**Non-volant mammals of the Serra da Macaca ParkRoad (SP-139)**

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**ABSTRACT**

This study aims at performing a survey of the non-volant mammals that use the Serra da Macaca ParkRoad (SP-139), particularly after closing the road. A list of species was obtained through visual surveys and the use of photographic traps. The estimator of species richness Jackknife 1 was employed to estimate the expected richness. The similarity of species between campaigns was evaluated through the Jaccard similarity index (Cj) and the variations in the diversity rates were calculated using the Shannon-Wiener Index (H’). We recorded 12 species of non-volant mammals, of which four are considerered vulnerable to extinction in the State of São Paulo. A greated similarity was observed between the results of the second and fourth sampling campaigns. These results highlight the locomotion of non-volant mammals on the Serra da Macaca ParkRoad (SP-139), including medium and large sized ungulates and felines.

**Keywords:** Fauna collisions; Mammalia; Atlantic Forest; Roads; Species richness.

The Atlantic Forest biome in Brazil is a world hotspot for biodiversity (Pinto *et al*., 2006), accounting for the second largest richness for mammal species in the country, with 298 species. Of these, 90 species are endemic to the biome (Paglia *et al*., 2006) and about 18% are officially considered threatened species (ICMBio, 2018).

However, despite the great ecological importance of the biome, the original landscape of the Atlantic Forest has suffered profound alterations since colonial times (Brandon *et al*., 2005). It is estimated that only about 11.4% to 16% still remains of a forest that in the past covered over 150 million hectares (Ribeiro *et al*., 2009), a scenario attributed in large part to the uncontrolled exploitation of the natural resources (Pinto *et al*., 2006).

Protection areas are the cornerstone in the maintenance strategies for the lifecycles of wild populations *in situ* (Bruner *et al*., 2001). Likewise, the remaining fragments of Atlantic Forest in rural properties are also highly relevant in ecological terms (Galetti *et al*., 2009). Protection areas should, ideally, act as a network of forest spots interlinked by ecological corridors in order to enable the reproductive connections between metapopulations (Wegmann *et al*., 2014).

Mammal surveys have a wide range of aplications (Tobler *et al*., 2008). The most widespread techniques for studies of this nature include linear transections, direct observations, searches for traces (tracks, fur, feces), captures and interviews (Voss & Emmons, 1996). On the other hand, the use of camera traps has gained popularity in the last decades (Tobler *et al*., 2008).

Even though mammals are seldom mentioned as bioindicators (Siddig *et al*., 2016), there are reports that the taxon is an early indicator of the incidence of alterations in natural areas (Carvalho *et al*., 2016).

This study aims at performing a survey of mammals to obtain a list of species that use the Serra da Macaca ParkRoad (SP-139), focusing particularly during the period when the road is closed between 8 p.m. and 6 a.m. of the following day.

The Nequinho Fogaça Road (SP-139) was constructed in 1942 as an unpaved one-way road linking the highlands (São Miguel Arcanjo, State of São Paulo, in the Alto Paranapanemaregion) with the coastal plains (Sete Barras*,* State of São Paulo, in the Vale do Ribeira do Iguaperegion). This road crosses the Carlos BotelhoState Park (PECB), an integral protection conservation unit for the Atlantic Forest (Figure 1) that houses several rare endemic species (Beisiegel, 1999).

The project to pave and install improvements on the Serra da Macaca ParkRoad (SP-139), which is the popular name for the 33 km stretch of road crossing the PECB, was discussed during the establishment of the management plan for the Park. The paving project selected a type of ecological paving (using interlocked concrete blocks that allow better rainwater drainage and store less heat), installed a drainage system, regularized hillside protections and installed metallic protective fences. The work started on October 2013 and finished on November 2015.

The Serra da MacacaParkRoad (SP-139) was contemplated with a series of preventive measures to avoid collisions with the fauna. For instance, the road has a total of 16 overpasses (canopy bridges), 12 underpasses (bridges and culverts), speed limits of 40 km/h, nocturnal closure and two OCR devices (at the entrance and exit of the PECB).

Data was collected between 2018 and 2019 during four different campaigns (10 days each): March 2018 (1st C), July 2018 (2nd C), November 2018 (3rd C), and February 2019 (4th C). All statistical analyzes were conducted in the software “R” v. 3.5.1 (RSTUDIO TEAM, 2020).

