Analysis of Wildlife Roadkill in a Road Circuit. Case study of a Colombian road in the Department of Huila: Neiva - Rivera - Campoalegre

Juan Sebastián Arana Rivera1, Santiago Gutiérrez Quintero2 and Natalia Álvarez L.3

Abstract

This research contributes information related to records of wildlife roadkill in the different roads of the department of Huila. The results come from samplings carried out during the rainy season from October to December of 2017 on the Neiva - Rivera - Campoalegre road circuit. The highest roadkill rate was recorded in section 1, Neiva - Rivera (Los Cauchos tollbooth); which had high traffic flow during the day (5045 vehicles/month), high speed limit (90 km / h), and an arboreal coverage that forms a green tunnel due to the lack of lighting on this road.

A total of 102 dead specimens were registered in this case study; predominantly mammals (53 specimens, 51.96%) and the species Didelphis marsupialis (48, 47.06%), followed by reptiles (34, 33.33%) whose most affected species were the Boa constrictor (9, 8.82%) and the Iguana iguana (7, 6.86%). Additionally, birds were the third most affected group (12, 11.76%) classified in 8 species, such as the Megascops choliba which was the most affected (4, 3.92%). Amphibians were the least affected group (3, 2.94%), mainly the Rhinella horribilis species (2, 1.96%).

Key words: Wildlife, Roadkill, Vehicular traffic, Rainy season, Huila.

Análisis de fauna atropellada en un circuito vial. Estudio de caso de una carretera colombiana en el Departamento del Huila: Neiva - Rivera - Campoalegre

Resumen

Esta investigación aporta información relacionada con los registros de atropellos de fauna silvestre en las diferentes vías del Departamento del Huila. Los resultados provienen de muestreos realizados durante la temporada de lluvias de octubre a diciembre de 2017 en el circuito vial Neiva – Rivera – Campoalegre. La mayor tasa de atropellamiento se registró en el tramo 1, Neiva - Rivera (peaje Los Cauchos); el cual tuvo un alto flujo vehicular durante el día (5045 vehículos/mes), un alto límite de velocidad (90 km/h), y una cobertura arbórea que forma un túnel verde debido a la falta de iluminación en esta vía.

*FR: 27-I-2020. FA: 12-VIII-2021.
1 Master(c) Comprehensive Project Management – Univesidad Surcolombiana, Environmental Engineer from Corporación Universitaria del Huila, CORHUILA, Technologist in Ecological Agricultural Production from SENA. Email: jsarana1993@hotmail.com orcid.org/0000-0002-4618-3012
2 Research Group Efecto Ambiental, Master in Ecology and Strategic Ecosystems Management - Universidad Surcolombiana, Biologist - Universidad de Caldas, Professor of the Environmental Engineering Program - Corporación Universitaria del Huila - CORHUILA. Email: santiago.gutierrez@corhuila.edu.co orcid.org/0000-0002-8769-1988 Google scholar
3 BA in Modern Languages, MA in Translation. Department of Modern Languages. Corporación Universitaria del Huila - CORHUILA, Neiva, Colombia. Email: natalia.alvarez@corhuila.edu.co orcid.org/0000-0002-1130-6027 Google scholar

CÓMO CITAR:
Arana-Rivera, J.S., Gutiérrez-Quintero, S. & Álvarez L., N. (2022). Analysis of Wildlife Roadkill in a Road Circuit. Case study of a Colombian road in the department of Huila: Neiva - Rivera - Campoalegre. Bol. Cient. Mus. Hist. Nat. Univ. Caldas, 26(1), 55-71. https://doi.org/10.17151/bccm.2022.26.1.4
Introduction

Road expansion is necessary for the socio-economic development of any region because it enables human communities to have access to different remote areas and districts; thus, they stay connected and their transportation of products is facilitated” (Alves et al. 2009, p.1). This continuous growth exceeds 50 % of the Earth’s land surface (Hooke et al. 2012).

However, “the negative effects of a road are immediate” (Baguer and Alves, 2011, p.851): “ecosystems adjacent to a road suffer strong impacts when a road is built or expanded, which usually lacks environmental planning” (Brum et al. 2018, p.126); “the adjacent vegetation is eliminated; and the soils are compacted, which alters the thermal conditions and relative humidity” (Jochimsen, 2005, p.351). Therefore, the impact on biodiversity is very complex since roads are a global concern because it affects the conservation of wildlife, (Cáceres et al. 2010. Forman and Alexander, 1998).

The ecological effects of roads include the discharge of toxic gases, substances such as oils and residues, light and noise pollution that significantly affect the behavior and biology of several species (Tejera et al. 2018), hydrological changes (Jones et al. 2000), introduction of exotic species (Forman et al. 2003) and loss of habitat or habitat fragmentation adjacent to a road in small areas (Kuykendall and Keller, 2011). These dynamics alter the exchange of genes as mentioned by Smith-Patten and Patten, (2008) “since roads have become barriers for wildlife movement that prevent gene exchange” (p.844), Therefore, isolated communities are more susceptible to the decline of their population and become vulnerable to local extinction (González-Gallina et al. 2013) due to inbreeding processes caused by geographical and genetic isolation.

The large amounts of roadkills are the consequence of the direct impact of roads on biodiversity (Santos et al. 2013). All species, ages, and sizes of animals are affected by roads (Smith-Patten and Patten, 2008), especially young animals in reproductive stages. Although roadkills may not affect many populations, it can have a significant impact on endangered species populations (Glista and Devault, 2008). It is estimated that one million animals die every day in the different roads of the United States.
In the last three decades, roadkill overtook hunting as the main cause of wildlife mortality (Forman and Alexander, 1998).

