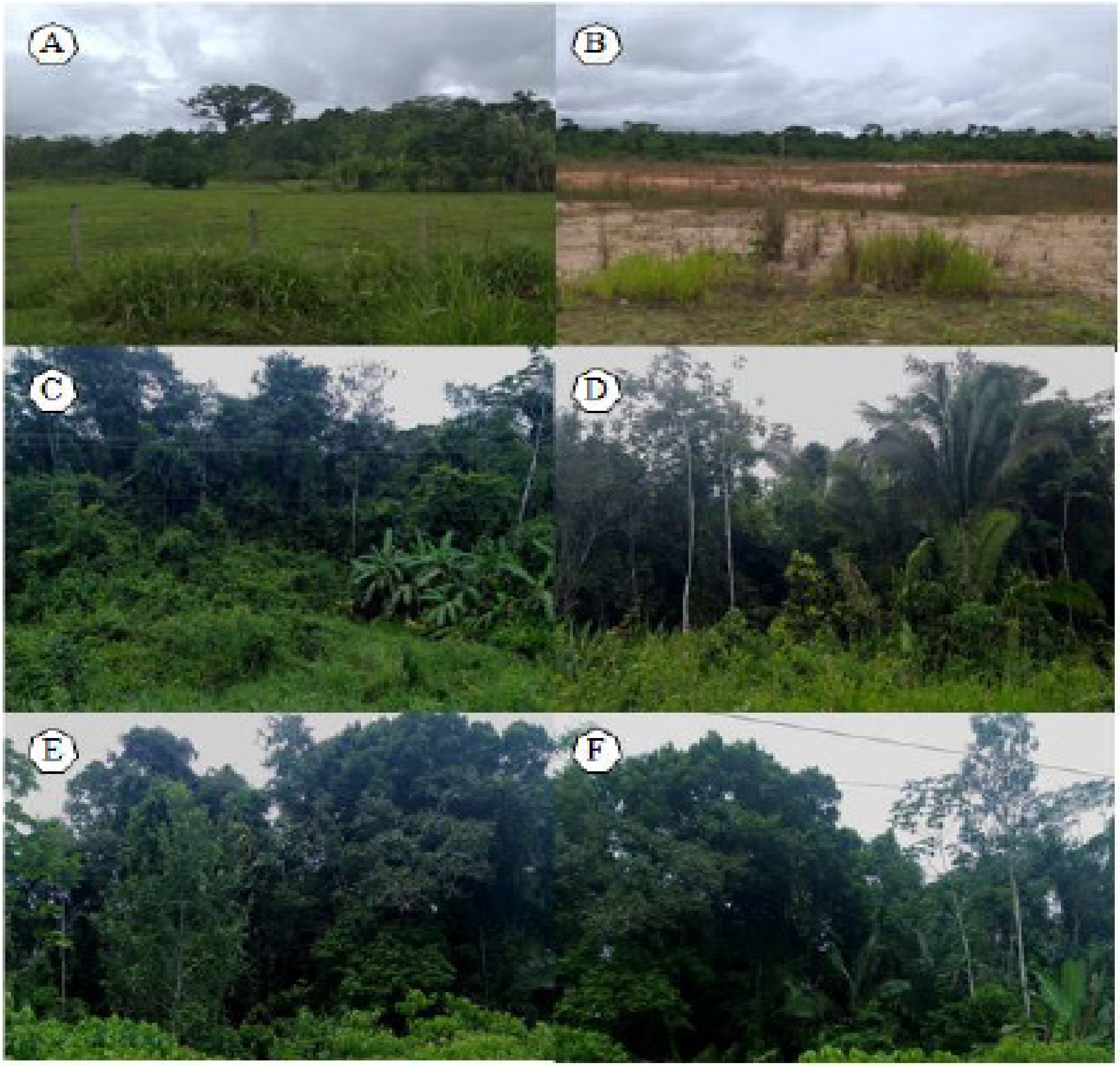
Identification of the road kills

Collected vertebrate road kills were identified using keys, descriptions, photographs, books and the appropriate scientific literature, along with consultation with specialists (reptiles and amphibians: ÁVILA-PIRES, 1995, BERNARDE et al., 2011, 2013, 2017, CAMPBELL and LAMAR, 2004, CUNHA and NASCIMENTO, 1993, DUELLMAN, 1978, DE LA RIVA et al., 2000, DIXON and SOINI, 1986, JORGE-DA-SILVA-JR, 1993, MARTINS and OLIVEIRA, 1998, VANZOLINI 2002, VITT et al., 2008; birds: BILLERMAN et al., 2020, GUILHERME, 2016, HILTY and BROWN, 1986, RIDGELY, 1989, 1994, SCHULENBERG et al., 2007, SICK 2001; mammals: EMMONS and FEER, 1997, REIS et al., 2006). We used standard nomenclature (SEGALLA et al., 2021, COSTA and BÉRNILS, 2018, REIS et al., 2006, GUILHERME, 2016).

Analysis

We tested an association between climate (temperature and rainfall) and the number of road kills using correlation analysis. We tested whether

Figure 2. Examples of the vegetation types found along highway BR307.



habitat type was associated with the likelihood of roadkill after controlling for the relative abundance of each habitat type using contingency analysis. We also used rarefaction and species accumulation curves to estimate the number of species and individuals that are likely to be killed along this section of highway, using the Biodiversity R package. Statistical analyses were carried out in R (R DEVELOPMENT CORE TEAM, 2019).

Results

We found a total of 442 vertebrate road kills during the year and a total of 264 km and 33 sampling days (*i.e.* 1.22 carcasses.km^{-1}.day^{-1}). Dead animals comprised the four classes of terrestrial vertebrates: Amphibia (55,4% of all road killed individual animals), Reptilia (25,8%), Aves (10,3%) and Mammalia (6,3%, Table 1). We identified 59 morphospecies, of which 27 were reptiles (45.8% of all species), 12 amphibians (20.3%), 10 birds (16,9%), and nine mammals (15.3%). Thus, a total of 37 species were clearly identified, and the remaining 22 taxa were identified to the closest taxonomic level possible (Table 1).

