

**Monitoring of highway impact on fauna as a component of
management of a protected area in the Brazilian Atlantic Forest**

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ABSTRACT

Although being conceived with economical and social significance, building roads is a high impact mechanism of landscape fragmentation, in which the involved environmental factors are not fully considered. The SP-613 highway segments the forest and divides in half the 34000 ha of Morro do Diabo State Park (MDSP), representing the major source of disturbance to the protected area's wildlife. A random monitoring was performed between 1989-1999 and counted 158 animals and 23 wild species killed in collisions with vehicles. Among these, 16% were endangered species. Data compiled between 2002 and 2010, following the same previous methodology, counted 46 dead animals and 15 species, indicating the geographic localizations of the collisions. A new stage of the monitoring was performed, with systematic data collection throughout two different periods: the first one with 197 days of monitoring and 56 days of sampling; the second one with 292 days of monitoring and 83 days of sampling. The species, sex, when possible, date, place and carcass conditions were registered, resulting in 29 individuals and 16 wild species. The three rounds of monitoring totaled 233 registered animals among 15 orders, 28 families and 33 impacted species. In this work, we revisit the data from the first two monitorings and present the analysis of the last survey, the most impacted species and the mortality rates after the adoption of measures aiming to diminish the fauna mortality along the highway.

KEY WORD: protected areas, highways, fauna, roadkill, fauna-vehicle collisions

INTRODUCTION

Pressures, threats and social-economic and environmental conflicts are common to protected areas since these were idealized and emerged in the geographic space built by mankind (DIEGUES, 1996). These factors are so relevant that the IV Worldwide Congress of Protected Areas concluded that for the full evaluation of protected areas' effectiveness it would be important to identify the elements that threaten them, both inside and outside the protected system, also suggesting a way of classifying them (UICN, 1993). In other words, the managers of protected areas often confront pressures and threats on a daily basis, having to build strategies to either cope with or adapt to them so these areas may accomplish their goals.

Highways dividing or passing by protected areas are sources of pressure that bring enormous trouble for the management of such areas and for biodiversity conservation, whether on habitat loss and fragmentation (FAHRIG, RYTWINSKI, 2009), high impact rates on biodiversity (e.g. roadkill; ABRA et al. 2021), by causing forest fires (Kumar et al., 2014), air, soil and water resources pollution (CALDERÓN-GARCIDUEÑAS, VILLARREAL-RÍOS, 2017) or yet noise (RHEINDT, 2003; FREIRE et al, 2011) and visual pollution, micro climate changes, making a way for dispersing exotic invasive species, among other impacts.

In protected areas some impacts are maximized when these infrastructures divide or pass by these areas, because they generally overlap important fauna and flora reserves and refuges (VAN DER ZANDE et al., 1980; AMARANTHUS et al, 1985; SCHONEWALD-COX, BUECHNER, 1991; LOPES e QUEIROZ, 1994; FORMAN, DEBLINGER, 2000; CLEVINGER, WALTHO, 2000; RODRIGUES et al., 2002; LAMY et al, 2006; SEMA-MT, 2007; FARIA E PIRES, 2012).

Collisions with wildlife are one of the main causes of unnatural removal of wild species individuals in Brazil, with estimates ranging between 14.7 (\pm 44.8) million (DORNAS et al., 2012) and 2 million mammals every year (GONZÁLEZ-SUÁREZ et al., 2018). In the state of São Paulo alone, the average estimate of fauna-vehicle collisions is 39.600 midsize and large mammals each year (ABRA et al., 2021).

Certainly, the number of fauna-vehicle collisions, from systematic monitoring or estimates, are underestimated, once the carcasses may be withdrawn from the road by

scavengers (RATTON et al., 2014; SANTOS et al., 2016) or even people (MEDICI, ABRA, 2019). Many animals, especially midsized and large ones, do not die on lanes or roadsides, but outside road domain (HUIJSER et al., 2006).

A recent management effectiveness study carried out on Serra do Mar State Park, the largest strict nature reserve of Brazilian Atlantic Forest, demonstrated that the impact caused by highways was considered the third major pressure source, supplanted only by hunting and precarious human resources. However, it is as frequent and worrisome as the extraction of non-timber forest products, lack or precariousness of human resources, invasion by exotic species, invasions, urbanization and contamination/pollution (FARIA et al, 2019). A research performed on highways of São Paulo shows the extent of this serious issue for fauna conservation, human security and economical aspects (ABRA, 2019).

On the other hand, there are few examples in Brazil of managers promoting adaptive management on protected areas with highways on their inside, articulating the landscape potential to road construction techniques (RIBEIRO e LIMA, 2017). Such techniques aim the mitigation of impacts and environmental communication, turning threat components into visitation attractions and valorization of these areas for ecotourism (DOUROJEANNI, 2003; LAMY et al, 2006; SORIANO, 2006; DUTRA et al, 2008; CONDE, 2009).