Other impacts of roads on biodiversity, such as fragmentation have promoted various studies (Trombulak and Frissell, 2000; Puig et al. 2012). The spatial distribution and information collected about wildlife roadkills will contribute to the identification of biodiversity corridors, along with the different routes (Beckers, 2008). Georeferencing of roadkill points is fundamental to design and develop solutions to this problem. Consequently, several studies related to this subject have been carried out around the world (Cserkész et al. 2013; Mizuta 2014).

In Latin America, research related to roads and biodiversity is still a novelty, therefore, related information is scarce (González-Gallina et al. 2013). In Colombia, the study of wildlife roadkill is incipient, although there is some research carried out in the Caribbean region (De la Ossa Nadjar and De la Ossa V, 2013; Monroy et al. 2015; De La Ossa-V and Galván-Guevara, 2015), in Popayán (Castillo-R et al. 2015) in the Magdalena Medio (Ramos Pallares and Mesa Joya, 2018) and in the Colombian Coffee Axis (López Herrera et al. 2016).

Consequently, this matter needs to be researched in the Department of Huila in order to identify the number of affected species by roadkills in a road circuit of the Department. Reliable information on the matter will allow to understand the root of problem and provide possible structural and non-structural alternatives to mitigate its impact.

**Methods**

This research was developed over the course of three months, from October to December of 2017, which includes the second rainy season. The information was collected once a week on Wednesdays; a total of 13 samples were obtained by a motorcycle rider who made observations at a speed of ≤ 30 km/h by looking at both lanes in search of roadkills. In addition, a campaign was conducted in the community by means of informative brochures about the registration of wildlife roadkills. At the time and place of a roadkill, a spreadsheet was used to record on-site data such as body length (Cm) (estimated with a measuring tape), weight (Kg) (estimated with a digital scale), coordinates (determined with a GPS), sex, common name, state of the body and its environment; additionally, photographs of the specimen were taken with a digital camera.

**Sampling Area:**
The sampling area is 54.22 km of the road that connects the municipalities of Neiva, Rivera and Campoalegre, a two-way roadway that turns into a dual carriageway. This route was divided into 4 tracks for better study and comparison as follows:
Track 1. Neiva (2°53’55.06”N 075°16’47.85”W) Rivera (Los Cauchos Tollbooth) 45 05 reference point (PR) 98 + 500 (2°45’22.70”N 075°18’30.51”W). It goes through the town center of Río Frío. This is a two-way first-order road (INVIAS, personal communication, January 29, 2018). This fully-paved section has a length of 16.4 km. The speed limit is 90 km/h in most sections; only a few sections have lighting.

Track 2. Campoalegre (2°41’56.03”N 075°19’11.96”W) Rivera town center (2°46’36.84”N 075°15’42.76”W). This two-way road goes through the town center of Riverita. The section comprises two roads that have been categorized as first and third-order roads (INVIAS, 2018). It is a fully-paved section that measures 14 km, the speed limit is 30 km/h all along, only a few sections have lighting.

Track 3. Rivera town center (2°46’44.84”N 075°15’38.26”W) Rivera road intersection (National Road) (2°47’40.26”N 075°17’59.75”W). This is a two-way second-order road (INVIAS, 2018); it is fully paved. This 4.72 km track does not have speed limit signs and only a few sections have lighting.

Track 4. Rivera town center (2°46’55.14”N 075°15’20.50”W) Neiva (2°54’33.25”N 075°16’29.41”W). It crosses the population centers known as El Guadual, La Ulloa and El Caguán. This is a two-way second-order road, (INVIAS, 2018). This 19.1 km route is fully paved and does not have speed limit signs and only a few sections have lighting. It is noteworthy to mention that there were not wildlife crossing signs in any of the tracks studied. The tracks are differentiated by color (Fig. 1) and their characteristics in terms of track, length, and locations are shown in Table 1.

Figura 1. Map of the study area Jun-20-2017 by Garzon, Y. Canon Camera. Source: Edited by Google Earth Pro, 2018.
For the analysis of the information collected, the books Guía de las Aves de Colombia (Hilty and Brown, 2001), Guía de Identificación de la Fauna Silvestre Colombiana (Min. Ambiente and CAM, 2009), and the reptile database (Lynch, Sierra and Gómez, 2014) were used. Also, El Libro Rojo de Reptiles de Colombia (Morales-Betancourt et al. 2015) as well as the Red List of Threatened Species website (UICN, 2019) were used for species identification. Additionally, as proposed by Clevenger et al. (2002), the roadkill spots were identified, and the link between habitat and geographic information system (GIS) was modelled to determine the location of the structures designed to mitigate the impact on wildlife. Google Earth Pro software was used to locate the number of dead specimens that were classified with different colors according to the species; a map of the spatial distribution of the wildlife-vehicle roadkills was drawn (Fig. 2).

### Tabla 1. Length and coordinates of sections investigated.

| Stretch | Section | Length (Km) | Colour | Start               | End               |
|---------|---------|-------------|--------|---------------------|-------------------|
| 1       | Neiva – Rivera (toll Los Cauchos) | 16.4 km | Red    | 2°53’55.06”N 75°16’47.85”W | 2°45’22.70”N 75°18’30.51”W |
| 2       | Campoalegre Urban center of Rivera | 14 km  | Green  | 2°41’56.03”N 75°19’11.96”W | 2°46’36.84”N 75°15’42.76”W |
| 3       | Urban center of Rivera - Rivera intersection (National Road) | 4.72 km | Yellow | 2°46’44.84”N 75°15’38.26”W | 2°47’40.26”N 75°17’59.75”W |
| 4       | Urban center of Rivera – Neiva | 19.1 km | Blue   | 2°46’55.14”N 75°15’20.50”W | 2°54’33.25”N 75°16’29.41”W |

Source: Compiled by authors
Results

The analysis showed that there were 100 wildlife-vehicle roadkills from October to December; it was necessary to include two more animals in the database because they were big and important species, although they were found outside the designated timeframe. Therefore, the total number of roadkill animals by vehicle collision was 102.

