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FAUNA RUN-OVER MITIGATION MEASURES ON BRAZILIAN FEDERAL HIGHWAY CONCESSIONS

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ABSTRACT – In many countries, socioeconomic development is related to the expansion and maintenance of road infrastructure. In Brazil, most of cargo and passengers transport is road based. However, this transportation modality can cause negative impacts to biodiversity, once it promotes habitats fragmentation and biological flow's reduction. Once fauna run-over figures among the main impacts caused by roads, the implementation of measures to mitigate it is necessary. Thus, based on data gathered up until 2017, this paper aims to present information about fauna run-over mitigation measures in Brazilian federal highway concessions. For this study, 461 mitigation measures and 627 devices that can be used as fauna underpasses were registered, of which 334 are near legally protected areas. Moreover, there are currently 158 planned fauna run-over mitigation measures.

Keywords: Brazil, fauna run-over, highways, mitigation.

RESUMO (**Medidas de mitigação ao atropelamento de fauna em rodovias federais concedidas no Brasil**) – O desenvolvimento socioeconômico de diversos países está relacionado à expansão e manutenção da infraestrutura rodoviária. No Brasil, o modo rodoviário é o mais utilizado, todavia, as rodovias podem causar impactos negativos à biodiversidade, pois contribuem para a fragmentação de hábitats e a redução de fluxos biológicos. Dentre os principais impactos causados pelas rodovias, destaca-se o atropelamento da fauna, de forma que medidas de mitigação para esse impacto se tornam necessárias. Com base nos dados coletados até o ano de 2017, o presente estudo tem por objetivo apresentar informações quanto às medidas mitigadoras ao atropelamento de fauna silvestre presentes nas rodovias federais concedidas do Brasil. Foram cadastradas 461 medidas de mitigação, mais 627 dispositivos de engenharia que podem ser utilizados como passagens, sendo que, desse total, 334 encontram-se nas proximidades de áreas legalmente protegidas. Existem 158 medidas em fase de planejamento para serem implementadas.

Palavras-chave: atropelamento de fauna, Brasil, mitigação, rodovias.

Supplementary Material: Electronic Supplement (Tables SI and SII).

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INTRODUCTION

Brazil's road network is about 1.6 million kilometers long distributed among federal, state and municipal roads (CNT, 2017). According to the National Transportation Confederation – CNT, roads are the most used transportation modality, comprising about 61% and 95% of cargo and passengers' transportation, respectively, being the main factor for the integration of Brazilian transport system. Out of this total, only 212,866 kilometers are paved roads (CNT, 2017), from which 9,344.80 kilometers are composed by federal highway concessions (ANTT, 2018) under the regulation of the National Land Transportation Agency – ANTT.

However, the expansion and maintenance of such infrastructure negatively impacts biodiversity, once road projects reduce the connectivity of the native vegetation fragments (Trocmé, 2006), which directly contributes to the decreasing of biological flow and diversity.

In this context, fauna run-over figures as one of the main negative environmental impacts caused by road projects (Forman & Deblinger, 2000; Formam *et al*., 2003), so that the effects of roads and traffic over animal populations are object of numerous studies of the last decades, in many countries (Forman &Alexander, 1998; Trombulak & Frissell, 2000; Formam *et al*., 2003; Grilo *et al*., 2016).

It is estimated that this kind of impact may lead to death millions of terrestrial vertebrates every year in Brazil (Bager *et al*., 2016). Thus, yet there is no consensus over the dimension of the impacts caused by fauna's mortality and habitats fragmentation and its effects, the installation of structures aimed to facilitate fauna's road transposition has been adopted as a standard measure by great part of developed countries (Lauxen, 2012). The adoption of such mitigation measures has been required in the scope of environmental licensing and managing of federal highway concessions.