As Road Ecology aims to study the effects of roads on populations and communities of plants and animals (FORMAN et al., 2003), the systematic monitoring of their most evident effects on protected areas is an undeniable management and decision making tool for solving or mitigating these pressure sources.

It is impossible to imagine the world without paths, roads and highways. Yet, building and operating them inside or near natural environments cause lasting negative impacts, today known by science and reported by broad specific literature. Depending on the circumstances and conditions to which the biota components are subjected and the frequency and magnitude of the disturbances, the impacts can be irreversible, as the scenery outlined for the population of *Tapirus terrestris* of Morro do Diabo State Park (MDSP) (MEDICI, 2010).

It does not take long for research results with proper methodologies to express the need for intervention (BAGER, ROSA, 2011), even if it's often required a window of opportunity that comes from political will. In MDSP, monitoring has been undertaken since 1990 and three decades weren't enough to provide a complete solution to the problem (FARIA, PIRES, 2012). If data from this monitoring taken over time hadn't informed the responsible bodies, this matter wouldn't have assumed the proportions that led the community and the entities responsible for the park and the highway to debate and dialogue about it.

In this work, we present a new look on two previous monitorings (FARIA, MORENI, 2000; FARIA, PIRES, 2012) that are analytic reference for the data collected more recently, which is prime and essential to the protected area management and the impacts on biodiversity caused by the state highway stretch that cuts the state park. Therefore, this is an article dedicated to Morro do Diabo State Park (MDSP) management and the adaptive management of the SP-613 highway stretch that crosses the park.

MATERIAL AND METHODS

Morro do Diabo State Park - MDSP is located between coordinates 22°27' to 22°40'S and 52°10' to 52°22'W, in the municipality of Teodoro Sampaio, São Paulo. Its 33.845,33 ha hold the largest sample of semi-deciduous forest of the state and an exuberant biodiversity. It is managed by the Foundation for Forest Conservation and Production of the State of São Paulo - FF. Its fauna is represented by tapir (*Tapirus terrestris*), collared peccary (*Pecari tajacu*), brown howler monkey (*Alouatta fusca*), puma (*Puma concolor*), jaguar (*Panthera onca*) and other felines and black lion tamarin (*Leontopithecus chrysopygus*), besides more than 300 species of birds and 400 of lepidopterans (IF, 2006).

The State Park is segmented from east to west by the SP-613 highway, built on the first half of the 1970 decade, when studies about environmental impacts caused by building these infrastructures were not considered, but seen as opponents to development, even if the resulting effects were significant (IF, 2006). The SP-613 highway spans, inside the protected area, for a length of 14 kilometers (from kilometer 5,9 to 19,9) by 50 meters wide, with an approximate area of 70 ha, which creates a physical barrier to fauna, promotes fauna-vehicle collisions, increases the edge effect and facilitates the access of fire to the forest, among other damages that are not less important.

The SP-613 is a highway that fits into the "Primary Arterial System" (Sistema Arterial Primário), being a two-way traffic single lane that gives vent to SP-563 highway and access to the states of Paraná and Mato Grosso do Sul, besides serving the municipalities of Teodoro Sampaio, Euclides da Cunha, Rosana, and the hydroelectric plants of de Primavera and Taquaruçu. The traffic intensity is under 5.500 vehicles/day, but is often used by heavy vehicles, like multiple-trailer hauling trucks, that prefer it because this stretch does not have regular weighing inspection (DER, 2008).

At the time of its construction, eight wild animal passages were installed, suggested by the park's manager (GARRIDO, 1975), maybe the first mitigation measure of this kind in Brazil. A few years ago, the Road and Traffic Department (DER) installed four radar sets on kilometers 8, 13 and 18, on 2014, and on kilometer 10,3 in January 2017. It was agreed, between the managing organizations, that the speed limit in the MDSP highway stretch would be 70km/h, in the area considered as a Conflicting Use Zone according to the Management Plan (IF, 2006).

Data collection and analysis

Data was collected on the 14 kilometers stretch that crosses MDSP. The collection routine was of two days per week throughout two sampling periods: the first one from 08/01/2015 to 04/15/2016, adding up to 197 days of monitoring and 56 days of sampling; and the second one from 08/15/2016 to 06/30/2017, adding up to 292 days of monitoring and 83 days of sampling. The observations were carried out on alternate weekdays and on different times, more often from 8:00 to 11:00 AM and from 4:00 to 6:00 PM, raining or not, in accordance with the sampling effort discussed by Barger and Rosa (2011). The discontinuity within the periods were due to resource scarcity and occasional holdbacks.