Table 2 shows the classification of wildlife-vehicle roadkills records according to the threat category reported in the red books (which showcase threatened species), the number of roadkills per track, and the total amount. Likewise, Table 3 shows the roadkills by taxonomic group according to number and percentage in each track.

Tabla 2. Wildlife-vehicle roadkills in the road circuit Neiva - Rivera - Campoalegre.

| TAXON       | COMMON NAME | SPECIES               | CATEG. | STRETCH 1 | STRETCH 2 | STRETCH 3 | STRETCH 4 | TOTAL |
|-------------|-------------|-----------------------|--------|-----------|-----------|-----------|-----------|-------|
| MAMMALS     |             |                       |        | 27        | 9         | 9         | 3         | 48    |
| Common opossum | Didelphis marsupialis     | LC    |          |           |           |           |           |       |
| Crab-eating fox | Cerdocyon thous       | LC    | -        | 1         | 2         |           |           | 3     |
| Southern tamandua | Tamandua tetradactyla | LC    | 2        | -         | -         | -         | -         | 2     |
| TOTAL MAMALS |             |                       |        | 29        | 10        | 11        | 3         | 53    |
## Analysis of Wildlife Roadkill in a Road Circuit. Case study of a Colombian road in the Department of Huila...

| REPTILES             | Species                          | Status | Row 1 | Row 2 | Row 3 | Row 4 | Total |
|----------------------|----------------------------------|--------|-------|-------|-------|-------|--------|
| **Brown rainbow boa**| Epicrates maurus                 | LC     | 1     | 1     | -     | -     | 2      |
| **Green iguana**     | Iguana iguana                    | LC     | 6     | -     | -     | 1     | 7      |
| **Boa constrictor**  | Boa constrictor                  | LC     | 7     | 1     | 1     | -     | 9      |
| **Redtail coral snake** | Micrurus mipuritus           | LC     | -     | 2     | -     | 1     | 3      |
| **Mimic false coral snake** | Erythrolamprus minus   | LC     | 3     | -     | -     | -     | 3      |
| **Bodaerts Tropical racer** | Mastigodryas boddaerti       | LC     | -     | -     | 1     | -     | 1      |
| **Common caiman**    | Caiman crocodilus                | LC     | -     | 1     | -     | -     | 1      |
| **Neuwied’s false boa** | Pseudoboa neuwiedii           | LC     | 1     | 2     | 1     | -     | 3      |
| **Cloudy Snail-eating Snake** | Sibon nebulatus            | LC     | -     | -     | 2     | 2     |        |
| **Banded Cat-eyed Snake** | Leptodeira annulata          | LC     | 1     | -     | -     | -     | 1      |
| **Mussurana**        | Clelia clelia                   | LC     | -     | 1     | -     | -     | 1      |
| **Forest flame snake** | Oxyrhopus petolarius          | LC     | -     | -     | 1     | 1     |        |
| **TOTAL REPTILES**   |                                  |        | 19    | 7     | 3     | 5     | 34     |

| BIRDS                | Species                          | Status | Row 1 | Row 2 | Row 3 | Row 4 | Total |
|----------------------|----------------------------------|--------|-------|-------|-------|-------|--------|
| **Tropical Screech owl** | Megascops choliba            | LC     | 2     | -     | 1     | 1     | 4      |
| **Saffron finch**    | Sicalis flaveola                | LC     | -     | -     | 1     | -     | 1      |
| **Smooth-billed Ani** | Crotophaga ani                  | LC     | 1     | -     | -     | 1     | 2      |
| **Grey-necked Wood Rail** | Aramides cajaneus            | LC     | 1     | -     | -     | -     | 1      |
| **Stripped owl**     | Pseudoscops clamator            | LC     | 1     | -     | -     | -     | 1      |
| **Black-billed Thrush** | Turdus ignobilis          | LC     | -     | -     | 1     | 1     |        |
| **Bar-crested Antshrike** | Thamnophilus multistriatus    | LC     | -     | 1     | -     | -     | 1      |
| **Roadside hawk**    | Buteo magnirostris             | LC     | -     | -     | 1     | -     | 1      |
| **TOTAL BIRDS**      |                                  |        | 5     | 0     | 4     | 3     | 12     |

| AMPHIBIANS           | Species                          | Status | Row 1 | Row 2 | Row 3 | Row 4 | Total |
|----------------------|----------------------------------|--------|-------|-------|-------|-------|--------|
| **Cane toad**        | Rhinella horribilis              | LC     | -     | 1     | -     | 1     | 2      |
| **Rufous frog**      | Leptodactylus fuscoerus          | LC     | -     | 1     | -     | -     | 1      |
| **TOTAL AMPHIBIANS** |                                  |        | 0     | 1     | 1     | 1     | 3      |

Source: Compiled by authors
Regarding the records taken in all of the tracks, the following information was obtained: in track 1 there were 53 wildlife-vehicle roadkills in the group of mammals that have the highest mortality rate; the *D. marsupialis* species was the most affected with a record of 27 roadkills. The second most affected taxonomic group were reptiles with a total record of 19 roadkills, and the *Boa constrictor* had the highest number with a record of 7 dead specimens.

