Roadkills of Lowland Tapir *Tapirus terrestris* (Mammalia: Perissodactyla: Tapiridae) in one of its last refuges in the Atlantic Forest

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Abstract: Highways limit the movement and dispersion of wild animals and contribute to their loss due to roadkills, leading to the isolation and decline of populations, increasing the risk of local extinction. The Lowland Tapir *Tapirus terrestris* is the largest neotropical herbivore-frugivore, and despite its wide distribution in South America it is threatened with extinction. In this study we report six roadkill events of tapirs between 2014 and 2019 in a section of a federal highway crossing the mosaic of Atlantic Forest reserves called Sooretama, one of the last tapir refuges in southeastern Brazil. The traffic in this area is heavy with inadequate speed control, while exotic fruit trees growing along the highway attract wild animals. Water drainage tunnels serve as passageways for some species, including tapirs. However, the tunnels located under the highway are not continuously maintained, reducing its effectiveness. The loss of at least one tapir per year can have serious long-term consequences for one of the last viable lowland tapir populations in the entire Atlantic Forest. Emergency measures are required to avoid vehicle-tapir collisions.

Keywords: Brazil, mitigation measures, road ecology, Sooretama, threatened species.

Editor: Priya Davijar, Sigur Nature Trust, Nilgiris, India. Date of publication: 26 November 2021 (online & print)

Citation: Banhos, A., A. Gatti, M.R.de D. Santos, L. Merçon, I. Westermeyer, N.C. Ardente, L.F.O.P. Gonçaga, L.M. Barreto, L. Damásio, T.L. Rocha, V.R. Schettino, R. Valls, H.G. Bergallo, M.V.F. Silva, A.S. Bittencourt, D.de O. Moreira & A.C. Srbek-Araujo (2021). Roadkills of Lowland Tapir *Tapirus terrestris* (Mammalia: Perissodactyla: Tapiridae) in one of its last refuges in the Atlantic Forest. *Journal of Threatened Taxa* 13:19921–19929. https://doi.org/10.11609/jott.6901.13.19921-19929

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Funding: This study was funded by the UFS, the Fundação de Amparo à Pesquisa do Espírito Santo (FAPES) [grant numbers 61901857/2013, 0607/2015, 510/2016, and 527/2016], the Fundação de Amparo à Pesquisa do Estado do Rio de Janeiro (FAPERJ) [grant number E26/201.267/2014], the Prociência of UERJ and National Council of Technological and Scientific Development (CNPq) [grant number 307781/2014-3 and 457458/2012-7].

Competing interests: The authors declare no competing interests.

Author details, Author contributions, Acknowledgements & Português abstract: See end of this article.
INTRODUCTION

Roads and highways lead to habitat loss and fragmentation, create barriers that limit the movement and dispersion of organisms, limit genetic flows, prevent wildlife from accessing resources that are vital for their survival, and cause direct animal mortality due to roadkill incidents, all with negative effects on biodiversity (Forman & Alexander, 1998; Trombulak & Frissell 2000; Coffin 2007; Laurance et al. 2009; Holderegger & Di Giulio 2010). Large mammal populations are among the most negatively affected by the presence of roads, mainly because they travel long distances, cross different roads, and have low reproductive rates and population densities (Fahrig & Rytwinski 2009).

In Brazil, one of the large mammal species affected by highways is the Lowland Tapir *Tapirus terrestris* (Linnaeus, 1758) (Grilo et al. 2018), the largest terrestrial mammal of Neotropics, with a body length of 1.70 to 2.00 m and weight up to 300 kg (Padilla & Dowler 1994; Eisenberg & Redford 1999; Medici 2011). This species presents the largest distribution within the genus and is found in the lowland regions of northern and central South America (Padilla & Dowler 1994; Eisenberg & Redford 1999; Varela et al. 2019). Despite its wide geographic distribution, the species is currently classified as Vulnerable, both globally (Varela et al. 2019) and in the Brazilian territory (Medici 2018). Nevertheless, in the Atlantic Forest, one of the most threatened biodiversity hotspots in the world (Myers et al. 2000), the conservation status of the Lowland Tapir is even more worrying because its habitat has been reduced to a few fragments and its population is extremely small, being reduced to a small number of areas (Medici et al. 2018).