This reasonable frequency of excursions is justified to avoid carcass deterioration and disappearance, whether by the action of scavengers or even damaging by other vehicles. Since it is not possible to retain the carcasses, these were removed to the vegetation alongside the road, preventing recounting and the possible attraction of animals that could be run over. For each individual hit, the following data were registered: date, coordinates, popular and scientific names, sex and carcass condition (HEGEL et al, 2012). Deaths of small sized (< 2kg) and midsized (2 to 10 kg) animals were registered according to Bagatini (2006) and Santos et al. (2010), while animals weighing more than 10 kg were considered large sized in this work.

The present monitoring's collections were performed two days per week, on alternate and never subsequent days, with a maximum three-day break between them, due to the understanding that even the small and midsized carcasses would be visually available, if they were not took by scavengers or dismembered by vehicles. Thereby, the estimate for the total number of animals smaller than 2 kilograms will follow Bagatine (2006); but given the maximum number of days the carcasses stayed on the road (3 days), we will adopt a factor two for midsized animals and a factor three for animals larger than 10 kilograms, restraining the underestimate for the data collection effort. The rate of encounter with hit mammals was calculated dividing the number of animals found on the road in the study period by the total of kilometers sampled (HEGEL et al, 2012; SANTOS et al, 2012).

In this monitoring we did a general scan on all the eight wild animal passages (Kms 7+400m, 7+800m, 8+400m, 13+700m (double), 14+600m, 14+700m and 15+900m) after the installation of the fauna conductive fences. We identified the four most promising passages in terms of localization, habitat quality and presence of traces (kms 13.7, 14.6, 14.7 and 15.9). In these, for 3 months we collected data twice a week, assessing footprints inside and outside the passages, which was facilitated by the presence of sand sediments carried for the entries and interiors of the tunnels. Such footprints were swepted after photographic record. Using these photographs allowed us to assemble a good image bank for the selected passages.

RESULTS

The three monitorings resulted in different record rates of fauna-vehicle collisions due to time and exactness of the sampling. Because of that, we are unable to compare the results, but they presented and still present valuable data and information for managing the road impacts on faunal biodiversity of the park. Regarding the first two monitorings, it is a revisit to the data for approaches not performed previously.

The 233 animals registered on the three monitorings are placed in 15 orders, 26 families and 33 species. The most affected taxa, according to collision frequency, are presented in Fig. 1. The list of species and frequencies registered on the three monitorings are in this paper's attachment.

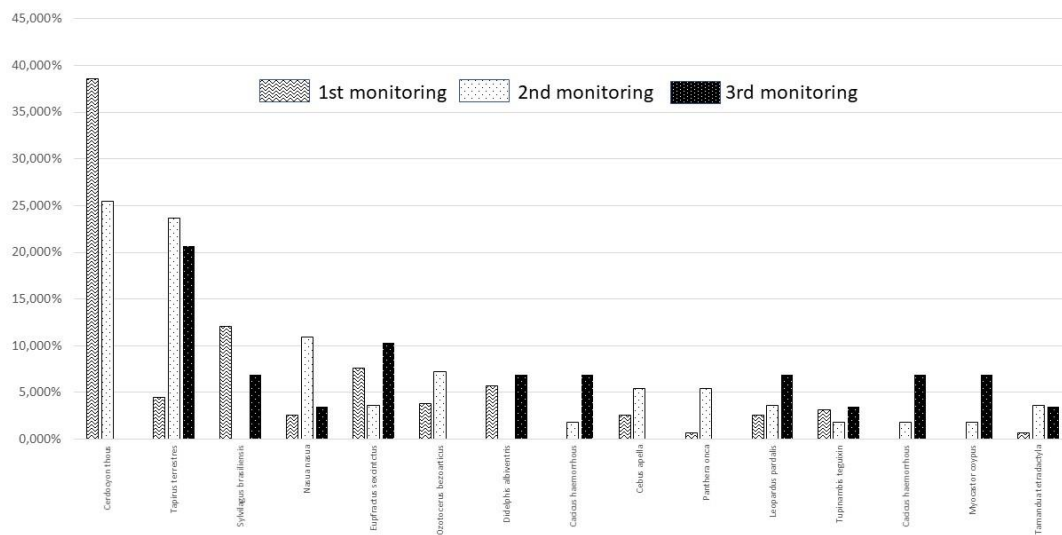
1st monitoring

The first data collection carried out by MDSP's management was presented by Faria and Moreni (2000), with an average 15,8 individuals/year in 10 years of data collection performed by the state park's team of park rangers (1990-99). These data were collected

according to fiscalization routines of the area, management conditions and sightings and alerts from highway users.

