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*Article*

# Survey of Wildlife Mortality on the Br-364 and Go-341 Highways in the Municipality of Mineiros-Goiás

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**ABSTRACT**
The expansion of the road network in the Cerrado biome represents one of the main threats to biodiversity conservation, promoting habitat fragmentation and increased mortality of wild vertebrates due to anthropogenic actions. This study aimed to quantify and analyze the spatial distribution of road mortality on the GO-341 and BR-364 highways, located in the municipality of Mineiros, Goiás, a region encompassing Emas National Park (ENP). Active monitoring was carried out between March and May 2024 (rainy-to-dry transition period), totaling 17 sampling expeditions and a cumulative effort of 3,694 km (2,280 km on GO-341 and 1,414 km on BR-364) through vehicle-based surveys (40–70 km/h). A total of 14 wild vertebrate victims were recorded, with a notable dominance of the class Mammalia (92.8%) over Reptilia (7.1%). The order Carnivora accounted for 42.85% of fatalities (n=6). Six of the recorded species are threatened with extinction at the national level: *Leopardus tigrinus* (Endangered - EN), as well as *Panthera onca*, *Chrysocyon brachyurus*, *Myrmecophaga tridactyla*, *Tapirus terrestris*, and *Leopardus pardalis* (all Vulnerable - VU). State highway GO-341 accounted for 64.29% of the accidents (n=9), showing marked spatial clustering in the peri-urban section (km 8 to 32), a pattern explained by the ecological trap effect and the attraction of the agricultural/water matrix. On BR-364 (35.71%), the mortality of large mammals probably resulted from the high intensity of heavy harvest traffic and the severe barrier effect. The results show that mortality disproportionately affects top predators and K-strategist species, compromising long-term population viability. It is concluded that the implementation of integrated mitigation measures is urgent, prioritizing wildlife underpasses associated with guiding fences in critical sections and speed control, in compliance with State Law No. 20,340/2018, to mitigate the impacts of highways in the surroundings of the ENP.
Keywords: Road ecology. Cerrado biome. Threatened species. Emas National Park.

**ABSTRACT**
The expansion of road network in Cerrado biome represents a major threats to biodiversity conservation, leading to habitats fragmentation and increased of wildlife mortality by anthropic actions. This study aimed to quantify and analise the spacial distribution of road mortality along the GO-341 and BR-364 highways located in the municipality of Mineiros, Goiás, region encompassing Emas National Park (ENP). Active monitoring was conduced between March and May 2024 (rainy to dry transition period), totaling 17 sampling surveys and an acumulated effort of 3,694 km (2,280 km on GO-341 and 1,414 km on BR-364) using vehicle-based searching (40–70 km/h). A total of 14 wild vertebrates were recorded, with a notable dominance of Mammalia (92.8%) compared to Reptilia (7.1%). The order Carnivora accounted for 42.85% of fatalities (n=6). Six of the identified species are nationally threatened with extinction: *Leopardus tigrinus* (Endangered - EN), as well as *Panthera onca*, *Chrysocyon brachyurus*, *Myrmecophaga tridactyla*, *Tapirus terrestris*, and *Leopardus pardalis* (all Vulnerable - VU). The state highway GO-341 concentrated 64.29% of roadkills (n=9), showing significant spatial clustering in the peri-urban section (km 8 to 32), a pattern driven by ecological trap effects and matrix attraction. On BR-364 (35.71), large mammal mortality probably resulted from heavy harvest traffic and severe barrier effects. Results demonstrate that road mortality disproportionately affects top predators and K-selected species, threatening long-term population viability. We conclude that integrated mitigation measures are urgently needed, prioritizing wildlife underpasses combined with guiding fences along critical stretches, speed control, and compliance with State Law No. 20,340/2018 to safeguard biodiversity around ENP.
Keywords**:** Road ecology. Cerrado biome. Threatened species. Emas National Park.