Visual searches on the road consisted in a slow car travel (approximately 20 km/h) in both ways by two observers during the morning (6 a.m. to 9:30 a.m.) and night (8 p.m. to 10:30 p.m.) periods, totalling 5.280 km travelled.

For the sampling with camera traps, 16 sampling points were selected in the studied area (Figure 1). A digital camara trap (Bushnel® Modelo ZT820) was installed at each point for five consecutive nights, always after the road was closed for traffic, totalling a sampling effort of 320 cameras/night. The equipment was installed on vertical traffic signs at a height of 40 cm from the ground and were programmed to film.

The species accumulation curve was plotted based on the records collected for non-volant mammals through a combination of visual searches and camera traps. Species richness estimates were obtained using the Jackknife 1 estimator, performing 1.000 randomizations. Species dissimilarity between the sampling campaigns was measured through the Jaccard similarity index (Cj), which was adopted to build a dendrogram through the Unweighted Pair Group Method with Arithmetic (UPGMA). The diversity of non-volant mammals observed during the four sampling campaigns was compared through the Shannon-Wiener Index (H’).

The scientific nomenclature used followed Paglia *et al*. (2012) and the species were identified according to Reis *et al.* (2011). Threat status was based on the List of Threatened Species in the State of São Paulo (Bressan *et al*. 2009).

Twelve species of non-volant mammals were recorded during the study (Table 1 and Figure 2). Four of the recorded species were classified as vulnerable to extinction: the ocelot (*Leopardus pardalis* Linnaeus, 1758), the puma (*Puma concolor* Linnaeus, 1771), the lowland tapir (*Tapirus terrestris* Linnaeus, 1758) and the small red brocket (*Mazama bororo* Duarte, 1996). There were also two records of near-threatened species: the black-horned capuchin (*Sapajus nigritus* Goldfuss, 1809) and the agouti (*Cuniculus paca* Linnaeus, 1766).

The species accumulation curve for this study did not show the tendency towards complete stabilization with the sampling effort undertaken (Figure 3). This result indicates that a greater sampling effort would certainly result in the addiction of some species that were not sampled. The estimated species richness obtained through the non-parametric estimator Jackknife 1 was 14.92 species (± 1.7).

The dissimilarity observed between campaigns two and four was the lowest (Cj = 0.20) – with eight species in common (Figure 4). On the other hand, campaign three was the most dissimilar (Cj = 0.68) and also presented the lowest diversity (Table 2).

The species richness observed around the Serra da Macaca ParkRoad (SP-139) corresponded to 22% of the species sampled by Brocardo *et al*. (2012) in the context of a survey of the non-volant mammals in the Carlos BotelhoState Park (PECB).

Among the species recorded, some are notable due to their conservation statuses, including felines such as puma (*Puma concolor*) and ocelot (*Leopardus pardalis*), as well as lowland tapir (*Tapirus terrestris*), which occur naturally in the wild in low densities (Saranholi, 2013; Affonso, 1998). Also noteworthy is the presence of the small red brocket (*Mazama bororo*), the largest species of deer endemic to Brazil and possibly the deer species with the smallest geographic distribution among all neotropical deers (Duarte *et al*., 2017).

The lowland tapir (*Tapirus terrestris*), despite the species’ populational attributes, was the second most abundant mammal during the sampling, behind only the brazilian commom opossum (*Didelphis aurita* Wied-Neuwiedi, 1826). The largest non-volant in Brazil was more commonly spotted on the higher parts of the road.

Regarding the methods employed, the visual searches when considered isolately led to the observation of five species: the southern tamandua (*Tamandua tetradactyla* Linnaeus, 1758), the black-horned capuchin (*Sapajus nigritus*), the tapeti (*Sylvilagus brasiliensis* Linnaeus, 1758), the small red brocket (*Mazama bororo*) and ingram’s squirrel (*Guerlinguetus ingrami* Thomas, 1901). Puma (*Puma concolor*) and ocelot (*Leopardus pardalis*) were detected exclusively by the camera traps. The remaining non-volant mammals were observed through both methods.

The concept of species diversity encompasses two components: species richness; and distribution, which is based in the relative abundance and the degree of dominance or lack thereof (Odum & Barrete 2007). The Shannon-Wiener Index used on the samples gives more weight to the species richness than to the distribution (Melo, 2008). Therefore, the dissimilarity of the third campaign in comparison to the others is related to the lower diversity observed.