In track 2, there were 18 roadkills. Mammals were the most affected with 10 roadkills, and the *D. marsupialis* species had a total of 9 roadkills. Reptiles were the second most affected group in this section with a record of 7 roadkills; *M. mipartitus* and *P. neuwiedii* had 2 roadkills each.

In track 3 there were 19 roadkills. Mammals were the most affected, the *D. marsupialis* species had 9 roadkills. Birds were the second most affected group with 4 roadkills. The species of birds affected in track 3 were *S. flaveola*, *B. magnirostris*, *M. and T. choliba multistriatus* with one roadkill each.

In track 4 there were 12 roadkills. Reptiles were the most affected with 5 roadkills, and the species *S. nebulatus* were the most affected with 2 roadkills. Birds (*Turdus ignobilis, Megascoops choliba and Crotophaga ani*) and mammals (*D. marsupialis*) had 3 roadkills each.

A roadkill rate (RR) of 0.145 individuals/km/day, and the detailed information per every taxonomic group were obtained with the data collected from roadkills in the different tracks, considering the length and frequency of 13 samplings (Table 4).

---

### Table 3. Records of roadkills per each taxonomic group in relation to 4 tracks.

| Group        | Tracks | % | %  | %  | %  | %  | %  | %  | %  |
|--------------|--------|---|----|----|----|----|----|----|----|
|              | N      | N | N  | N  | N  | N  | N  | N  | N  |
| Mammals      | 29     | 10| 11 | 3  | 53 | 53 | 51.96|
| Reptiles     | 19     | 7 | 3 | 5 | 34 | 34 | 33.33|
| Birds        | 5      | 0 | 4 | 3 | 12 | 12 | 11.76|
| Amphibians   | 0      | 0 | 1 | 1 | 3  | 3  | 2.94 |
| Total Specimens | 53 | 18 | 19 | 12 | 102 | 102 |
One of the main evident causes of roadkills is high traffic flow (Ruiz-Capillas et al. 2015). This was corroborated with the information given by the administrator of ALIADAS in the Los Cauchos tollbooth (personal communication, January 29, 2018): average daily traffic (ADT) of 5,372 vehicles per month.

A statistical test of normality was administered to the data obtained from the different sections. However, the data were found to be non-parametric. As a consequence, an ANOVA test could not be carried out. A Kruskal-Wallis test was used instead and the results can be detailed in Table 5 and Table 6.
Since non-normal data were found, the Kruskal-Wallis test was used and the results are shown in Figure 2; they show that track 1, compared to other tracks, is the most prone to wildlife roadkills, since the average for track 1 was 4.08 and the maximum was nine animals, followed by track 3, with an average of 1.46 and a maximum of 4 roadkills.

![Figure 3](image_url)  
*Figura 3.*  
*Mortality comparison represented in a Box and Whisker plot.*  
*Note: Compiled by authors.*

The information collected from the animals was uploaded to Google Earth Pro for a better visualization, then a number and a different color were assigned to each species. This classification facilitates the location of different species and areas prone to roadkills in the Neiva - Rivera - Campoalegre road circuit (Fig. 2).
Mammals had the highest number of roadkills with 51.96% (3 specimens), whose species *D. Marsupialis* was the most affected with a total of 48 killed specimens (Fig. 4). The sex of 31.25% of the individuals was identified, 14.58% were males, and 16.66% were females. Reptiles were the second most affected group with 33 killed specimens. The *B. constrictor* was the most affected by roadkills (Fig. 5), followed by *I. iguana*. Birds were the third most affected group with 11.76% and 8 species; *M. choliba* was the most affected group with 4 individuals (Fig. 6); amphibians were the least affected group with 2.94% with 2 individuals of *R. horribilis* (Fig. 7).
Discussion

The studied roads are characterized by the fragmentation of land extensions for agricultural production activities that provides a favorable environment for different species. These roads also show lack of environmental management measures and poor lighting. Forman and Alexander (1998) and Gagné et al. (2015) claim “the average daily traffic (ADT) and speed are the main causes of high wildlife mortality” (p.214) (p.1012). These factors may have been the cause of the 53 roadkills in track 1, with respect to 19 in track 3, 18 in track 2 and 12 in track 4.

The most affected species was *D. marsupialis*, a result similar to the findings of the research by Castillo-R et al. (2015) on the Panamerican highway. These authors claim that high number of deaths of marsupials can be attributed to the great presence of this species in the region and to its ecological niche that includes the fruit coming from adjacent trees and dead animals on the roads; besides, nocturnal animals are blinded by car headlights (De la Ossa-V and Galván-Guevara 2015). Another cause of death of this animal is poor waste management (Arroyave et al. 2006), since waste is thrown and accumulated on the side of the road, which attracts several species and makes them vulnerable to roadkills.

The results of this study show that most wildlife roadkills belong to the group of mammals, affecting mainly the *D. marsupialis*, which coincides with results obtained in Argentina (Bauni et al. 2017), and Brazil (Reynie Omena et al. 2012), who also have similar results to those of Gumier Costa and Sperber (2009), Seijas et al. (2013), De La Ossa-Nadjar and De La Ossa-V (2013) and Delgado Vélez (2014). These results refer to animals that get blinded by car headlights and, therefore, they become more vulnerable to this problem (Delgado Vélez, 2007, Castillo-R et al. 2015).