Of the 37 clearly identified, 14 were found

Table 1. List of animals encountered as road kills along an 11 km section of highway BR 307 connecting the cities Cruzeiro do Sul and Rodrigues Alves, Acre, between March 2016 and March 2017 (33 samples), with the inclusion of the list of animals from Pinheiro and Turci (2013) that was collected along the same section of highway, for comparison.

Taxa	Number of individuals	
	This study	PT
AMPHIBIA		
Anura		
Hylidae		
Dendropsophus triangulum (Günther, 1869)	1	0
Boana boans (Linnaeus, 1758)	3	0
B. cinerascens (Spix, 1824)	1	0
B. lanciformis Cope, 1870	4	0
Scinax ruber (Laurenti, 1768)	55	0
Scinax sp.	0	1
Trachycephalus typhonius (Linnaeus, 1758)	3	0
Unknown hylid	3	0
Phyllomedusidae		
Phyllomedusa bicolor (Boddaert, 1772)	1	0
Leptodactylidae		
Leptodactylus macrosternum Miranda-Ribeiro, 1926	13	0
L. pentadactylus (Laurenti, 1768)	0	2
Leptodactylus sp.	0	2
Unknown leptodactylid	1	0
Pipidae		
Pipa pipa (Linnaeus, 1758)	4	0

Unknown turtle	1	0
Crocodylia		
Alligatoridae		
Paleosuchus sp.	1	0
SQUAMATA		
Iguania		
Teiidae		
Ameiva ameiva (Linnaeus, 1758)	16	4
Dracaena guianensis (Daudin, 1801)	5	1
Tupinambis cuzcoensis Murphy, Jowers, Lehtinen, Charles, Colli, Peres Jr, Hendry & Pyron, 2016	1	0
Iguanidae		
Iguana iguana (Linnaeus, 1758)	1	3
Tropiduridae		
Plica umbra (Linnaeus, 1758)	1	0
Unknown lizards	2	0
Amphisbaenia		
Amphisbaenidae		
Amphisbaena sp.	0	1
Serpentes		
Colubridae		
Atractus sp.	1	0
Chironius fuscus (Linnaeus, 1758)	4	0
C. scurrulus (Wagler in Spix, 1824)	2	13
Chironius sp.	5	6
Dendrophidion dendrophis (Schlegel, 1837)	0	2