The main conservation threats to the Lowland Tapir are habitat loss, poaching and competition with livestock (Garcia et al. 2012; Medici et al. 2012, 2018; Varela et al. 2019). However, in recent years, roadkill incidents with tapirs have attracted increasing attention due to their negative consequences. In Brazil, tapirs killed by collisions with vehicles have been reported in the Amazon (Carvalho et al. 2014; de Freitas et al. 2017), Pantanal (de Souza et al. 2015), Cerrado (Ascensão et al. 2017), transitional areas between Cerrado and the Atlantic Forest (Cáceres et al. 2010; Cáceres 2011), and the southwestern region of the Atlantic Forest (Medici & Desbiez 2012). These events are even more severe for tapir populations when combined with other threats, especially in the Atlantic Forest, where very few areas support viable populations of more than 200 individuals (Medici et al. 2012).

Here we report tapir roadkills and relate them to the species’ high locomotion ability combined with poor road management in one of the last areas with viable Lowland Tapir populations, located in the north of Espírito Santo State, southeastern Brazil (Flesher & Gatti 2010; Gatti et al. 2011; Medici et al. 2012; Ferreguetti et al. 2017), in a complex of protected areas known as Sooretama. Sooretama, which means “land of the animals of the forest” in the Brazilian native language Tupi Guarani (Instituto Brasileiro de Desenvolvimento Florestal 1981), consists of a group of four protected areas amount approximately 53,000 ha. These areas have been recognized as one of the best preserved large lowland forests with high priority for the conservation of large mammals in the biome (Galetti et al. 2009).

METHODS

Study area

We conducted the study in a forest complex formed by Sooretama Biological Reserve (SBR; 27,858 ha), a federal protected area; the Vale Natural Reserve (VNR; 22,711 ha), a private protected area; the Private Natural Heritage Reserves (PNHR) Recanto das Antas (2,212 ha) and the PNHR Mutum-Preto (379 ha) (Figure 1). This contiguous protected areas complex is one of the 77 Atlantic Forest remnants with more than 10,000 ha (Ribeiro et al. 2009), located between the coordinates -18.905458, -40.212713 and -19.244815, -39.945269, in the northern part of the Espírito Santo state, southeastern Brazil, hereon referred as Sooretama (Figure 1).

The Sooretama reserves form one of the largest remnants of Tabuleiro Atlantic Forest, a lowland forest (formed on sedimentary plains originated in the Pliocene) intersected by wide and shallow valleys (Rolim et al. 2016). The climate is tropical with dry winter (Aw) according to Köppen’s system (Alvares et al. 2013). Since the 1960’s, the Sooretama forest complex has been bisected by the busiest highway in Brazil, the federal BR-101 highway (Instituto Brasileiro de Desenvolvimento Florestal 1981) (Figure 1). Approximately 23 kilometers of BR-101 intersects the SBR buffer zone, with 5 kilometers crossing the interior of SBR (Figure 1).

Data collection

We obtained data on tapirs killed by collisions with vehicles on the section of BR-101 crossing Sooretama between 2014 and 2019. The roadkill events were reported to us by the SBR staff. We visited the sites,
recorded the date, the location on the highway, and the age class and sex of each animal. Necropsies were performed on individuals that were not in an advanced stage of decomposition. The tapir bones and heads were collected and deposited at the Museu de Ciências da Vida (Museum of Life Sciences), Federal University of Espírito Santo.

RESULTS

We recorded six events of tapir roadkills in the study area: two males (an adult and another juvenile) and four females (three adults and juvenile) (Figure 1; Table 1; Image 1). The second roadkilled tapir was a pregnant adult female with a well-developed male fetus (Últimos Refúgios 2014a; Image 2). Two other tapirs were found on the roadside in an advanced stage of decomposition, one on 17 September 2015, and another on 15 September 2019 (Table 1). The roadkill of the last tapir was reported by a highway user who saw the moment of the collision in the late afternoon, days before the animal being found dead. Four confirmed roadkills occurred at night and one afternoon, caused by two cars, two trucks, and one bus (Table 1). Five tapirs were roadkill on the stretch of the highway that cuts through the VNR, in the SBR buffer zone (Figure 1). Only the last roadkill happened within the SBR area (Figure 1).