Similarly, 12 species of reptiles were registered, representing 21.43% of the species registered in the department of Huila (Vera-Pérez et al. 2017). It is likely that roadkills are due to the rainy season. Since poikilotherms need to regulate their body temperature by absorbing heat from the environment, they rest on the pavement to benefit from the heat that has accumulated due to sunlight (Mendoza and Marcos, 2016). As Pragatheesh and Rajvanshi (2013) mentioned “the locomotion of snakes is very slow on the pavement” (p.20) and some of them stop moving when a vehicle approaches, which exposes them to roadkills (Castillo-R., 2015).

The number of roadkills recorded is greater in main roads between the municipalities of Neiva and Rivera because there is greater presence of riparian forests that offer a great variety of resources. According to Castillo-R (2015), wet forests hold more diversity of species than dry forests since they have the adequate environmental conditions for the development of species; therefore, many of the animals of the
tropical dry forest migrate to humid areas or even look for a riparian to get better environmental conditions.

The time that an animal’s corpse remains on the road has to do with three main aspects: the presence of scavengers, the weather, and traffic flow (Santos et al. 2011, Ratton et al. 2014). The number of killed animals on the roads can vary because some of them crawl or reach for the adjacent vegetation where they die later (Brum et al. 2018). In the case of amphibians, the time their bodies remain on the road after a roadkill is very short (Antworth et al. 2005) and it may be due to any of the factors previously mentioned. This study may have some margin of error, for example, only three specimens were registered in the amphibian group.

The deaths of animals on the road are analogous to the catch per unit effort (CPUE) where “catch” is the number of animals run over and “effort” is a direct function of vehicular traffic. If the traffic increases, a decrease (or stagnation) in the RR is interpreted as a decrease in the population of the analyzed species (Seijas et al. 2013, Monroy et al. 2015).

The RR equals 0.145 ind/day/Km, a key figure very similar to 0.160 reported in the study conducted by Monroy et al. (2015) in the Caribbean region during the rainy season, which was developed under similar weather conditions to this study, but with different species recorded since the type of ecosystem is different. Mammals obtained a RR of 0.02, lower than this research (0.075). This could be attributed to the fact that the Andean region offers more resources to mammals in its ecosystems compared to the Caribbean region. However, the RR of amphibians was 0.096, which was higher than the one obtained in this research (0.004), contrasting values that reflect the problem of wildlife roadkills in different ecosystems.

**Recommendations**

Habitat connectivity structures have been implemented by some projects that look for the construction of a new road or even the extension of it (Clevenger and Waltho, 2000), in fact, the Neiva - Rivera - Campoalegre road circuit is projected as a dual carriageway, which is why the collected information about roadkilled wildlife should be considered in order to determine the structural and non-structural strategies that contribute to the mitigation of this impact. Figure 3 shows several areas with high records of wildlife roadkills, where mammals and reptiles are the most affected groups, which calls for their preservation.

In this case, the species *Didelphis marsupialis*, which is the most affected by roadkills, requires projects or actions for its conservation, since according to Rueda et al. (2013)
“opossums play a very important role in the trophic chain as predators, scavengers and the prey of nocturnal birds” (p.150); they are also medium-sized mammals. Furthermore, Clevenger et al. (2001) claims that underpass tunnels could help mitigating the impact of roadkills in the pathway to small and medium mammals (p.1347) and the conservation of the species Didelphis marsupialis. These structures must not be installed in sharp bends or speed bumps since vehicles circulate at low speed and generate higher and more frequent noises, one of the factors that affect the behavior and reproductive cycle of wildlife (Warren et al. 2006). This is one of the main factors that causes greater ecological impacts to wildlife and produces several effects such as reduction of the activity area and low reproductive success, associated with hearing loss, displacement, and increase in stress hormones (De la Ossa-V and Galván-Guevara, 2015).

Taking into account the recommendation by Clevenger et al. (2001) to improve the permeability of roads for small and medium mammals, the first sewers should be located at more frequent intervals (150-300 m) to provide sufficient opportunities for animals of all sizes to avoid crossing heavy traffic roads. The diameter of the underpass tunnel will highly depend on the size of the fauna in that location (p.1347); in this case, for the species D. marsupialis it would be a diameter of 24”, but considering that other mammals such as C. thous and T. Tetractyla also suffer the impact of roadkills, it would be good to extend the underpass tunnels to 36”, thus giving a benefit to the different species of mammals affected in the studied route.

Reptiles are very vulnerable to being collided in the rainy season because they are ectoderm (Vargas Salinas et al. 2011, Ramos Pallares and Mesa Joya 2018). “They also have many characteristics that increase their probability of being involved in vehicle roadkills, such as age, sex, body size, activity pattern, household size, food search strategy, defense mechanism, habitat requirements, among others” (p.123) (p.87); Therefore, another strategy to benefit reptiles in the rainy season would be to pave certain places next to the road or to create an area for wildlife to take the sun safely (Pragatheesh and Rajvanshi, 2013).

Finally, trees adjacent to the road meet and create green tunnels that allow wildlife to cross to other ecosystems that have been fragmented due to road construction (Cypher, 2017), therefore, cutting and removing them from roads can significantly reduce the species preservation. This phenomenon could potentially increase the risk of roadkills (Grilo et al. 2011).

Acknowledgments

The authors want to thank Empresas Públicas de Rivera S.A. E.S.P. and its manager José Manuel Ortiz Cuellar for the transportation and the tools provided for this
research. In addition, special thanks to María Paula Palomá Herrera, Juan C. Vásquez for the support, reviews and advice in the research. Finally, thanks to several professors of the Corporación Universitaria del Huila “CORHUILA” who actively contributed to the research with their knowledge in different sciences.