Leptophis ahaetulla (Linnaeus, 1758)	0	4
Spilotes pullatus (Linnaeus, 1758)	0	6
Dipsadidae		
Dipsas catesbyi (Sentzen, 1796)	1	0
D. indica Laurenti, 1768	1	0
Dipsas sp.	4	4
Drepanoides anomalus (Jan, 1863)	5	1
Erythrolamprus dorsocorallinus (Esqueda, Natera, La Marca & Ilija-Fistar, 2007)	5	7
Erythrolamprus reginae semilineatus (Wagler in Spix, 1824)	0	2
Helicops angulatus (Linnaeus, 1758)	21	16
Helicops sp.	1	0
Imantodes cenchoa (Linnaeus, 1758)	2	0
Leptodeira anulata (Linnaeus, 1758)	2	1
Oxyrhopus m. melanogenys (Tschudi, 1845)	1	2
Oxyrhophus sp.	2	0
Pseudoeryx plicatilis (Linnaeus, 1758)	0	1
Boidae		
Epicrates cenchria (Linnaeus, 1758)	0	2
Boa constrictor Linnaeus, 1758	2	1
Elapidae		
Micrurus surinamensis (Cuvier, 1817)	5	5
M. lemniscatus (Linnaeus, 1758)	0	2
Viperidae		
Bothrops atrox (Linnaeus, 1758)	1	4
Unknown snakes	21	0

AVES		
Columbiformes		
Columbidae		
Columbina talpacoti (Temminck, 1810)	0	3
Caprimulgiformes		
Trochilidae		
Phaethornis hispidus Gould, 1846	0	1
Unknown hummingbird	3	0
Caprimulgidae		
Hydropsalis albicollis (Gmelin, 1789)	1	0
Nyctidromus sp.	0	6
Cuculiformes		
Cuculidae		
Crotophaga ani Linnaeus, 1758	1	31
Piaya cayana Linnaeus, 1766	1	0
Cathartiformes		
Cathartidae		
Coragyps atratus Bechstein, 1793	3	4
Strigiformes		
Strigidae		
Athene cunicularia (Molina, 1782)	0	1
Bubo virginianus (Gmelin, 1788)	0	1
Falconiformes		
Accipitridae		
Buteogallus urubitinga (Gmelin, 1788)	0	1
Passeriformes		

Furnariidae		
Furnarius sp.	1	0
Tyrannidae		
Megarynchus pitangua (Linnaeus, 1766)	0	1
Myiozetetes sp.	0	7
Tyrannus melancholicus (Vieillot, 1819)	0	19
Ochthornis littoralis (Pelzeln 1868)	0	3
Thraupidae		
Ramphocelus carbo (Pallas, 1764)	0	1
Tangara episcopus (Linnaeus, 1766)	0	2
Turdidae		
Turdus ignobilis Sclater, 1858	2	0
Turdus sp.	1	0
Unknown passerines	24	0
Unknown bird	11	0
MAMMALIA		
Didelphimorphia		
Didelphidae		
Caluromys lanatus (Olfers, 1818)	0	3
Didelphis albiventris Lund*, 1840*	1	0
Didelphis marsupialis Linnaeus, 1758	7	8
Didelphis sp.	1	0
Metachirus nudicaudatus (Desmarest, 1817)	0	1
Chiroptera		
Phyllostomidae		
Artibeus lituratus (Olfers, 1818)	0	2