In this scenario, we have verified that the Brazilian Institute of Environment and Renewable Natural Resources – IBAMA usually demands the installation of mitigation measures as condition for emitting environmental licences related to road projects. Among these conditions, there are measures aimed to shift drivers' behaviour, such as road signs indicating collision risk in segments with high wild fauna incidence, as well as speed reducers, which are installed in locations of higher environmental sensibility (Lauxen, 2012).

It is also common the adoption of measures aimed at fauna's management that require the implementation or adaptation of engineering devices, such as the installation of different types of wildlife crossing structures or the adaptation of engineering structures, such as drainage devices and bridge spans (Lauxen, 2012; Clevenger & Huijse, 2011).

Among the measures that require installation or adaptation of engineering projects, wildlife-crossing structures stand out as devices that aim to allow the safe flow of animals between environments intercepted by road projects, which effectiveness has been studied in Brazil and in the world (Abra, 2012; Beckmann *et al*. 2010; Corlatti *et al*., 2009). The typology and scale of these structures are directly related to the ecology of the species of which the mitigation measure is aimed to assist (Trocmé, 2006), being classified basically in underpasses and overpasses and distributed in types described below.

The underpasses are engineering devices that allow animals to cross under the highway (Clevenger & Huijse, 2011), and the dimensioning of these passages is directly associated with the group of species to be favoured by them, which can vary from small species, such as amphibians and small mammals to medium and large species, such as deer and big cats. These structures' dimensions can vary between 0.30 and 7.00 meters wide and 0.30 to 4.00 meters high (Clevenger & Huijse, 2011). The length of underpasses varies according to the width of the highways on which they are installed. The efficiency of this type of device depends on drift fences, which intent to lead animals to crossing points. They are widely disseminated in several countries, such as the United States, Canada, the Netherlands, Germany, Spain and Portugal. In Brazilian highways, underpasses are the most used type of mitigation device (Lauxen, 2012).

On many occasions, engineering devices, such as bridge spans and drainage galleries, can be adapted to work as wildlife crossing structures. It should be noted that these structures might constitute corridors for fauna dispersion, since they are usually associated with rainfall drainage areas and environments with native vegetation (Lauxen, 2012). Thus, simple adaptations, such as the installation of dry walkways and drift fences in these structures, may contribute to the fauna dispersion processes and to reduce run-over rates, according to studies conducted in Europe and North America (Iuell *et al*., 2003; Trocmé, 2006; Clevenger *et al*., 2001).

The overpasses are structures that allow animals to cross over the highways (Clevenger & Huijse, 2011) that can be configured as canopy crossings, which are designed to meet the arboreal and semi-arboreal species. They are associated with forest environments and aim to connect the treetops on opposite sides of the highways. These structures can be constituted by ropes intertwined with wood or metal structures, linked with the treetops also by ropes (Clevenger & Huijse, 2011).

Wildlife overpasses, which consists in a type of overpass, are mitigation measures of greater cost and complexity. These devices can be found in some countries, such as the United States, Canada, France, Spain, Germany, Switzerland and Australia (Corlatti *et al*. 2009; Jones, 2010; Clevenger & Huijse, 2011). Usually, they measure from 40 to 70 meters wide (Clevenger & Huijse, 2011) and their lengths are directly associated to the width of the highway on which these devices are intended to be installed. They are mainly aimed to serve larger land mammals, but can be used by several species, according to types of vegetation and environments implanted on these structures (Clevenger & Huijse, 2011). In Brazil, the implementation of wildlife overpasses was recently requested in the scope of the environmental licensing processes of three major infrastructure projects: Pará's Southeast Railway

Branch, in Pará State; the BR-280/SC highway duplication, in Santa Catarina State and Tamoios' highway works, in São Paulo State.

It is important to notice that the demand for fauna run-over mitigation is recent in Brazil, beginning in the first decade of the 2000s. Therefore, the environmental licensing agencies have required increasingly diversified conditions aiming at minimizing impacts on fauna.

In this scenario, the objectives of this study are: to present information regarding fauna run-over mitigation measures on federal highway concessions; to relate these measures to the presence of legally protected areas; and to present information regarding the mitigation measures planning and the using of wildlife crossing structures.