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## Introduction

Brazil is made up of six main biomes: the Amazon, Caatinga, Atlantic Forest, Pantanal, Pampa, and Cerrado. The latter, being the second largest, covers about two million square kilometers, about 23% of the national territory, and harbors approximately 12,800 cataloged plant species and 200 mammal species. Within this biome lies the municipality of Mineiros, Goiás, which stands out for its high floristic diversity and for attracting a varied fauna, in addition to harboring the headwaters of important water resources, such as the Araguaia River (Aguiar et al. 2004; Gomes et al. 2006). This municipality is home to Emas National Park (ENP), a Conservation Unit of high relevance in the Southwest region of Goiás, which extends into neighboring municipalities (Chapadão do Céu, Serranópolis, and Costa Rica) and borders Mato Grosso and Mato Grosso do Sul. In this region, however, wildlife carcasses are frequently seen on roads and roadsides, constituting a warning sign relevant to environmental monitoring.

This scenario is a direct reflection of road expansion which, although fundamental for economic development by connecting urban and rural hubs (Fischer 2014), generates severe habitat fragmentation. From an ecological point of view, mortality occurs primarily due to the intersection of roads with the natural movement routes of wildlife and, secondarily, due to the availability of attractants on the road, such as fallen grains and carcass remains, which attract herbivores and mesopredators (Lima & Obara 2004). In the Southwest region of Goiás, one of the main hubs of agricultural and livestock trade, there is greater pressure for road expansion, and the scarcity of current research on wildlife mortality is notable, having been reported only on GO-080 and GO-060 (Cortez et al. 2024; Miranda et al. 2021). Although the present survey does not characterize deaths resulting from roadkill, it is essential for understanding the impacts of this expansion on Cerrado biodiversity.

In this context, GO-341 acts as the main connecting road between the urban perimeter of Mineiros and the buffer zone of Emas National Park, located adjacent to the northwestern portion of the park, where an intensive use zone is characterized and which integrates strategic activities for mitigating environmental depredation and the mortality of local animals, according to the Management Plan of the PNE-GO (IBAMA 2005). At the same time, BR-364 is a federal axis with high heavy-vehicle traffic for the transportation of harvests (DNIT 2024), associated with the intense agricultural profile of Mineiros (IBGE 2023), which aggravates ecological vulnerabilities, given the absence of wildlife protection structures and driver recklessness, factors that generate determining anthropogenic variables on these highways (Garcia 2025).

It is important to emphasize that collisions between large and medium-sized animals and motor vehicles on roads can not only compromise the populations of these animals but can also generate significant impacts on human safety and the economy. In 2019, the cost of collisions involving animals on São Paulo highways was estimated at R$ 56 million per year, which also leads to deaths and economic losses (Abreu et al. 2019). The main collision targets are mammals, especially wild felids and canids, due to their ecological behavior. However, the number of roadkills is considered underestimated, and animals that survive collisions are taken to medical centers or shelters, with rare data surveys and even fewer records (Souza 2012).

To reduce road mortality, preventive measures that ensure landscape connectivity are necessary, such as the installation of guiding fences, underpasses (tunnels), and vegetated overpasses (Aresco 2005). However, the adoption of these structures is still incipient and lacks systematic monitoring to prove their effectiveness (Abra 2012). Furthermore, it is necessary to understand the behavior of the most affected species for the maintenance of other populations and which factors influence the increase in wildlife accidents on road networks, focusing on the natural resources found around these highways, which highlights the need for more comprehensive and regionalized studies to design more efficient mitigation measures. Therefore, the objective of this study is to report the survey and spatial analysis of wild animals found dead on the main highways surrounding large Cerrado conservation areas in the municipality of Mineiros, Goiás.

## Materials and Methods

Active monitoring of carcasses of road-killed wild animals was carried out on state highway GO-341 (coordinates -18.411770, -49.193092 to -17.353551) and on federal highway BR-364 (coordinates -52.672563, -17.385643 to -52.883149), located in the surroundings of Emas National Park, in the municipality of Mineiros (GO).

The sampling effort consisted of 17 expeditions (round trips), conducted exclusively during the daytime over three months (March, April, and May 2024); in total, 3,694 kilometers were traveled, of which 2,280 were on GO-341 in 10 trips from Km 01 to 114. On BR-364, 1,414 kilometers were traveled in 7 trips from Km 240 to 341. Travel was carried out by motor vehicle at an average speed of 40 to 70 km/h, lasting approximately 1

to 2 hours per trip. To avoid duplicate records, the locations where the animals were found were recorded on clipboards and photographed.