Table 1. Records of roadkill events of lowland tapirs in a section of BR-101 highway that crossing the Sooretama complex, in southeastern Brazil.

| Date       | Sex     | Life stage | Km   | Period | Vehicle type |
|------------|---------|------------|------|--------|--------------|
| 30.vi.2014 | male    | adult      | 119  | night  | truck        |
| 24.x.2014  | female  | adult      | 121  | night  | car          |
| 08.ii.2015 | male    | juvenile   | 116  | night  | car          |
| 17.x.2015  | female  | adult      | 120  | unidentified | unidentified |
| 17.xii.2018| female  | adult      | 119  | night  | bus          |
| 15.xi.2019 | female  | juvenile   | 105  | afternoon | truck        |
DISCUSSION

In the six decades since its construction, many animals of various species have been killed on this portion of the BR-101 (Instituto Brasileiro de Desenvolvimento Florestal 1981; Klippel et al. 2015; Srbek-Araujo et al. 2015; Damásio et al. 2021). Since 2014, we have followed roadkill records of tapirs to understand their negative effects on the conservation of the species in the forest complex of Sooretama. Roadkill records described in this study are extremely worrisome for the lowland tapir conservation on Espírito Santo, as well as on the Atlantic Forest biome as a whole. There is only one known record from before the monitoring period of a Lowland Tapir killed via a vehicle collision in the neighboring area of Sooretama. This occurred in 1997, when a school bus hit a tapir on an unpaved road located south of Sooretama reserves, in Córrego Farias, municipality of Linhares (Lorenzutti & Almeida 2006). Unlike this isolated record, this study shows that the loss of Lowland Tapir due to vehicle collisions is an old problem in the region, emphasizing the role of this threat in removing individuals of reproductive age from the population of Sooretama.

It is possible that some tapir deaths due to collisions were not recorded. Animals may have died in the forest due to injuries resulting from a collision, or carcasses may have been lost for other reasons. For instance, two tapirs were found only days after they were roadkilled, when the presence of vultures and decaying animal smell near the highway was noticed. Nonetheless, on 21 July 2019 we received notification of another tapir roadkill on BR-101 but its carcass was not found. Thus it is likely that we underestimated the number of tapir roadkills.

Tapir roadkills occurred most often at night and outside of the SBR area, on a stretch of highway within VNR fragmented forest. These factors must be considered in designing mitigation strategies. In addition to tapirs, other large mammals have been killed within the SBR area, including a Jaguar Panthera onca in 2000 (Srbek-Araujo et al. 2015) and two Pumas Puma concolor, one in 2009 (Srbek-Araujo et al. 2015) and another in 2015 (Últimos Refúgios 2015).

Roadkill events can rapidly reduce tapir population growth and increase the probability of local extinction, especially when adults and sub-adult females are lost (Medici & Desbiez 2012). Tapirs are long-lived and have slow reproductive rates, which makes the species more vulnerable to anthropogenic pressures (Medici & Desbiez 2012; Medici et al. 2012; Varela et al. 2019). In Sooretama, of the six recorded tapir kills, four were adult and sub-adult females. According to Ferreguetti et al. (2017), the population size in Sooretama was 200±33 individuals, which suggests that the local population is genetically and demographically viable, based on the population viability analysis for the species in the Atlantic Forest (Gatti et al. 2011; Medici & Desbiez 2012). However, the incidence of female roadkill can be a warning for the long-term survival of the population. Tapir population reduction and even extinction can result in the loss of ecological services, such as seed dispersal (Barcelos et al. 2013; Bueno et al. 2013; Giombini et al. 2016; Paolucci et al. 2019), since they are responsible for dispersing seeds of high wood density trees that store tons of carbon, thus providing an ecological service with an estimated worth of billions of dollars (Bello et al. 2015; Peres et al. 2015).
Wildlife underpasses and their use by tapirs on the BR-101 highway

The stretch of the BR-101 that intercepts Sooretama is a straight paved road with 23 water drainage culverts (hereafter “tunnels”), and some of them are used by wild species (Banhos et al. 2020). Five of these tunnels are tall and wide (more than 2 m in diameter) and are frequently used by mammals, such as lowland tapirs. Since 2014, the use of these tunnels by wild animals has been monitored using camera traps, and tapirs were registered using the crossings (Video 1). Despite this, the six killed tapirs were found close to the big tunnels (between 5 m and 800 m away), at km 106, 116, 119, and 120.