Author Contribution

Juan Sebastián Arana-Rivera: Conceptualization (lead); Data curation (lead); Formal analysis (equal); Funding acquisition (lead); Investigation (lead); Methodology (equal); Writing-original draft (equal); Writing-review and editing (equal). Santiago Gutiérrez-Quintero: Conceptualization (supporting); Data curation (supporting); Formal analysis (equal); Investigation (supporting); Methodology (equal); Writing-original draft (equal); Writing-review and editing (supporting). Natalia Álvarez: Methodology (supporting); Writing-review and editing (supporting).

References

Alves, C., Hobus, Q. & Bager, A. (2009). Uso e ocorrência de lontra longicaudis em ambientes influenciados pela rodovia BR-392, no extremo sul do Brasil. Anais do LX Congresso de ecologia do Brasil. São Lourenço: Instituto de Biociências, Universidade de São Paulo.

Antworth, R.L., Pike, D.A. & Stevens, E.E. (2005). Hit and run: effects of scavenging on estimates of roadkilled vertebrates. Western Wildlife, 4(4), 467–466. https://doi.org/10.1046/j.0165-5240.2005.00049.x

Arroyave, M.D., Gómez, C., Gutiérrez, M. E., Múnera, D.P., Zapata, P.A., Vergara, I.C., Andrade, L.M., Ramos, K.C., (2006). Impactos de las carreteras sobre la fauna silvestre y sus principales medidas de manejo. Revista EIA (5), 45-57.

Baguer, A. & Alves, C. (2011). Influence of sampling effort on the estimated richness of road-killed vertebrate wildlife. Environmental Management, 47(5), 851-858. http://www.scielo.org.co/scielo.php?script=sci_arttext&pid=S1794-12372006000100004

Bauni, V., Anfunso, J. & Schivo, F. (2017). Mortalidad de fauna silvestre por atropellamientos en el bosque atlántico del Alto Paraná, Argentina. Revista Ecosistemas, 26(3), 54-66. https://doi.org/10.7818/ECOS.2017.26-3.08

Beckers, D. (2008). Good from bad: is there an upside to roadkills? In D. Lunney, A. Munn, & W. Meikle, Too close for comfort: contentious issues in human-wildlife encounters, (pp. 103-104). Mosman, Royal Zoological Society of New South Wales.

Brum, T.R., Santos-Filho, M., Canale, G.R. & Ignácio, A.R. (2018). Effects of roads on the vertebrate’s diversity of the indigenous Territory Paresi and its surrounding. Brazilian Journal of Biology, 78(1), 125-132. https://www.scielo.br/j/bjb/a/svglglpBW5akDbq7/1LWJf/lанг-en

Cáceres, N.C., Hannibal, W., Freitas, D.R., Silva, E.L., Roman, C. & Casella, J., 2010. Mammal occurrence and roadkill in two adjacent ecoregions (Atlantic Forest and Cerrado) in south-western Brazil. Zoologia, 27(5), 709-717. https://www.scielo.br/j/zoool/a/qajMcLjSjFbGyshntRZz/lанг-en

Castillo-R, J.C., Urmendez-M, D. & Zambrano-G, G. 2015. Mortalidad de fauna por atropello vehicular en un sector de la vía panamericana entre Popayán y Patía. Boletín Científico Centro de Museos. Museo de Historia Natural, 19(2), 207-219. http://www.scielo.org.co/pdf/bccm/v19n2/v19n2a12.pdf

Clevenger, A.P. & Waltho, N., 2000. Factors Influencing the effectiveness of wildlife underpasses in Banff National Park, Alberta, Canada. Conservation Biology, 14(1), 47-56. http://www.jstor.org/stable/2641903?origin=JSTOR-pdf

Clevenger, A.P., Chruszcz, B. & Gunson, K., 2001. Drainage culverts as habitat linkages and factors affecting passage by mammals. Journal of Applied Ecology, 38(6), 1340–1349. https://doi.org/10.1046/j.0021-8901.2001.00678.x

Clevenger, A.P., Wierzchowski, J., Chruszcz, B. & Gunson, K. 2002. GIS-generated, expert-based models for identifying wildlife habitat linkages and planning mitigation passages. Conservation biology, 16(2), 503-514. https://www.jstor.org/stable/3061376

Cserkész, T., Ottlecz, B., Cserkész-Nagy, Á. & Farkas, J. (2013). Interchange as the main factor determining wildlife–vehicle collision hotspots on the fenced highways: spatial analysis and application. European Journal of Wildlife Research, 59(4), 587-597. https://doi.org/10.1007%2Fs10344-013-0710-2

Cypher, B.L. (2017). Road effects on rodents in Salbush scrub habitat. Western Wildlife, 4, 12-16. https://www.wj.org/wp-content/uploads/sites/9/2021/05/Cypher_WW_2017.pdf

De la Ossa Nadjar, O. & De la Ossa V., 2013. Fauna silvestre atropellada en dos vías principales que rodean los Montes de María, Sucre, Colombia. Revista Colombiana de Ciencia Animal RECLA, 5(1), 158-164. https://doi.org/10.24188/recia.v5.n1.2013.481

De la Ossa V., J. & Galván-Guevara, S. (2015). Registro de mortalidad de fauna silvestre por colisión vehicular en la carretera Toluviejo–Ciénaga la Caimanera, Sucre Colombia. Biota Colombiana, 16(1), 67-77. http://hdl.handle.net/20.500.11761/9428