MATERIAL AND METHODS

- ***Study Area***

The federal highway concessions are distributed in a 9,344.80 kilometers long road network (ANTT, 2018), distributed among 20 concessions that are regulated by the ANTT. These highways intercept environments of the following Biomes: Amazon Forest, Cerrado, Atlantic Forest, Caatinga and Pampa (Figure 1).

- ***Database***

The information regarding quantity and locations of fauna run-over mitigation measures, as well as about the planned ones, were obtained from the ANTT's database, containing data gathered up until December 2017. Devices specifically built as wildlife crossing structures, as well as engineering devices, such as drainage gallery and bridges that could work as such, were considered in this study. In addition, the mitigation measures aimed at driver's behaviour alteration, such as signs and speed reducers were taken into account too, since they are installed near environmentally sensitive areas, potential fauna dispersion corridors and run-over occurrence spots.

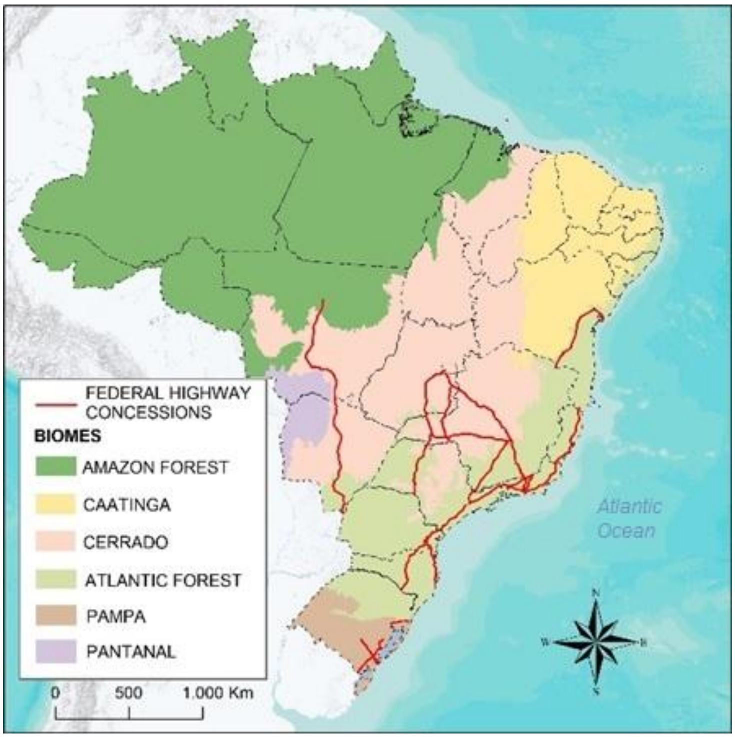

Figure 1. Federal highway concessions in Brazil and the Biomes intercepted by them.

- ***Indicatives of use of wildlife crossing structures***

In order to indicate the species recorded using wildlife crossing structures or engineering devices that work as so, we used information from ANTT's database, which were previously collected by those highway concessionaires monitoring the use of these structures: *Autopista Planalto Sul* (APL, 2017) *Concessionária da Rodovia Osório Porto Alegre* (CONCEPA, 2017) and *Concessionária Rio-Teresópolis* (CRT, 2017). The methodologies use in this type of monitoring include the use of camera traps, footprints recording and active search for fauna's traces, such as tracks and feces (Abra, 2012).

- ***Fauna run*-over *mitigation measures and legally protected areas***

Based on the mitigation measures data, we have created a map showing the distribution of those highways and measures in close proximity of legally protected areas. For that, we used Geographic Information System – GIS tools and shapefiles from the Brazilian Ministry of Environment – MMA. The legally protected areas consist in Conservation Units that are in the scope of Federal Law 9,985/2000, which established the National Conservation Units System – SNUC (Brasil, 2000). The areas considered to be in the influence zone of the highways were those within a radius of 3 kilometers, as dictated by the Resolution n. 428/2010 of the Environment National Council – CONAMA (CONAMA, 2010) and by the MMA's Ordinance n. 55/2014 (MMA, 2014a).