Although wild animals are using the tunnels in the area, the lack of maintenance and cleaning of the structures results in tunnels completely obstructed by sediments, branches, and tree trunks, often precluding the use by of wildlife. During the camera trap monitoring period, we did not witness any event of tunnel maintenance or cleaning. Occasionally, we cleaned the tunnels ourselves. On 22 September 2015, a camera recorded an attempt by a tapir to cross the tunnel at km 120, which was blocked by fallen bamboo branches (Video 2). We confirmed in the images of the cameras that the blockade happened on 11 September 2015 and that a tapir went through the tunnel days before, on 8 September 2015. Five meters from the tunnel entrance, a tapir was found dead on 17 September 2015.

Tunnels are often used as wildlife passages and are therefore one of the measures used to mitigate roadkill incidents. Even though the tunnels in BR-101 were not originally installed as a mitigation measure, they are often used for crossings by some species. Thus, these tunnels make the highways less risky for wildlife (Clevenger et al. 2001; Goosem et al. 2001; Cain et al. 2003; Taylor & Goldingay 2003; Dodd Jr. et al. 2004; Ascensão & Mira 2007; McCollister & Manen 2010; Lesbarrères & Fahrig 2012). However, periodic maintenance of the tunnels is necessary so that they can be effectively used by fauna.

Socioeconomic impacts and risks for highway users

The high speed of vehicles is one of the factors that increases the risk of roadkill events (Forman & Alexander 1998; Fahrig & Rytwinski 2009), and the large-sized vertebrates killed along the BR-101 highway in Sooretama in recent years are indicative of that. It was not uncommon to observe reckless drivers that ignored the speed cameras when they were operating.

From June 2014 and October 2016, we measured the speed of vehicles (including cars and trucks) driving between the 102 and 107 km stretch of the BR-101 that intercepts Sooretama, in both directions, using a hand-held speed camera (Bushnell®). In addition, in February 2020, we measured speeds at km 102 and km 107. Measurements were conducted in the morning, afternoon, and evening on different days. The maximum speed limit allowed along the 23 km of the BR-101 that intercepts Sooretama is 80 km/h (from km 101 to 102 and km 107 to 124) or 60 km/h (from km 102 to 107, the stretch that intercepts the SBR). From 2011 to 2017 there were electronic speed monitoring devices (radars) at the beginning and end of the 60 km/h stretch, but in 2017, the radars were removed. The speed of 580 vehicles was measured in the 80 km/h limit stretch of the BR-101 that intercepts Sooretama, 70% of the vehicles exceeded the speed limit, the lowest recorded speed was 48 km/h, the highest recorded speed was 170 km/h, and the average speed was 92 ± 20 km/h. In the 60 km/h limit stretch, we measured the speed of 662 vehicles, of which 80% exceeded the speed limit, the lowest recorded speed was 36 km/h, the highest recorded speed was 138 km/h, and the average speed was 76 ± 18 km/h. In February 2020, the speed of 40
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Roadkills are a major threat to biodiversity, but they can also cause a great impact on human health and safety because they can result in serious accidents, which risk human health/life and come at high economic costs (Seiler 2005; Huijser et al. 2009; Freitas & Barszcz 2015). For example, accidents with large-sized animals, such as tapirs, can result in serious human injury or death (Freitas & Barszcz 2015). Between 2014 and 2020, over 30 human deaths occurred in accidents at 23 km of the BR-101 in Sooretama. However, it was not possible to confirm whether these accidents involved animals on the road. In a collision with a tapir in Sooretama (on 24 October 2014), the car driver obtained severe injuries and was hospitalized. The resulting costs from vehicle-animal collisions are high, but these accidents can be avoided or reduced by implementing mitigation measures that increase the safety of roads and reduce the damage caused by this type of accident (Huijser et al. 2009).