Delgado-Vélez, C.A. (2007). Muerte de mamíferos por vehículos en la vía del Escobero, Envigado (Antioquia), Colombia. Actualidades Biológicas, 29(87), 1-6. https://revistas.udea.edu.co/index.php/acbion/article/view/329342
Delgado-Vélez, C.A. (2014). Adiciones al atropellamiento vehicular de mamíferos en la vía del Escobero, Envigado (Antioquia), Colombia. Revista EIA, 11(22), 147-153. https://revistas.eia.edu.co/index.php/reviea/article/view/679
Forman, R.T. & Alexander, L.E. (1998). Roads and their major ecological effects. Annual review of ecology and sistematics, 29(1), 207-231. https://doi.org/10.1146/annurev.ecolsys.29.1.207
Forman, R.T., Sperling, D., Bissonette, J.A., Cleveringa, A.F., Cutshall, C.D., Dale, C.D. & Jones, J., (2003). Road ecology Island Press. Gagné, S.A., Bates, J.L. & Bierregaard, R. O. (2015). The effects of road and landscape characteristics on the likelihood of a barred Owl (Strix varia)-vehicle collision. Urban Ecosystems, 18(3), 1007-1020.
Glista, D.J. & Devault, T.L. 2008. Vertebrate road mortality predominantly impacts amphibians. Herpetological Conservation and Biology, 3(1), 77-87. http://www.herpcobio.org/Volume_3/Issue_1/Glista_etal_2008.pdf
González-Gallina, A., Benítez-Badillo, G., Rojas-Soto, O.R. & Hidalgo-Mihart, M.G. (2013). The small, the forgotten and the dead: highway impact on vertebrates and its implications for mitigation strategies. Biodiversity and Conservation, 22(2), 325-342.
Grilo, C., Ascensão, F., Santos-Reis, M. & Bissonette, J. A. (2011). Do well-connected landscapes promote road-related mortality? European Journal of Wildlife Research, 57(4), 707-716. https://doi.org/10.1007/s10344-010-0478-6
Gunier-Costa, F. & Sperber, C. F. (2009). Atropelamientos de vertebrados na Floresta Nacional de Carajás, Pará, Brasil. Acta Amazonica, 39(2), 459-466. https://doi.org/10.1590/S0044-59672009000200027
Gunson, K.E. & Chruszcz, B. (2003). Large animal-vehicle collisions in the central Canadian Rocky Mountains: patterns and characteristics, UC Davis: Road Ecology Center, 355-366. https://escholarship.org/uc/item/3qm680qb
Hiley, S.L. & Brown, W.L. (2001). Guía de las aves de Colombia. American Bird Conservancy.
Hokke, R.L., Martín-Duque, J.F. & Pedraza, J. (2012). Land transformation by humans: a review. GSA Today, 22(12), 4-10.
INVIA, 2018. Instituto Nacional de Vías. https://hermes.invias.gov.co/carreteras/
Jochimsen, D.M., 2005. Factors influencing the road mortality of snakes on the Upper Snake River Plain, Idaho. Wildlife Impacts and Conservation Solutions, 351-365.
Jones, J.A., Swanson, F.J., Wempe, B.C. & Snyder, K.U., 2000. Effects of roads on hydrology, geomorphology, and disturbance patches in stream networks. Conservation Biology, 14(U), 76-85. https://www.jsor.org/stable/2641906
Kuykendall, M.T. & Keller, G. S., 2011. Impacts of roads and corridors on abundance and movement of small mammals on the llano Estacado of Texas. The southwestern naturalist, 15, 9-16. https://https://www.jsor.org/stable/23028105
Litvaitis, J.A. & Tash, J.P. (2008). An approach toward understanding wildlife-vehicle collisions. Environmental Management, 42(4), 688-697. https://doi.org/10.1007/s10662-008-9108-4
López-Herrera, D.F., León-Yusti, M., Guevara-Molina, S.C. & Vargas-Salinas, F., (2016). Reptiles en corredores biológicos y de movilidad. Boletín de la Asociación Colombiana de Ciencias Biológicas, 1(27), 88-95. https://doi.org/10.47499/revistaaccb.v1i27.106
Lynch, J.D., Sierra, T.A., & Gómez, F.J.R. (2014). Programa nacional para la conservación de las serpientes presentes en Colombia. Ministerio de Ambiente y Desarrollo Sostenible. https://www.ins.gov.co/Comunicaciones/Infografias/PROGRAMA%20NACIONAL%20SERPIENTES.pdf
Mendoza, S., J.F & Marcos P., O.A. (2016). Observatorio de movilidad y mortalidad de fauna en carreteras en México. Publicación Técnica. http://www.imt.mx/medios/Publicaciones/PublicacionTecnica/pr454.pdf
Ministerio de Ambiente & CAM. (2009). Guía de Identificación de fauna silvestre Colombiana. Corporación Autónoma Regional del Alto Magdalena. http://cam.gov.co/site/images/documents/photocadownload/guias_de_identificacion/guia%20identificacion%20fauna%20silvestre%20colombiana.pdf
Mizuta, T. (2014). Moonlight-related mortality: lunar conditions and roadkill occurrence in the Amami Woodcock Scolopax mira. The Wilson Journal of Ornithology, 126(3), 544–552. https://doi.org/10.1676/13-159.1
Moroy, M.C., De La Ossa-Lacayo, A. & De la Ossa V., J. (2015). Tasa de atropellamiento de fauna silvestre en la vía San Onofre – María La Baja, Caribe Colombiano. Revista de la Asociación Colombiana de Ciencias Biológicas, 1(27), 88-95. https://doi.org/10.47499/revistaccb.v1127.106
Morales-Betancourt, M.A., Lasso, C.A., Páez, V.P., & Bock, B.C. (Ed.). (2015). Libro Rojo de Reptiles de Colombia. Ministerio de Ambiente y Desarrollo Sostenible. http://www.soyambiente.gov.co/Comunicaciones/Infografias/PROGRAMA%20NACIONAL%20SERPIENTES.pdf
Mora, C., Ascensão, F., Santos-Reis, M. & Bissonette, J. A. (2011). Do well-connected landscapes promote road-related mortality? European Journal of Wildlife Research, 57(4), 707-716. https://doi.org/10.1007/s10344-010-0478-6
Ramos Pallares, E. & Mesa Joya, F.L. (2018). Reptile road mortality in a fragmented landscape of the middle Magdalena Valle, Colombia. Herpetology Notes, 11, 81-91. https://www.biorxiv.org/hn/article/view/29825
Ratton, P., Secco, H., & Da Rosa, C.A. (2014). Carcass permanency time and its implications to the roadkill data. Revista EIA, 11(22), 147-153. https://revistas.eia.edu.co/index.php/reviea/article/view/8252
Puig, J., Sanz, L., Serrano, M. & Elosegui, J. (2012). Wildlife roadkills and underpass use in northern Spain. Environmental Engineering and Management Journal, 11(6), 1141-1147. http://www.eemj.icpm.tuiasi.ro/issues/vol11/vol11n606.htm
Ramos Pallares, E. & Mesa Joya, F.L. (2018). Reptile road mortality in a fragmented landscape of the middle Magdalena Valle, Colombia. Revista de la Asociación Colombiana de Ciencias Biológicas, 1(27), 88-95. https://doi.org/10.47499/revistaccb.v1127.106
Ratton, P., Secco, H., & Da Rosa, C.A. (2014). Carcass permanency time and its implications to the roadkill data. European Journal of Wildlife Research, 56(3), 543-546. https://doi.org/10.1007/s10344-014-0798-z
Reynie Omena, J., Pantoja Lima, J., Wendt Santos, A. L., Aguiar Ribeiro, G.A. & Rocha Aride, P.H. (2012). Characterization of the vertebrate fauna hit on roadway BR 174, Amazonas, Brazil. Revista Colombiana de Ciencia Animal, 4(2), 291-307. https://doi.org/10.24188/recia.v4.n2.2012.211
Rueda, M.C., Ramírez, G.F., & Osorio, J.H. (2013). Aproximación a la biología de la zarigüeya común (Didelphis marsupialis). Boletín científico centro de museo, Museo de historia natural, 17, 141-153. http://www.scielo.org.co/pdf/bcm/v17n2/v17n2a13.pdf
Ruiz-Capillas, P., Mata, C. & Malo, J.E. (2015). How many rodents die on the road? Biological and methodological implications from a small mammals’ roadkill assessment on a Spanish motorway. Ecological research, 30(3), 417-427.
Santos, S., Lourenc, O., Mira, A. & Beja, P. (2011). How long do the dead survive on the road? carcass persistence probability and implications for road-kill monitoring surveys. Plos One, 6(9), 1-12. https://doi.org/10.1371/journal.pone.0025383
Santos, S., Lourenc, O., Mira, A. & Beja, P. (2013). Relative effects of road risk, habitat suitability, and connectivity on wildlife roadkills: the case of tawny owls (strix aluco). Plos One, 8(11), 1-11. https://doi.org/10.1371/journal.pone.0079967
Seijas, A.E., Araujo Quintero, A. & Velásquez, N. (2013). Mortalidad de vertebrados en la carretera Guanare-Guanarito, estado Portuguesa, Venezuela. Revista de Biología Tropical, 61(4), 1619-1636. https://doi.org/10.15517/rbt.v61i4.12803