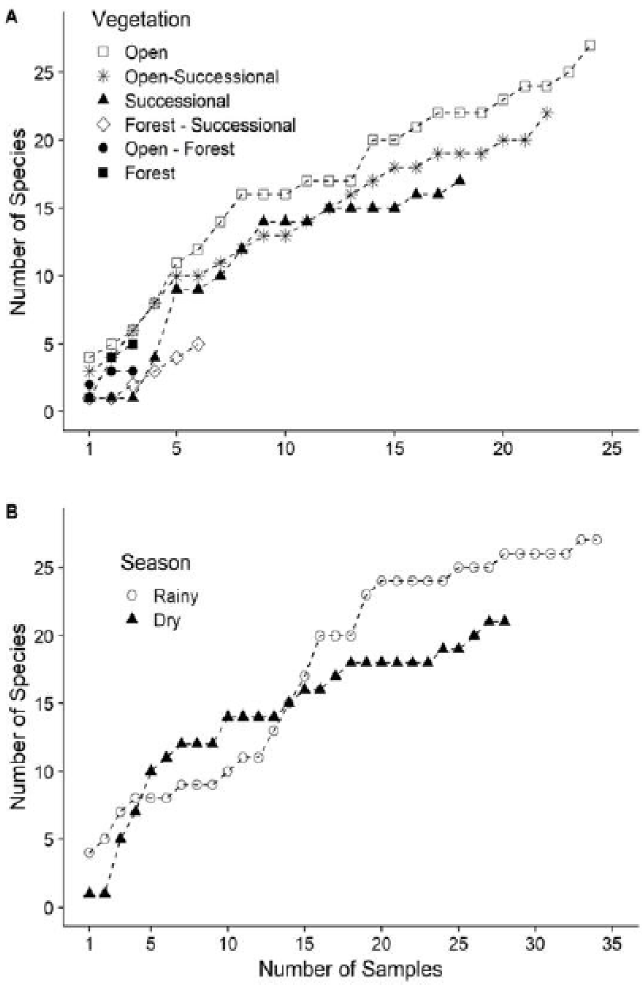
Unknown bat	8	2
Carnivora		
Canidae		
Canis lupus familiaris Linnaeus, 1758	4	0
Felidae		
Felis catus (Linnaeus, 1758)	2	0
Rodentia		
Muridae		
Rattus sp.	0	3
Unknown rat	1	0
Cingulata		
Dasypodidae		
Dasypus novemcinctus Linnaeus, 1758	0	1
Indirect registration of primates	1	0
Unknown mammals	3	0
VERTEBRATA		
Unknown vertebrates	7	0

PT = Pinheiro and Turci (2013)

only once, six found two times, three found three times, four and five species were found four times. The more abundant species were found seven (the mammal, *Didelphis marsupialis*), 13 (the frog, *Leptodactylus macrosternum*), 16 (the lizard, *Ameiva ameiva*), 21 (the snake, *Helicops angulatus*), 55 (the frog *Scinax ruber*) and 156 (the toad, *Rhinella marina*) times each (Table 1). In comparison with Pinheiro and Turci (2013), they did not encounter 23 (59%) of our 37 species, and we did not encounter 25 (56%) of their species. Thus, 16 species were common to both studies (34% of their species, 27,1% of ours, Table 1).

Using rarefaction, the expected number of road kills was 49 (Bootstrap) to 64 (Chao) species. However, the slope of the species-accumulation curve is still quite steep and suggests that many more species may be found (Figure 3). Using the actual number of species encountered (the collector curve) and separated by habitat type, more road kills than expected were found in the open and successional vegetation types (Figure 3A). We estimated that of the 11 km of roadway, 6.5 km was open (open fields), 3.1 km was open on one side of the road with successional vegetation on the other, 1.4 km was successional on both sides of the road, and less than 1 km was forest on one side and either open, successional or primary forest on the other side. Accordingly, the vast majority of road kills (n = 248,

Figure 3. Species accumulation (collector) curves, illustrating that (A) more samples were collected in open areas all of which had similar accumulations of species over samples, and (B) that more species tend to be killed on the road during **the rainy season.**



Open: both sides of the highway have deforested environments; Open-Succession: one side of the highway has a deforestation environment and the other regenerating forest; Succession: both sides with regenerating forest; Primary-Succession: one side with primary forest and the other with regenerating forest; Open-Primary: one side with open environment and the other with primary forest; Primary: both sides with primary forest.

or 59%) were found adjacent to open habitat (on both sides of the road), followed by open and secondary succession (103, or 28%), successional on both sides (67, or 12%), with the remaining 15 (~1%) road kills found in association with forest. Because of the tendency for open and successional vegetation to be so predominant in the area due to deforestation, a statistical comparison of the association between road kills and adjacent habitat is unnecessary and not possible.