When a carcass was sighted on the roadway or shoulder, the vehicle was safely parked to record the point. Taxonomic identification of the specimens and systematic photographic recording (1 to 3 photos per individual) were performed. The collected data, including the species and the highway kilometer marker, were tabulated and the animals grouped into classes (mammals and reptiles). Based on kilometer georeferencing, the sections with the highest collision rates were established.

**Results and Discussion**

During the three months of active monitoring in March, April, and May 2024, over 17 sampling expeditions covering a total effort of 3,694 km (2,280 km on GO-341 and 1,414 km on BR-364), 14 wild vertebrates possibly killed by vehicle collisions were recorded in the municipality of Mineiros, Goiás (**Table 1**). The class of mammals represented almost all records, with 13 carcasses (92.8%), followed by the class of reptiles, with only 1 record (7.1%), with no records verified for birds or amphibians.

However, this dominance of mammals diverges from other surveys in the state. In a study carried out by Cesário et al. (2022) in the central region of Goiás, out of 41 records, reptiles led road mortality (43.9%), followed by birds (31.7%) and mammals (19.5%). On the other hand, the pattern recorded in Mineiros closely approximates the findings of Cortez et al. (2024) on the GO-080 highway (between Goiânia and Petrolina de Goiás), where mammals accounted for 72 individuals out of the 76 carcasses counted (94.7%).

This variation in taxonomic dominance reflects the interaction between the ecological context of the landscape and the sampling methodology employed. The municipality of Mineiros is home to Emas National Park (ENP), which acts as a source area with a high density of medium- to large-sized mammals. In addition, the presence of extensive forest fragments and headwaters of large river networks, such as those of the Araguaia River, constantly attracts mammals to grazing and movement areas around the roads. Additionally, the sampling method adopted, a vehicle-based search at speeds between 40 km/h and 70 km/h, favors the detection of medium and large carcasses, whereas small mammals, amphibians, small reptiles, and birds suffer accelerated rates of removal by scavengers and destruction by vehicle traffic, making them hardly detectable without surveys on foot (Teixeira et al. 2013; Carvalho-Roel et al. 2021).

The highway with the highest number of animals found was GO-341, which resulted in 9 (nine) deaths, representing 64.29% of the records of animals found dead on the road networks surveyed. It was also the section with the largest number of medium- to large-sized mammals observed, as seen in **Figure 1**. It is essential to highlight that most of them have a relevant threat classification by ICMBio (2026), such as the Oncilla (*Leopardus tigrinus*), listed as Endangered (EN), as well as the Maned wolf (*Chrysocyon brachyurus*), Geoffroy's cat (*Leopardus geoffroyi*), Jaguar (*Panthera onca*), Southern tamandua (*Tamandua tetradactyla*), and Lowland tapir (*Tapirus terrestris*), all classified as Vulnerable (VU). Despite the proximity of this highway to the ENP, it can be noted that a greater number of carcasses were found closer to the urban center (km 8 to 32), since only two animals were sighted in the sections bordering the ENP, both located at km 92.

On BR-364, 5 animals were found (35.71%), of which 4 (80%) were mammals and 1 (20%) was a reptile compatible with a snake, but without species identification (**Table 1**). Among the other animals, the Crab-eating fox (*C. thous*), Geoffroy's cat (*Leopardus geoffroyi*), Giant anteater (*Myrmecophaga tridactyla*), and Lowland tapir (*Tapirus terrestris*) were identified, all classified as VU by ICMBio (2026), except *C. thous*. The perimeter in which these animals were found also corresponds to areas close to urban zones, revealing the severity of the rate of dead animals in areas of exacerbated habitat fragmentation (Coffin, 2007; Soler & Verburg, 2010). Thus, the spatial distribution of roadkills revealed marked heterogeneity, in which state highway GO-341 concentrated the largest proportion of accidents, accumulating 9 deaths (64.29% of the total) over 2,280 km traveled (crude rate of 0.0039 carcasses/km), while federal highway BR-364 recorded 5 deaths (35.71%) over 1,414 km traveled (crude rate of 0.0035 carcasses/km).