RESULTS AND DISCUSSION

- ***Quantity and typologies of fauna run-over mitigation measures on federal highway concessions***

On 9,344.80 kilometers of federal highway concessions we have recorded 461 mitigation measures, as well as 627 devices that can be used as fauna underpasses, like rainwater drainage devices or spans of bridges and viaducts that potentially work as animal crossing points.

Among the 461 mitigation measures, there are 35 devices that were installed specifically as wildlife crossing structures (Table 1), being 34 underpasses with drift fences and 1 canopy crossing, which are aimed to animals of arboreal and semi-arboreal locomotion habits.

Table 1. Quantification of fauna run-over mitigation measures on federal highway concessions.

Mitigation Measures	Quantities
Devices specifically installed as wildlife crossing structures	35
Measures aimed at drivers' behavior changing and fences	426
Total	**461**

The other 426 measures are distributed among fences along the roadsides and those aimed at drivers' behaviour changing. Regarding the mitigation measures aiming at driver's behaviour changing, a total of 397 devices were registered. They are distributed among speed reducers and road signs. It should be noted that such measures are installed at conservation interest spots, once they are associated with potential fauna dispersion routes, close to legally protected areas or near locations with high frequency of fauna run-over. In addition, there are 29 locations with fences that act as barriers to animal highway crossing (Table 2).

Table 2. Quantification and typologies of fauna run-over mitigation measures that are aimed at changing drivers' behavior on federal highway concessions and fences to prevent animal highway crossing.

Mitigations measures aimed at changing drivers' behavior	Quantities
Road signs	318
Speed reducers	79
Fences	29
Total	**426**

The 627 registered devices that can be used as fauna underpasses are distributed in three categories: drainage galleries, bridge spans and viaduct spans (Table 3).

Table 3. Quantification of engineering devices that can work as wildlife crossing structures on federal highway concessions.

Device type	Quantities
Drainage galleries	436
Bridge spans	179
Viaduct spans	12
Total	**627**

Among the recorded drainage galleries and bridge spans, 101 are somehow adapted to optimize their use by fauna. These adaptations include drift fences, with a total length of approximately 44 kilometers, as well as dry walkways adapted on drainage galleries and bridge spans. (Table 4).

Table 4. Typologies and quantification of adapted engineering devices that work as wildlife crossing structures on federal highway concessions.

Engineering devices' adaptation types	Quantities
Drift fences	90 locations
Dry walkways	11 locations
Total	**101**

- ***Quantity and typologies of planned fauna run-over mitigation measures on federal highway concessions***

Regarding the fauna run-over mitigation measures that are planned to be implanted, we have registered 253 structures (Table 5).

Table 5. Quantification and typologies of planned fauna run-over mitigation measures on federal highway concessions.

Type of planned mitigation measures	Quantities
Drift fences	104
Underpasses	94
Speed reduction devices	31
Canopy crossing	12
Road signs	10
Viaduct underpass	1
Wildlife overpass	1
Total	**253**

Among the planned devices, the wildlife overpass stands out as a structure covered by Atlantic Forest typical vegetation to be installed in BR-101/RJ highway, near the Biological Reserve – REBIO Poço das Antas and inside the Environmental Protection Area – APA São João. Those Conservation Units are located in Rio de Janeiro State, being notable for the occurrence of *Leontopithecus rosalia* (Linnaeus, 1766) (golden lion tamarin). This primate species is endemic to the Atlantic Forest, and its distribution is restricted to a small portion of that State (IUCN, 2017). Still, concerning conservation issues, according to MMA's Ordinance n. 444/2014, the species stands out as an endangered one in the Official List of Brazilian Endangered Species. The occurrence of other endangered species such as *Puma concolor* (Linneus, 1771) (cougar), *Alouatta guariba* (Humboldt, 1812) (brown howler monkey) and *Bradypus torquatus* (Illiger, 1811) (maned sloth), is also noteworthy.