Emergency measures

The BR-101 poses one of the major threats to the biodiversity of the Sooretama region because of its negative effect on species. In addition, there are concerns about the duplication plan for the BR-101 highway, which could be implemented in the coming years, including the duplication of the stretch that intercepts the protected areas (Srbek-Araujo et al. 2015). Among the proposals to mitigate the impacts of the BR-101 duplication, there is the construction of viaducts for cars and wildlife bridges, or the relocation of the vehicle flow to areas with a lower conservation priority (Srbek-Araujo et al. 2015). However, until the mitigation of the highway expansion is resolved, accidents will continue to kill animals, including lowland tapirs. Thus, due to pending permanent mitigation measures for the highway expansion, emergency measures must be taken to avoid wildlife accidents.

There are several commonly used mitigation measures for reducing wildlife-vehicle collisions (see Goossem et al. 2001; Clevenger 2005; Glista et al. 2009; van der Ree et al. 2009; Lesbarrères & Fahrig 2012; van der Griff et al. 2013; Rytwinski et al. 2016), and high-cost mitigation measures are reported to be more effective in reducing accidents with large mammals (Rytwinski et al. 2016), although they require more planning and time to implement. However, some mitigation measures can be implemented quickly and without high costs, which would substantially reduce fatal accidents (Lester 2015). In 2014, during the workshop “Impactos da rodovia BR-101 na Reserva Biológica de Sooretama: Estudos, Alternativas e Mitigação”, a multidisciplinary team of experts (see Últimos Refúgios 2014b) recommended the following emergency measures: (1) the maintenance of the drainage culverts to serve as wildlife passages; (2) the elimination of jackfruit trees Artocarpus heterophyllus, mango trees Mangifera indica, and other exotic fruit trees that grow on the margins of the highway and attract wildlife; (3) a speed limit reduction to 60 km/h along the whole stretch; (4) the installation of speed bumps and electronic speed monitoring devices along the whole stretch; (5) the installation of warning signs informing about the possibility of wildlife crossings and risk of wildlife accidents; and (6) the monitoring of the effectiveness of the implemented mitigation measures (Universidade Federal do Espírito Santo 2014). The mitigation measures were discussed with the Federal Public Prosecution Ministry and agreed upon with the other regulatory bodies, including the National Land Transport Agency and Chico Mendes Institute for Biodiversity Conservation, as well as representatives of the company responsible for the highway administration. However, more than seven years have passed and only one recommendation has been implemented (the removal of fruit trees from km 119 to 123 in August 2018). If all measures had been implemented as proposed, fatal accidents involving wildlife that have occurred in the following years of the workshop could have been avoided. From the proposal of the measures until the conclusion of this article, an average of one tapir died per year.

We agree that the relocation of the BR-101 highway from Sooretama is the best measure to guarantee the conservation of the landscape and local biodiversity for the long term. Sooretama has a long history of protection that precedes the existence of the highway, with all administrative acts that guarantee its conservation documented (Instituto Chico Mendes de Conservação da Biodiversidade 2019; Instituto Brasileiro de Desenvolvimento Florestal 1981). The highway was built across the protected area in the late 1960s, even though this was prohibited by the Forest Code (Instituto Brasileiro de Desenvolvimento Florestal 1981). Furthermore, no documents were found that show the administrative act that allowed the construction of this...
highway within Sooretama. As a result, the preservation of the local biodiversity is jeopardized because one of Brazil's busiest highways crosses the interior of this protected areas complex.

CONCLUSION

The BR-101 highway represents a great threat for the conservation of the lowland tapir and many other species in the forest complex of Sooretama, one of the last regions that harbors viable tapir populations in the Atlantic Forest. The maintenance of tunnels used by fauna is necessary to mitigate the impact of road, but it is not a definitive solution for the fauna roadkill. In addition to the loss of biodiversity, vehicle collisions with tapirs result in risk to human life, economic losses, and loss of valuable ecological services. Emergency mitigation measures must be implemented to avoid further losses due to the chronic impact of the highway on biodiversity along the stretches that cross the protected areas of Sooretama region. Furthermore, we suggest building a detour to remove the BR-101 highway from within Sooretama.