While road kills were always found during all field sessions, they were more likely to occur during the rainy season (November – April). A total of 325 carcasses were found in the rainy season, 115 in the dry season ($\chi2 = 32.8$, df = 1, $P < 0.001$, Figure 3B). A total of 27 species were recovered only in the rainy season (~8%), while nine species were only found during the dry season (also ~8%).

Discussion

This tropical environment is extremely diverse, and so many species that are likely to be killed were not found in our study. Probably well over 60 species of vertebrates are commonly killed on a short stretch of highway connecting two small cities in the Brazilian Amazon. During a single year, a minimum of 442 individual animals were killed. Of these animals, the most common are amphibians (frogs and toads), followed by many samples of unidentifiable birds, lizards and snakes. Of course, common mammals, such as dogs, cats and opossums (marsupials) also are frequently killed (PEREIRA et al., 2006; PINOWSKI, 2005; SILVA; SILVA, 2009; TURCI; BERNARDE, 2009).

While estimating road kills it is likely that the true number is underestimated (RODRIGUES, 2002; VIEIRA, 1996) because animals may be thrown from the right-of-way, or consumed by predatory or carrion-eating birds and mammals and perhaps carried away from the edge of the road (OXLEY et al., 1974; RODRIGUES, 2002; SILVA et al., 2007). Because of this underestimation, we recognize that animal death due to highways is an important conservation issue because of its magnitude and indiscriminant nature. Thus, more species of reptiles were killed on the highway (27 sp., 45,8%) and a greater number of amphibians were killed (n = 245, 55,4%). Reptiles and amphibians are extremely vulnerable and are often the most numerous animals killed on highways, followed by birds (HENGEMÜHLE; CADEMARTORI, 2008; TURCI; BERNARDE, 2009, PINHEIRO; TURCI, 2013).

Only four years earlier, Pinheiro and Turci (2013), found a very different assemblage of species than we found (see Table 1). Their larger sample size for distance traveled (1,760 km) resulted in a rate of 0.28 carcasses.km-1.day-1 while we found an order of magnitude more road-killed animals (1.22 carcasses. km-1.day-1). They did not quantify vegetation type at each road kill and so we cannot estimate the changes nor the importance of changing habitat during this four year interval between studies. Nonetheless, we can affirm that deforestation has been the cause of an increasing open areas adjacent to the roads in this study, seen in the greater number of dead birds found in Pinheiro and Turci (2013) (Table 1).

Considering the many road kills, it is not surprising that during our sampling periods we saw many vultures (*Caragyps atratus*) feeding on animal remains in the road way. Consumption of road kills results in the loss of many animals prior to our being able to record their presence. For example, 60% of birds and 97% of reptiles killed on the highway were removed within 36 h of their deaths (ANTWORTH et al., 2005).

We found 12 species and 245 individual amphibians dead on the highway, while Pinheiro & Turci found four amphibian species and 61 individuals. The toad *Rhinella marina* was the most abundant frog killed along the highway in both studies, and the many frogs killed in our study suggests that the habitat has changed in favor of frogs during the four years between studies. *Rhinella* sp., indeed, frogs in general, are commonly killed on highways, especially in the Amazon (TURCI; BERNARDE, 2009, SILVA; SILVA, 2009) as well as elsewhere (RODRIGUES, 2002; SILVA et al., 2007). Their movement speed and method of locomotion apparently leaves them vulnerable (TROMBULAK; FRISSEL, 2000).

The snake *Helicops angulatus* is aquatic and widespread in the Amazon wherever standing water is available (BERNARDE et al., 2011; FRANÇA; VENÂNCIO, 2010; MARTINS; OLIVEIRA, 1998). This species was the most common snake and reptile killed (n = 21), followed by the lizard *Ameiva ameiva* (16). *Helicops angulatus* was also the most common road-killed reptile in Pinheiro and Turci (2013), followed by the snake *Chironius scurrulus* (13), while only four *Ameiva ameiva* were found in that study. Changing habitat type and ability to live near humans probably have resulted in an increase in *Ameiva ameiva* in the time interval between studies (AVILA-PIRES, 1995).