This monitoring brought the attention of responsible bodies and society to the tragedy of faunal mortality, providing important information to the management of the highway within the state park, such as: the faunal species registered in the period (n=23); the number of individuals of species somehow endangered, 25 individuals among 4 or 17% of endangered species according to the Ministry of Environment (MMA) (2014); the season of the year in which the fauna-vehicle collisions were more common, on winter and the dry season, agreeing to Turci and Bernarde (2008), who also got different results between the dry and rainy seasons.

Fig. 1: Most affected taxa in the three monitoring periods



Of all species listed by Faria and Moreni (2000), the high registration rates of *Cerdocyon thous*, 61 individuals in 10 years, draws attention; Faria and Pires (2012), based on records from 2002-2010, counted 12; and on the most recent surveys the species is not registered. This species inhabits from open areas to forest environments, but occurs more predominantly in open areas (TROVATI et al, 2007). This species, like others (opossum *Didelphis* sp. and tegu lizard *Tupinambis texiguim* p.e.), get used to human presence and take advantage of roads as food sources and may present super populations in the absence of their natural predators, who distance themselves from the road's disturbances.

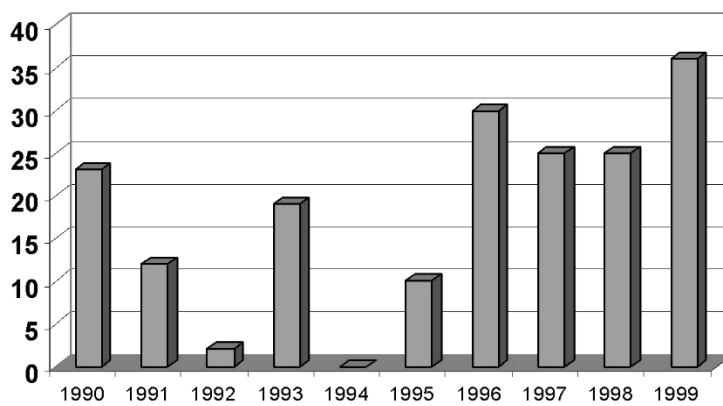
Empirically, the negative oscillation on *Cerdocyon* deaths may be associated with significant enhancement in habitat quality on the road's margins, where they were most commonly killed. This site was called "sapezal" due to the predominance of the grass *Imperata brasiliensis*, but it has been recovering, in the last 30 years, from the frequent forest fires that devastated the area, and currently the vegetation no longer resembles to savannah vegetation profile¹.

¹ In 2011, researcher Ademar Faria Coimbra-Filho (1924-2016), considered to be the Father of Primatology in Brazil and who rediscovered the black lion tamarim (*Leontopithecus chrysopygus*) in the MDSP forests in 1970, has visited the state park and noticed (wondered) the positive change in the

This is a quite optimistic scenario, but there's also the hypothesis concerning the decrease in the species' reproductive success as a function of population decline throughout time, a scenario that reflects itself on the food and ecological chain, which, in this case, requires testing hypotheses.

An aspect to be considered in this review is the years with minimum or no occurrences registered (Figure 2), in 1992 and 1994, which can be associated with resources and surveillance reduction, loss of the record sheets, park rangers' demotivation, management priorities or another unfavorable variable affecting data collection.

Fig. 2: Frequency of animals killed on SP-613 inside MDSP 1990-99.



Source: Faria, Moreni (2000)

In contrast, the graphic also shows a considerable increase on records of that sampling's last periods. Faria and Moreni (2000) explained by inferring that the vehicles technological improvements, making them faster and quieter, the creation of new municipalities and the establishment of agrarian reform's human settlements in the region were aspects that contributed to the rise of traffic on the highway. This increase on records may also be associated with the motivation stimulated by managers or researchers in the area at that point in time.

These questions lead to the intuition that the average number of animals hit during that period has been much greater than 15,8 individuals/year. It may reach or surpass the figure estimated by Barrella (2002)², of almost 1000 individuals in 10 years. This represents an extremely significant withdrawal of preys and predators from an island-shaped protected area, with, at that time, little ecological connectivity (CHAZDON et al, 2002).

2nd monitoring

The second data collection was taken between 2002 and 2010, collected in the same way as the first ones, and the temporal voids stand out, such as the lack of data in 2003. The episodes of vertebrate wild animals hit by vehicles started getting registered as Police Reports, being framed in the Environmental Crimes Law, 9.605/1998, by the local police station (FARIA,

successional stage of the park's vegetation. Especially those located alongside the road, between kilometers 6 and 8, in an area the park's crew used to call "sapezal".