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In the Atlantic Forest, roadkills of large mammals are a significant threat to wildlife. To address this issue, several mitigation strategies have been implemented to reduce collisions and improve habitat connectivity.

1. **Cost-benefit analysis of mitigation measures**: Studies such as those by McGowen (2009) and Klippel et al. (2012) have evaluated the effectiveness of different mitigation measures, including underpasses and fencing, in reducing wildlife mortality on roadways.

2. **Population viability analysis**: Medici et al. (2012) used modeling to assess the viability of tapir populations in fragmented landscapes, highlighting the importance of preserving corridors and corridors.

3. **Adaptive management**: Efforts to restore habitat connectivity for large mammals, such as the Brazilian tapir Tapirus terrestris, have focused on creating wildlife corridors to ensure long-term persistence.

4. **Mitigation strategies for the Brazilian tapir**:措施 aimed at reducing collisions with tapirs in degraded areas have included wildlife crossings and fencing along roads to enhance population viability and genetic diversity.

5. **Impacts of road connectivity**: Researchers have studied the impacts of road connectivity on tapir distributions and adaptability, with a focus on maintaining genetic integrity and ensuring long-term survival of populations.

6. **Population distribution and adaptability**: The adaptability of the genus Tapirus terrestris has been studied in fragmented landscapes, with efforts to maintain population viability through habitat restoration and connectivity.

7. **Socio-cultural aspects**: The role of social and cultural factors in the management of wildlife populations has been explored, highlighting the importance of community involvement in conservation efforts.

8. **Population monitoring and connectivity**: Continued monitoring of wildlife populations and connectivity patterns is crucial for effective conservation planning and adaptive management strategies.

These studies and initiatives emphasize the need for a comprehensive approach to conserving large mammals in the Atlantic Forest, integrating habitat connectivity, population viability, and socio-cultural considerations to ensure the long-term survival of these species.
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Resumo (Português): As rodovias limitam a movimentação e a dispersão de animais silvestres e contribuem para a perda de indivíduos por atropelamento, levando ao isolamento e ao declínio das populações, aumentando o risco de extinção local. A anta brasileira Tapirus terrestris é o maior herbívoro-frugívoro neotropical e, apesar de sua ampla distribuição na América do Sul, está ameaçada de extinção. Neste estudo, nós relatamos eventos de atropelamento de antas, entre 2014 e 2019, em um trecho de rodovia federal BR-101 que intercepta um mosaico de reservas da Mata Atlântica, denominado Sooretama, um dos últimos refúgios de antas no sudeste do Brasil. O tráfego de veículos nesta área é intenso, com controle inadequado de velocidade, enquanto árvores frutíferas exóticas crescem ao longo da rodovia atraindo animais silvestres. Túneis de drenagem de água servem de passagem para algumas espécies, incluindo antas. No entanto, os túneis localizados sob a rodovia não recebem manutenção periódica, reduzindo a eficácia da perda. A perda de pelo menos uma anta por ano pode ter consequências graves a longo prazo para uma das últimas populações viáveis de anta brasileira em toda a Mata Atlântica. Assim, medidas emergenciais são necessárias para evitar colisões entre veículos e antas.

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Acknowledgements: We would like to thank the Chico Mendes Institute for Biodiversity Conservation for the permission to collect biological samples in the Sooretama Biological Reserve (number SISBIO 45446-3). Furthermore, we would like to thank the SBIR director, Eliton Lima, and the environmental analysts, Valdir Martins and Marcel Redling Moreno. We also thank our helpers: Yhuri Nóbrega, Alexandre Bastos, Bárbara Fonseca Dias, Brenner Farbes, Fabiana Mendonça Cruz, Genilson Tadeu Silva Junior, Jardel Brandão Seibert, Juliana Krüger Arpini, Maria Alice Moreira Machado, Moara Cuzzol Gomes, Paula Modenesi Ferreira, Savio Augusto de Souza Machado, and Thais Cordeiro Sathler Sperandio. Finally, we would like to thank Alexandra Rosa dos Santos and Eduardo de Sá Mendonça, from the Federal University of Espírito Santo. This study is part of a research program in biodiversity (PPBio MA).
Communications

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