Many dead birds were simply impossible to identify to the species level. As a maximum estimate, we found 10 species (16,9%) and 48 individual (10,9%) of birds. In contrast, four years earlier 14 species and 81 individuals were found, with the ani *Crotophaga ani* (31) being most common and vulnerable to being hit by cars (SICK, 2001). *Tyrannus melancholicus* (19) was the second most common bird found, and which also uses open areas and thus roadways, as habitat (SICK, 2001; PINHEIRO; TURCI, 2013).

Nine species (15,3%) and 28 individuals (6,3%) of mammals were killed on this road, with unidentifiable bats (Chiroptera) being the most numerous (n = 8), followed by the marsupial *Didelphis marsupialis* (7). Earlier, two additional species of marsupial were reported, along with several exotic rats (PINHEIRO; TURCI, 2013). The opossum has become quite common around humans (ROSSI et al., 2006).

We found a much greater (~10x) rate of road kill (1.67 ind. km-1) than that of only four years earlier (0.14 ind. km-1; PINHEIRO; TURCI 2013). Because they did not note vegetation at each sampling location, we can only speculate that habitat differences between then and now account for this increased rate of road kill, however, we identified a greater number of road kills in areas of open vegetation and succession (Figure 3A), considering that the roads cause a series of disturbances such as fire, hunting and habitat reduction due to the loss of vegetation cover (SCOSS et al., 2004). During that interval the road was paved, where before it was simply a dirt road. Also, the human population size has increased considerably during this time, with many more houses along the road way. But especially, we suspect that much more land is open now due to deforestation and that has had the greatest effect, in addition, they cause a series of other physical impacts (erosion, alteration of local hydrology, destruction of natural environments, edge effect) and chemical (dispersion of pollutants) (FORMAN; ALEXANDER, 1998, FERREIRA et al., 2004). They can also cause extinction of wild species at the site, in addition to facilitating the invasion of exotic species (NEPSTAD et al., 1997; TROMBULAK; FRISSEL, 2000). These mechanisms are responsible for behavioral changes that interfere with the natural movement of individuals (ROSA et al., 2012; VAN DERR REE et al., 2015).

While many more animals were killed during the rainy season (325 versus 115 in the dry season), species accumulations curves increased at nearly the same rate, but with a few more species in the rainy season (Figure 3B). Other climate variables were relatively unimportant because humidity and temperature are not extremely variable at this location (INMET, 2019). Movement patterns of many animals change seasonally with rainfall (FORMAN; ALEXANDER, 1998; RODRIGUES, 2002; SMITH; DODD-JR, 2003; PINOWSKI, 2005; HARTMANN et al., 2011; PINHEIRO; TURCI, 2013). Indeed, if frogs become an important prey item, because they usually breed more during the rainy season, their predators will also become more active searching for them at that time (SANTOS et al., 2012). Nonetheless, some studies find a greater rate of road kill during the dry season although they could not rule out increased traffic at that time as the cause (PEREIRA et al., 2006; TURCI; BERNARDE, 2009).

Road killed animals remain a constant reminder of the human impact on nature, especially in regions with a wide diversity of species of animals. It becomes our duty as stewards of the land to find ways to reduce this mortality, and to do so, we must continue to monitor road kills. In many regions of the world, methods are used to reduce road kills (tunnels or overpasses for animals, fences, etc.). Because of the extreme diversity in the tropics, especially Amazonian Brazil, we recommend that actions be taken to reduce the rate of road kill here, even as new roads are being opened. The human impact of land clearing and conversion to agriculture already has a large impact, and we should not further exacerbate that impact by reckless road kills along the newly opened highways.

Conclusions

The results show that roads are a serious fauna conservation problem and that the extensive deforestation and the rainiest period may have a strong influence on the assemblage of animals that are then killed as they cross the roads. We suggest that further studies of vertebrate roadkill should be conducted for a longer sample period and analyzing the flow of vehicles. In addition, several authors have suggested possible alternatives to mitigate the impacts of road kills, such as the construction of walkways and tunnels for wildlife, implementing road signs and speed reducers. However, once implemented, we suggest studies that analyze its real effectiveness.

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