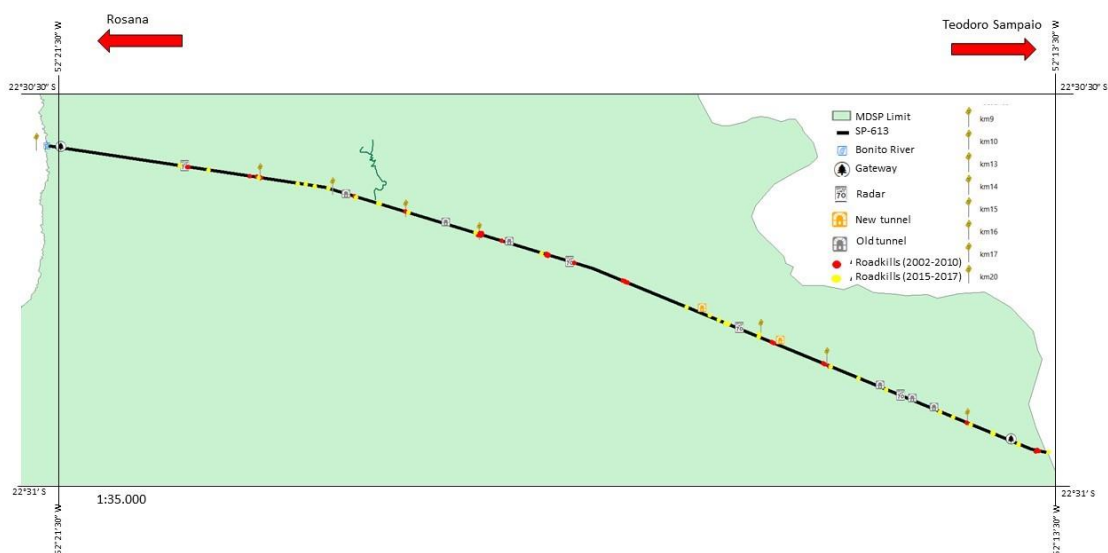
² Walter Barrella. Estimate of trampling and deaths of wild animals in MDSP. Personal Comm. Cited by Faria and Pires (2012).

PIRES, 2012); from 2005 on occurrences started getting georeferenced and entered into a digital database.

On this period, 46 animals and 15 species were accounted for; most of the victims being crab-eating foxes (*Cerdocyon thous* (n=14)), tapirs (*Tapirus terrestris* (n=13)), ring-tailed coatis (*Nasua nasua* (n=6)), pampas deer (*Ozotocerus bezoarticus* (n=4)), jaguars (*Panthera onca* (n=3)) and ocelots (*Felis pardalis* (n=2)), with a mortality rate of 7 individuals/year. Registering a specimen of *Myocastor coypus* was an unexpected fact, since it is considered to be an exotic invasive species, never seen before and absent from the mammal list found on the Management Plan, concluded in 2005 (IF, 2006).

This monitoring stage pointed out the parts of the highway in which the fauna-vehicle collisions were more frequent (Figure 3), allowing the park and road managers to define the location where the radar sets, which were claimed in a public civil action, would be installed, as well as the fences to conduct fauna to the wild animals passages.

Fig. 3: Sketch with tunnels, radar sets and collision sites registered on the 2nd and 3rd monitorings



3rd monitoring

This monitoring covered a total period of 489 days, with 139 days of sampling divided into two periods. It was carried on when the conductive fences were already installed by the side of the eight original wild animal passages and the four radar sets were also in operation.

29 individuals and 16 species were registered, with a high predominance of tapirs *Tapirus terrestris* among mammals; from the six accounted tapirs, two were lactating and, certainly, the offspring also died in the forest. We can highlight the two specimens of nutria (*Myocastor coypus*) found, whose records indicate their establishment in MDSP. The species inhabits from São Paulo to southern Brazil and is generally associated with water bodies, although they were found on the road next to dry forest areas.

Following the established methodology, we estimated the total number of animals hit per year as shown in the following table.

Table 1: Data collected in 2016-17 in MDSP

1st period	2nd period
197 monitoring days 56 collecting days	292 monitoring days 83 collecting days
489 monitoring days 139 collecting days Total sampled kilometers – 14 x 139 = 1946km 29 dead individuals 16 species Mammals – 22 (including 6 tapirs, 2 lactating) Reptiles – 2 Birds – 5	

For animals smaller than 2 kg the estimate was 31 collisions; for animals between 2 and 10 kg fourteen collisions and for those over 10 kg seven collisions, totalizing a possibility of 52 specimens/year, with a prevalence of 60% of small sized animals, which agrees with Santos et al. (2012). Among mammals, a substantial loss of *Tapirus terrestris*, 36% if we consider the offspring of the two lactating females.

For large sized animals the estimated deaths is similar to the observed reality, a statement supported by collection frequency and the animals size. However, for small and midsized animals it may be quite underestimated due to reasons pointed out by Rodrigues et al. (2002) and Milli and Passamani (2006), among others.