The higher incidence of roadkill observed on GO-341 in the section near the urban perimeter (km 8 to 32), compared with the section adjacent to the ENP, can be explained by the concept of an ecological trap (*ecological trap*) and by the matrix attraction effect (Alberici et al. 2022; Cortez et al. 2024). Near the city of Mineiros, the landscape presents a heterogeneous mosaic of small forest remnants interconnected with watercourses, such as the basin that forms the Araguaia River, and pastures which, when associated with the daily movement of animals in search of water and food, force constant road crossings in areas where vehicle speeds are high and lighting/signage is poor (Lima & Obara 2004; Coffin 2007). In turn, BR-364 is characterized as a logistics corridor for grain transport from the Central-West (DNIT 2024), in which the uninterrupted

traffic of B-train trucks at high speeds, added to the total absence of underpasses or guide fencing, increases the severity of the barrier effect and of direct mortality (Van der Ree et al. 2015; Abra et al. 2019).

An analogous pattern was identified by Cáceres, Casella, and Goulart (2012) on BR-262 in Mato Grosso do Sul, where mammal mortality peaks occurred in intermediate sections with availability of water resources and continuous vegetation cover, and not necessarily at the borders of closed conservation units. Furthermore, Cortez et al. (2024) observed on GO-080 that 53.9% of roadkills occurred where the road cuts through forest fragments and water bodies, demonstrating that riparian vegetation acts as a passage corridor to the asphalt. In this context, it is noted that landscape factors and climatic seasonality play a determining role in modulating the rate of accidents with wildlife in the Cerrado biome. The sampling period of this study (March to May 2024) covers the transition window between the end of the rainy season and the beginning of the dry season in southwestern Goiás. In this phase, there is a gradual reduction in rainfall, concomitant with the beginning of the decline in water and food resources within forest fragments, which begins to induce the first longer movements of wildlife (Santos et al. 2012). As verified by Cortez et al. (2024) on GO-080, winter/dry season concentrated 38% of annual roadkills, this increase being also catalyzed by the occurrence of fires and heat spots that deprive wildlife of their natural shelters, forcing escape crossings (Nascimento & Gering 2018). In a daily study on GO-341, Carvalho-Roel et al. (2021) observed that species with specific seasonal feeding behaviors, such as the blue-and-yellow macaw (*Ara ararauna*), showed roadkill peaks exclusively during the dry months (May to August), coinciding with the fruiting of palm trees along the highway.

However, one of the most critical findings of the present survey is the high percentage of wild carnivores killed, which accounted for 42.85% of the total carcasses found on the two highways. Ecologically, felids and large carnivores occupy the top of food webs and act as "umbrella species" (*umbrella species*) and bioindicators of ecosystem integrity (Roberge & Angelstam 2004). Due to their physiological and behavioral requirements, these predators require extensive home ranges for foraging and reproduction, maintaining naturally low population densities (Oliveira & Cassaro 2005). Thus, landscape fragmentation induced by agricultural matrices and road axes forces frequent asphalt crossings, transforming highways into lethal population sinks (Nielsen et al. 2006). This impact is amplified by the conservation crisis affecting the Cerrado, considered a global biodiversity hotspot under a continuous process of deforestation and fragmentation of remnants (Strassburg et al. 2017), which drains the demographic resilience of large mammal populations in the face of additional losses due to roadkill (Ascensão & Desbiez 2022). As highlighted by Bolze (2019), mesopredators such as *L. pardalis*, although they prefer dense vegetation, frequently use rights-of-way and service roads as routes that facilitate locomotion and territorial marking, exposing themselves directly to vehicle traffic.

The recurrent road mortality of these species may disproportionately compromise long-term population viability. As demonstrated by Grilo et al. (2021) in global population viability analysis (PVA) models, populations of Carnivora and ungulates in tropical biomes enter sharp decline even under low absolute roadkill rates. In the case of the lowland tapir (*Tapirus terrestris*), the loss of adult individuals, such as the female recorded on BR-364 (km 24), may represent a significant impact on the population of these mammals. It is a K-strategist species, characterized by a long gestation of approximately 13 months, single offspring, and late maturity, whereby the unnatural removal of reproductive females prevents the demographic recovery of the population in the short and medium term (Medici & Abra 2019; Banhos et al. 2021).