There are also 10 canopy crossings that are exclusively aimed to species of arboreal or semi-arboreal locomotion habits, which are also planned to be installed in the region of REBIO Poço das Antas and APA São João.

- ***Use of wildlife crossing structures***

From the databases of three highway concessionaires, we have registered 21 species using bridge spans and drainage galleries as crossing points (Table 6). There are evidences of use by generalist species, that occur more frequently, as well as by species of relevant conservationist interest, which are in extinction risk, such as the smaller felines recorded using bridge spans of a highway in southern Brazil.

Table 6. List of wild mammal species of southern and southeastern regions of Brazil recorded using bridge spans and drainage galleries as highway crossing points.

TAXON	COMMON NAME
DIDELPHIMORPHIA	
Didelphidae	
Didelphis aurita (Wied-Neuwied, 1826)	Big-eared Opossum
Philander sp. (Brisson, 1762)	Four-eyed Opossum
PILOSA	
Myrmecophagidae	
Tamandua tetradactyla (Linnaeus, 1758)	Southern tamandua
CINGULATA	
Dasypodidae	
Cabassous tatouay (Desmarest, 1804)	Armadillo
Dasypus novemcinctus Linnaeus, 1758	Nine-banded Armadillo
CARNIVORA	
Canidae	
Cerdocyon thous (Linnaeus, 1766)	Crab-eating Fox
Procyonidae	
Nasua nasua (Linnaeus, 1766)	South American Coati
Procyon cancrivorus (G. Cuvier, 1798)	Crab-eating Racoon
Mustelidae	
Eira barbara (Linnaeus, 1758)	Tayra
Galictis cuja (Molina, 1782)	Lesser Grison
Lontra longicaulis (Olfers, 1818)	Neotropical Otter
Felidae	
Leopardus guttulus (Hensel, 1872)	Oncilla*
Leopardus pardalis (Linnaeus, 1758)	Ocelot
Puma yagouarundi (É. Geoffroy, 1803)	Jaguarundi*
ARTIODACTYLA	
Cervidae	
Mazama gouazoubira (G. Fischer, 1814)	S. American Brown Brocket
LAGOMORPHIA	
Leporidae	
Sylvilagus brasiliensis (Linnaeus, 1758)	Tapeti
RODENTIA	
Caviidae	
Hydrochoerus hydrochaeris (Linnaeus, 1766)	Capybara
Cuniculidae	
Cuniculus paca (Linnaeus, 1766)	Spotted paca
Dasyproctidae	
Dasyprocta sp. (Illger, 1811)	Agouti
Echimydae	
Myocastor coypus (Molina, 1782)	Coypu
Erethizontidae	
Coendou sp. (Lacépède, 1799)	Porcupine

* Species classified as vulnerable in the species at risk of extinction list given by the MMA Ordinance n. 444/2014 (MMA, 2014b).

- ***Mitigation Measures near Conservation Units and within the influence areas of federal highway concessions***

In total, we have recorded 127 Federal, State and Municipal Conservation Units within the influence areas of federal highway concessions (Electr. Suppl.: Tables SI and SII). Of this amount, 49 are Integral Protection Conservation Units while 78 belong to the Sustainable Use group (Figure 2). This scenario constitutes a landscape shaped by areas that may be fauna’s flow and dispersion spots and, in this context, are also points with potential high frequency of animal run-overs.