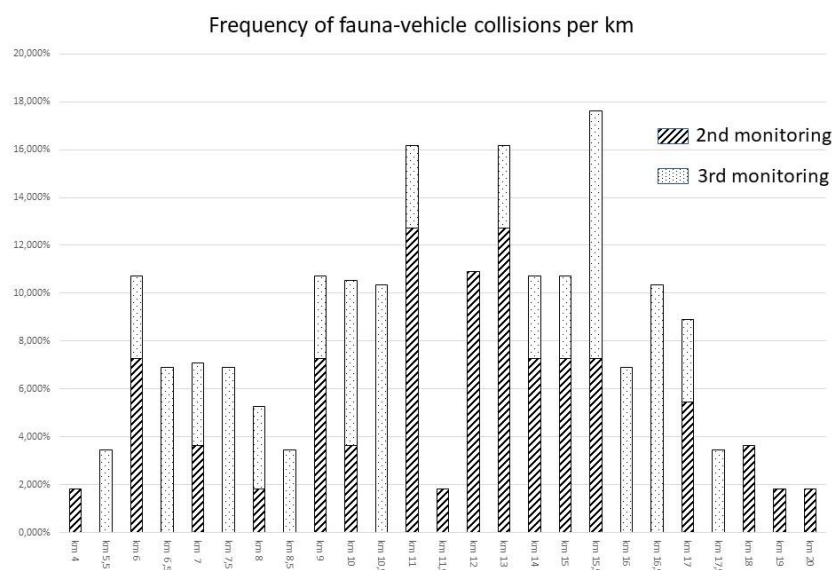
Distinctly, two of the collisions with tapirs took place right next to one of the radar sets (km 10) and, in 2018, another one happened on the same spot, which suggests an expected behavior from the highway users, who slow down next to the radar sets and accelerate after passing by them.

The *Tapirus terrestris* situation is concerning, since 6 individuals were killed in the monitoring period, one of the figures Medici (2010) used to perform scenarios analysis and reach a realistic prediction. Considering a population of 126 individuals in MDSP, an average of six individuals killed per year and a natality rate around 1,63 animals/year, the researcher concluded that this rate of collisions would take tapir population to local extinction in 38 years. This is a cruel scenario for the forest dynamics, given the species well known ecological function in these ecosystems.

Considering the 22 mammals specimens, the mortality rate was 22/1946 or 0,0113 individuals/km. This rate holds close relation to the collecting/observation technique (vehicle at 50-70 km/h) and the sampling effort (BARGER, ROSA, 2011). It does not take a sharp intuition to add up the consequences of simultaneously driving and observing the road and roadsides, even if it is at a low speed on a straight and smooth road. Even if mammals mortality rate appears to be low, it is recommended to compare this data to the dimensions populations have in MDSP and their consequences, as Medici (2010) did. On the other hand, this mortality data's greatest meaning for the park's faunal biodiversity management and conservation is the finding that to every 6 vehicles going through the highway there's a (good) chance of an animal being hit and killed.

There was a noticeable decrease in fauna-vehicle collisions next to the four radar sets, although it did occur in specific cases, demonstrating the user’s attitude of accelerating once they’re past them. There was also a concentration of collisions on kilometers 10 and 15 to 16,5 of the highway (Figure 4), differing from data compiled between 2002 and 2010, assessed to determine the radar sets’ installation locations (FARIA, PIRES, 2012). This reveals there was a spatial pattern “migration” on the collisions, which may have happened due to radar sets and conductive fences leading animals to contiguous areas. On the other hand, the slopes within the park favor gain in speed and raise collision risk, suggesting a need to find a solution for traffic flow that prevents these fatalities.

Fig. 4: Frequency of fauna-vehicle collisions along the road in MDSP through the 2nd and 3rd monitorings



Among the eight wild animal passages built by the time the highway was constructed, one is 80 centimeter in diameter, two are 1,45 meter in diameter and the others are rectangular, 1,5 meter wide by 1,7 meter high, most of them on natural drainage spots, where rainwater flow drains. It was observed that few species actually use these passages, which are mainly used by small and mid-sized animals, such as rats, small cats, agoutis, marsupials, armadillos and lizards³.

On the tunnel's entrance there were found footprints of crab-eating fox, crab-eating raccoon, tapir, deer, small birds and, probably, ocelot. Even though there is an intense trampling on the entrances, this is not observed in the passages interiors, a fact reported by Olmos (1996).

One of the passages attracted large sized animals, *Tapirus*, due to the formation of small rainwater puddles, a potential collision threat since there was no evidence of these animals crossing the tunnel (Figure 5). That was probably due to passage size, as suggested by Clevenger e Waltho (2000) about the ungulates preference for bigger tunnels, 2,4 meter high and 7 meter wide.