Likewise, for the giant anteater (*Myrmecophaga tridactyla*), studies conducted by the Anteaters & Highways Project in the Cerrado of Mato Grosso do Sul revealed that vehicle collisions halve the population growth rate (*r*) of the species, hindering the maintenance of these populations in the face of other simultaneous threats such as deforestation and fires (Desbiez et al. 2020; Ascensão & Desbiez 2022). Furthermore, the recurrent recording of *C. thous* and *M. tridactyla* in Mineiros aligns with the national patterns described by Coelho, Kindel, and Coelho (2008) and Cirino and Freitas (2018), who point to both taxa among the mammals most frequently killed on Brazilian highways.

It is essential to recognize, however, the limitations inherent to raw data accumulated in road surveys. The 14 records obtained in this study represent an underestimated sample of the real impact of mortality. In the specialized Road Ecology literature, simple carcass counts without statistical correction incur sampling errors arising from variables related to observer detection efficiency (*p*) and carcass persistence time (*TR)* (Teixeira et al. 2013; Coelho et al. 2014; Barrientos et al. 2018). As demonstrated by Franceschi et al. (2021) and emphasized in the manual of the *Siriema* program (Coelho et al. 2014), decision-making for mitigation based solely on observed data may mistakenly alter the prioritization of critical sections, since many injured individuals move 100 m to 600 m outside the right-of-way before dying in the vegetation (Ascensão & Desbiez 2022). Therefore, the 14 fatalities recorded in Mineiros in 3 months suggest that the estimated real mortality may reach dozens of individuals annually on the GO-341 and BR-364 highways.

In addition, aspects such as poorly maintained pavement, expanding cropland areas, pastures around the highways, and little signage, added to the absence of speed cameras that control the permitted speed limit on the road, contribute to the scenario of vehicle-collision mortality of these animals in the state of Goiás. Thus, emphasis is placed on the state legislation for the mitigation of wildlife roadkill (Law No. 20,340/2018), which determines the adoption of measures to prevent accidents with wild animals on state highways, establishing obligations such as adequate signage, educational campaigns, and, when necessary, the implementation of wildlife crossings. Although lacking technical detail, the law recognizes the problem of roadkill and assigns responsibilities to public managers and concessionaires (Brasil 2026). Currently, the protection devices on the analyzed highways are restricted to a few wildlife warning signs in poor condition and without strategic location guided by *hotspots*. To ensure the effectiveness of biodiversity protection and driver safety, the adoption of an integrated strategy based on technical guidelines is recommended (Abra et al. 2020; Rytwinski et al. 2016; Saito & Balestieri 2021).

Studies applied in Brazil confirm that isolated wildlife underpasses have very low efficiency if they are not associated with guiding fences (Rytwinski et al. 2016). For ungulates such as the tapir (*T. terrestris*) and large carnivores such as the jaguar (*P. onca*), the installation of wide-section concrete culverts (dry box with a crossing walkway for rainy periods) integrated with high-strength mesh fencing (minimum height of 1.80 m to 2.20 m) along critical sections (GO-341 km 8–32 and BR-364 km 20–30) is the most recommended measure (Abra et al. 2020; Saito & Balestieri 2021). For xenarthrans such as the giant anteater (*M. tridactyla*) and the southern tamandua (*T. tetradactyla*), which avoid enclosed structures without fencing, guide fencing is indispensable (Noonan et al. 2021).During the present survey, it was evident that wild specimens are frequently found dead both on the roadway and on the shoulders. In addition, regular cleaning of the right-of-way by road agencies can be carried out to remove fallen grains and carcasses, in order to avoid attracting herbivores, coatis, and scavengers to the roadbed, as highlighted by CETESB (2018) and Pagotto (2021).