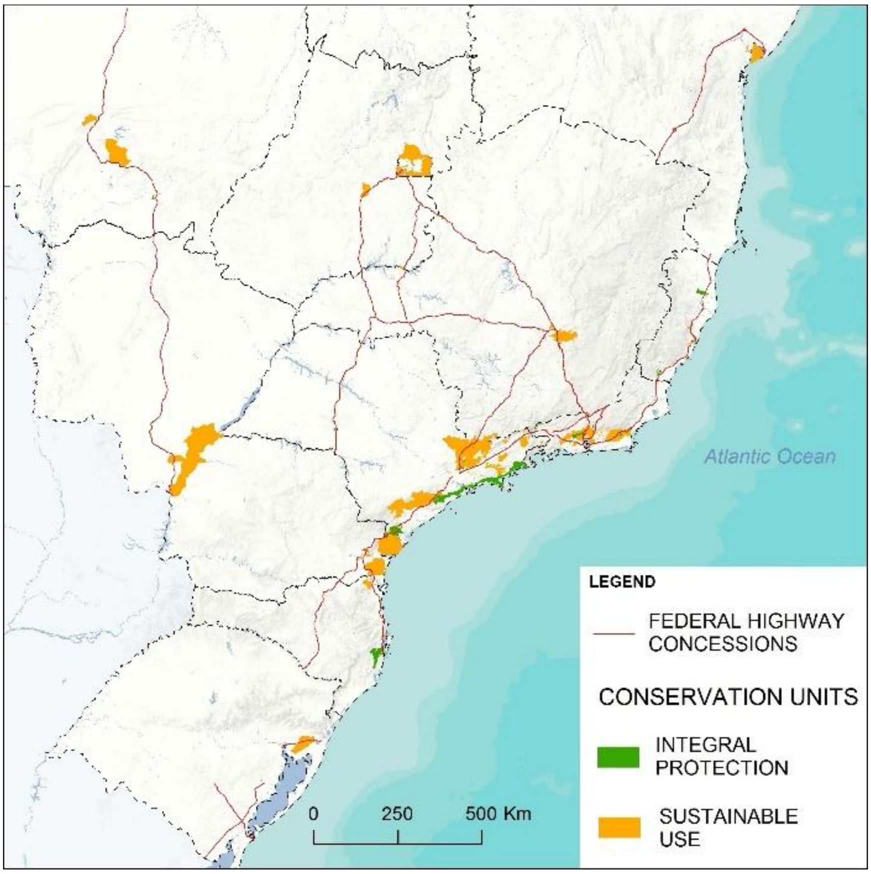

Figure 2. Conservation Units within the influence area of federal highway concessions.

Currently, there are 146 mitigation measures near Conservation Units, within the influence area considered in this study, being 119 road signs and 27 speed reducers. In addition, there are 115 drainage galleries, 49 bridge, 11 viaduct spans that may be used by fauna for highway crossing by and 9 fences that can act as barriers to animal crossing.

Moreover, there are 62 mitigation measures planned to be installed near Conservation Units, being 12 canopy crossings, 28 underpasses, 1 viaduct underpass, 1 wildlife overpass, 10 bridge spans adaptations, 3 drift fences spots and 7 road signs. Among these measures, those to be installed in the stretch of BR-101/RJ that intercepts the APA São João and touches the REBIO Poço das Antas, in Rio de Janeiro State, are worth to mention, being: 7 road signs, 10 adapted dry walkways on bridge spans, 10 canopy crossings, 15 underpasses and 1 wildlife overpass.

CONCLUSIONS

We have found that fauna run-over mitigation measures are already adopted in Brazilian federal highway concessions. Moreover, we have observed that new measures are planned to be installed on these highways.

As shown in international literature concerning fauna run-over mitigation measures, we have verified that engineering devices, adapted or not, can be utilized as fauna crossing over structures. Still, on this subject, we have found that the utilization of such devices occurs more frequently than the installation of fauna crossing over structures specifically designed to function as so.

Monitoring the use of crossing over structures by fauna is essential for verifying the effectiveness of these assemblies. In this context, we have identified that such monitoring is already taking place on federal highway concessions, which made possible the gathering of information about fauna species that are using engineering devices as highway crossing points, including endangered species (Table 6).

This study also quantified the mitigation measures near Conservation Units. In this sense, we have found that these measures are implemented or planned to be installed inside or around these areas, which may contribute to mitigate fauna run-over in these regions.

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