³ Identification provided by people with a lot of wilderness experience

Fig. 5: Wild animals passages 1,45m in diameter under SP-613 highway inside MDSP, with formation of rainwater puddles that attract animals.



Source: Authors

These devices may not perform the desired effectiveness, especially for megafauna, but three more passages were recently installed using the non-destructive “*tunnel liner*”⁴ technique. The passages have a diameter of 1,90m (kilometers 9+700m, 10+800m and 13+200m) and extended fences a hundred meters to the sides of the passages, which are located on the highway stretches where fauna-vehicle collisions are more frequent, according to data from the 2nd and 3rd monitorings.

The installation of conductive fences to the underground passages was of one the measures suggested by scientific literature (CLEVENGER, WALTHO, 2000; FARIA, MORENI, 2000; VAN DER ZANDE et al, 2009; NAUDERER, 2014; FIGUEIRÓ, 2017) implemented in MDSP, to which many authors agree to be the complementary measure to diminish fauna-vehicle collisions on highways. However, such devices may be increasing the effects of habitat fragmentation in MDSP, since they are another barrier for species genetic conservation. This aspect adds to the night workers report of a *Tapirus* specimen trapped on the lane between one of these fences. The ecological tension for arboreal species is minimized by the installation of aerial devices that involve structures of considerable dimensions (SECCO et al, 2014).

Besides the existing structures, reclaiming and implantation of appropriate environmental communication and education among users deserve attention, in the context of a Park Road concept (DOUROJEANNI, 2003; SORIANO, 2006), whether through a set of road signs adapted to this context, as there once was; or through ecological campaigns involving the interested social segments: Road and Traffic Department (DER), Environmental and Road Police, FF, local management, NGOs, management board and the community (PIRES, FARIA, 2015). Many national highway stretches crossing protected areas are examples of the opportunities for environmental communication with society, such as Biological Reserves of Sooretama and

⁴ Three underground passages costing US238.634,68 (R\$1.344.730,29) in 11/01/2022 (www.bcb.gov.br), investment made by the Road and Traffic Department (DER) in 2020.

União, in the states of Espírito Santo and Rio de Janeiro, respectively, and SP-139 highway in Carlos Botelho State Park in São Paulo⁵, among others.

FINAL CONSIDERATIONS

As initially stated, this is an article addressed to the management of a protected area and the road crossing it, in which the most relevant information is the persistence of road impacts on protected fauna. Although the first two monitorings hadn't followed a rigid scientific protocol, they generated valid information that resulted in the installation of radar sets and underground passages, including this kind of threat in the park and road managing organizations agendas.

The adoption of a technical protocol on the 3rd monitoring resulted in more robust data and a glance on new data processing detected some species sensibility to fauna-vehicle collisions, specially *Tapirus terrestris*, and pointed out some conclusions.

The radar sets installation caused a positive effect on highway users and decreased the fauna-vehicle collisions frequency on their proximities, but not along the whole highway stretch. Mortality rate is still high for a strict nature reserve in which the main goal is biodiversity conservation, an unacceptable condition that cannot be normalized.

The underground passages, including new ones, need to be monitored by more effective methods than trace observations. The use of photograph traps is recommended to prove their effectiveness on the patch in question, since, as shown by literature, their little effectiveness is due to their dimensions. For the arboreal species it is relevant to observe where primate groups occur near the highway so it is possible to find potential contact spots for planting trees and installing "aerial corridors", aiming to allow them cross the 50 meter "road-roadside-firebreak" set.

The persistence of collisions after new devices installation, radar sets and fences alongside underground passages, indicates that new alternatives need to be adopted on adaptive management of roads. Reducing vehicle speeds is considered, by the authors, to be the best solution and may be achieved by implementing and operating intelligent transportation systems, or simply "intelligent radar sets", which run on OCR (Optical Character Recognition) technology.

This is a high-tech system that gathers hardware, software and telecommunication resources that are able to extract and transmit the vehicles average speed data, from one point to another, registering it if it is above the established limit (Bernardi, 2014). Although it is already available in Brazil, this technology awaits DENIT regulations for use on Brazilian roads.

Adopting this system will eliminate the need for fences, common devices on roads, but represents yet another anthropic element in natural landscape, raising the habitat fragmentation effect and therefore antagonizing biodiversity conservation since it is a barrier to gene flow. An argument that supports this suggestion is the withdrawal/deactivation, on early 2021, of the four radar sets mentioned in this article. The reasons to it are unknown, but it is

⁵ In these highway stretches the informative/educational signs and panels follow distinct patterns from the rules applied to highways by the Traffic Infrastructure National Department (DENIT), but seem to be accepted by the regulatory body (authors' observation).

probably due to contract interruption or due date, and it is certainly contributing to increase average vehicle speeds and, therefore, vehicle-fauna collisions⁶.