Table 1. Species of wild animals killed by vehicle collisions on the GO-341 and BR-364 highways in the municipality of Mineiros (GO) between March and May 2024

| ***Class / Order*** | ***Species (Common Name)*** | ***Quantity*** | ***Frequency (%)*** | ***Highway and Section (km)*** | ***Threat Status (ICMBio 2026)*** |
|---|---|---|---|---|---|
| Mammalia/ Carnivora | *Cerdocyon thous* (Crab-eating fox) | **3** | 21,43% | GO-341 (km 92 and others) | Least Concern (LC) |
| Mammalia/ Carnivora | Leopardus pardalis (Ocelot) | **2** | 14,29% | GO-341 (km 28 and others) | Vulnerable (VU) |
| Mammalia/ Carnivora | *Leopardus tigrinus* (Oncilla) | **1** | 7,14% | GO-341 (km 22) | Endangered (EN) |
| Mammalia/ Carnivora | *Leopardus geoffroyi* (Geoffroy's cat) | **1** | 7,14% | BR-364 (km 16) | Least Concern (LC) |
| Mammalia/ Carnivora | *Panthera onca* (Jaguar) | **1** | 7,14% | GO-341 | Vulnerable (VU) |
| Mammmalia/ Carnivora | Nasua nasua (South American coati) | **1** | 7,14% | GO-341 (km 8) | Least Concern (LC) |
| Mammalia/ Carnivora | Chrysocyon brachyurus (Maned wolf) | **1** | 7,14% | GO-341 | Vulnerable (VU) |
| Mammalia/ Perissodactyla | *Tapirus terrestris* (Lowland tapir) | **1** | 7,14% | BR-364 (km 24) | Vulnerable (VU) |
| Mammalia/ Pilosa | Myrmecophaga tridactyla (Giant anteater) | **1** | 7,14% | GO-341 | Vulnerable (VU) |
| Mammalia/ Pilosa | *Tamandua tetradactyla* (Southern tamandua) | **1** | 7,14% | GO-341 | Least Concern (LC) |
| Reptilia | Unidentified snake | **1** | 7,14% | GO-341 | Not evaluated |
| Total | **11 taxa identified** | **14** | 100,00% | GO-341 and BR-364 | **5 VU / 1 EN** |

Source: Prepared by the authors (2024)




Figure 1. Road-killed wild animals found on highways. A - Oncilla (Leopardos tigrinus), in dorsal recumbency on highway 341 Km 22 B – Crab-eating fox (Cerdocyon thous), in ventral recumbency on highway 341 Km 92 C - Ocelot (Leopardos pardalis), in right lateral recumbency on highway 341 Km 28 D – Geoffroy's cat (Leopardos geoffroyi), in left lateral recumbency on highway 364 Km16 E – South American coati (Nasua nasua), in left lateral recumbency on highway 341 km 8 F - Tapir (Tapirus terrestres), in right lateral recumbency on highway 364 km 24.Source: Authors' collection (2024)

## Conclusion

The assessment of presumed road mortality on the GO-341 and BR-364 highways, in the municipality of Mineiros (GO), confirmed the vulnerability of local wildlife to intense logistics traffic and landscape fragmentation in the Cerrado. Although the total number of carcasses recorded represents an underestimated sample, directly influenced by the detection bias inherent to vehicle-based monitoring, which favors the visualization of medium and large mammals to the detriment of smaller classes, the killing of species categorized as threatened with extinction by ICMBio (2026) highlights the need for immediate intervention on the roads.

The spatial distribution of the records demonstrates that animal crossings are not restricted to the limits of the buffer zone of Emas National Park, occurring significantly in rural and peri-urban sections near the urban core of Mineiros. This pattern reflects the intense movement of wildlife through the agricultural matrix and proves that the current mitigation infrastructure of the evaluated highways is insufficient, since the exclusive presence of warning signs does not act as a physical barrier to prevent specimens from accessing the roadways.

It is concluded that the effective mitigation of roadkill in Southwest Goiás requires the transition from passive measures to integrated physical interventions. The adoption of exclusion fences connected to wildlife crossings (underpasses or overpasses) is necessary, in addition to the installation of speed reducers in the sections with the highest occurrence. For the continuity and scientific refinement of this line of research, it is recommended that future studies adopt detectability correction methodologies (observer bias and carcass

removal rate) and use exact geographic coordinates, ensuring the rigorous basis required for the formulation of public policies on road engineering and conservation.

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