Smith-Patten, B.D. & Patten, M. A. (2008). Diversity, seasonality, and context of mammalian roadkills in the Southern Great Plains. Environmental Management, 41(6), 844-852. https://doi.org/10.1007/s00267-008-9089-3

Tejera, G., Rodríguez, B., Armas, C., & Rodríguez, A. (2018). Wildlife-vehicle collisions in Lanzarote Biosphere Reserve, Canary Islands. PloS One, 13(3), 1-15. https://doi.org/10.1371/journal.pone.0192731

Trombulak, S.C., & Frissell, C.A. (2000). Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology, 14(1), 18-30. https://doi.org/10.1046/j.1523-1739.2000.99084.x

UICN. (2019). The IUCN Red List of threatened Species. http://www.iucnredlist.org

Vargas Salinas, F., Delgado Ospina, I. & López Aranda, F., 2011. Mortalidad por atropello vehicular y distribución de anfibios y reptiles en un bosque subandino en el occidente de Colombia. Caldasia, 33(1), 121-138. https://revistas.unal.edu.co/index.php/cal/article/view/36380/37973

Vera-Pérez, L.E., Mendoza Roldán, J.S. & Díaz, G.P. (2017). Fauna Herpetológica del bosque seco, Alto Magdalena, Field Museum. https://fieldguides.fieldmuseum.org/sites/default/files/rapid-color-guides-pdfs/753_colombia_fauna_herpetologica_alto_magdalena_v2_0.pdf

Warren, P.S., Katti, M., Ermann, M. & Brazel, A., 2006. Urban bioacoustics: it’s not just noise. Animal Behaviour, 71(3), 491-502. https://doi.org/10.1016/j.anbehav.2005.07.014