Speed reduction may also be achieved by different interventions, as in the specific case of Morro do Diabo Geological Monument proximities, where slopes on the road favor gain in speed and fauna-vehicle collisions in both directions of the road. The Road and Traffic Department (DER) have installed, years ago, a rustic parking lot for Morro Trail visitors, the park's main attraction, a singular place and installation that associated with some sort of roundabout on the paved bed will be convenient to highway and trail users and also to conservation.

Ecological studies about the effects of park's defaunation, in consequence of the highway presence, on certain species, as *Cerdocyon thous* and *Tapirus terrestris*, that present high collision rates, should be encouraged and supported, aiming to establish answers about the conservation quality of these and other species, their influence in their respective populations and the protected habitat quality.

As demonstrated, the park's management already had its own highway monitoring system and dropped it with no plausible reason besides the most recent managers' profile and interests. Carrying out and maintaining a simple but effective monitoring system is fully doable, even with scarce human and material resources.

Taking into account that social participation in environmental management in Brazil has been gradually increasing, strengthening of the managing board by local management is considered to be quite pertinent and achievable so it is possible to develop collaborative monitoring methods with highway users, involving neighbors, regional agricultural companies workers and the municipality's citizens.

The environmental communication through signs with messages related to MDSP ecosystem needs to be brought back, like there was in the past when the park's management took advantage of local expertise, proposing and implementing 20 casual and cheerful educative/informative signs. The concept realization of parkways in MDSP depends on managing organizations, FF and DER, debating on road planning in ecosystem and fragmented landscape contexts and the impacts the road causes on biodiversity, a principle that should be followed for all interventions in the highway stretch, with proper participation of the Managing Board and other parts interested in effective park management.

⁶ Only in September 2021, two specimens of *Tapirus* were killed.

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Anexo 1. List of faunal species of Morro do Diabo State Park impacted by SP-613 highway in the three monitoring rounds presented.

Ordem	Família	Espécie	Nome popular
Squamata	Teiidae	<i>Tupinambis teguixin</i>	Tegu lizard
	Boidae	<i>Boa constrictor</i>	Python/Boa constrictor
	Colubridae	<i>Spilotes pullatus</i>	Yellow rat snake
	Viperidae	<i>Crotalus durissus</i>	Rattlesnake
Tinamiforme	Tinamidae	<i>Crypturellus sp</i>	Partridge chick
Falconiforme	Falconidae	<i>Caracara plancus</i>	Crested caracara
Cariamiformes	Cariamidae	<i>Cariama cristata</i>	Red-legged Seriema/Crested cariana
Cuculiforme	Cuculidae	<i>Piaya cayana</i>	Squirrel cuckoo
Passeriformes	Icteridae	<i>Cacicus haemorrhous</i>	Red-rumped cacique
Didelphimorphia	Didelphidae	<i>Didelphis albiventris</i>	Opossum
Pilosa	Myrmecophagidae	<i>Myrmecophaga tridactyla</i> *	Giant anteater
		<i>Tamandua tetradactyla</i>	Collared anteater
Cingulata	Dasypodidae	<i>Dasyus novemcinctus</i>	Long-nosed armadillo
	Chlamyphoridae	<i>Euphractus sexcinctus</i>	Six-banded armadillo
Primate	Callitrichidae	<i>Leontopithecus chrysopygus</i> *	Blak Lion Tamarim
	Atelidae	<i>Allouata guariba</i>	Brown howler monkey
	Cebidae	<i>Cebus apella</i>	Tufted capuchin
Carnivora	Canidae	<i>Cerdocyon thous</i>	Crab-eating fox
	Procyonidae	<i>Nasua nasua</i>	Ring-tailed coati
		<i>Procyon cancrivorus</i>	Crab-eating raccoon
	Mustelidae	<i>Eyra barbara</i>	Tayra
	Felidae	<i>Leopardus pardalis</i>	Ocelot
		<i>Leopardus sp.</i>	"Wild cat"
		<i>Panthera onca</i> *	Jaguar
<i>Puma concolor</i> *		Puma	
Perissodactyla	Tapiridae	<i>Tapirus terrestres</i>	Tapir
	Tayassuidae	<i>Pecari tajacu</i>	Collared pecari
	Cervidae	<i>Ozotocerus bezoarticus</i> *	Pampas deer

Artiodactyla Rodentia	Echimyidae	<i>Myocastor coypus</i>	Nutria
	Hyaeridae	<i>Hydrochaeris hydrochaeris</i>	Capybara
	Agoutidae	<i>Agouti paca*</i>	Lowland paca
	Dasyproctidae	<i>Dasyprocta azarae</i>	Azara's agouti
Lagomorpha	Leporidae	<i>Sylvilagus brasiliensis</i>	Brazilian rabbit