The data collected indicate that non-volant mammals do use the Serra da Macaca ParkRoad (SP-139). Individuals of certain species, such as the felines and ungulates, were recorded moving along the road, particularly at nighttime. On the other hand, the agouti (*Cuniculus paca*), the crab-eating raccoon (*Procyon cancrivorus*) and the black-horned capuchins (*Sapajus nigritus*) were filmed crossing the road. The primates benefited from the forest canopy to cross the road where the treetops touched over it.

The closure of the Serra da Macaca ParkRoad (SP-139) during nighttime makes it a very unique road. The results observed allow us to infer that closing the road during nighttime is essential for the maintenance of the low roadkill rates in the region.

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Legends:

Figure 1. Location of the 16 points sampled through the camera trap method along the Serra da MacacaPark Road (SP-139).

Figure 2. Records of non-volant mammals at the Serra da Macaca ParkRoad (SP-139). A = *Cuniculus paca*, B = *Tapirus terrestris*, C = *Procyon cancrivorus*, D = *Leopardus pardalis*, E = *Mazama bororo*, F = *Sapajus nigritus*, G = *Guerlinguetus ingrami*, H = *Philander frenatus*, I = *Didelphis aurita,* J = *Puma concolor.*

Figure 3. Rarefaction curve for the richness of non-volant mammals recorded through visual searches and camera traps at the Serra da Macaca ParkRoad (SP-139).

Figure 4. UPGMA dendrogram based on the species dissimilarity index between the four sampling campaigns (1st C = Mar / 2018, 2nd C = Jul / 2018, 3rd C = Nov / 2018 and 4th C = Feb / 2019) conducted at the Serra da Macaca ParkRoad (SP-139).

| Table 1. Non-volant mammals recorded at the Serra da Macaca ParkRoad (SP-139). Types of records: Af = Camera trap, Bv = Visual search. \* Species threatened in the State of São Paulo (BRESSAN *et al*., 2009). |
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| **Taxon** | **Popular Name** | **1stC** | **2ndC** | **3rdC** | **4thC** |
| **Didelphimorphia** |  |   |   |   |   |
| Didelphidae |   |   |   |   |   |
|  *Didelphis aurita* Wied-Neuwied, 1826 | Brazilian common opossum | Bv | Af, Bv | Bv | Bv |
|  *Philander frenatus* Olfers, 1818 | Southeastern four-eyed opossum | Bv | Af, Bv | Bv | Bv |
| **Pilosa** |  |  |  |  |  |
| Myrmecophagidae |  |  |  |  |  |
|  *Tamandua tetradactyla* Linnaeus, 1758 | Southern anteater | Bv |  |  |  |
| **Primates** |  |  |  |  |  |
| Cebidae |  |  |  |  |  |
|  *Sapajus nigritus* Goldfuss, 1809 | Black-horned capuchin | Bv | Bv |  | Bv |
| **Lagomorpha** |  |  |  |  |  |
| Leporidae |  |  |  |  |  |
|  *Sylvilagus brasiliensis* Linnaeus, 1758 | Tapeti |  |  | Bv |  |
| **Carnivora** |  |  |  |  |  |
| Felidae |  |  |  |  |  |
|  *Leopardus pardalis* Linnaeus, 1758\* | Ocelot | Af | Af |  | Af |
|  *Puma concolor* Linnaeus, 1771\*  | Puma |  | Af |  | Af |
| Procyonidae |  |  |  |  |  |
|  *Procyon cancrivorus* G. Cuvier, 1798 | Crab-eating raccoon | Af | Bv |  | Af |
| **Perissodactyla** |  |  |  |  |  |
| Tapiridae |  |  |  |  |  |
|  *Tapirus terrestris* Linnaeus, 1758\* | Low-land tapir | Af, Bv | Af, Bv | Af, Bv | Af |
| **Cetartiodactyla** |  |  |  |  |  |
| Cervidae |  |  |  |  |  |
|  *Mazama bororo* Duarte, 1996\* | Small red brocket |  | Bv |  |  |
| **Rodentia** |  |  |  |  |  |
| Sciuridae |  |  |  |  |  |
|  *Guerlinguetus ingrami* Thomas, 1901 | Ingram’s squirrel |  | Bv |  |  |
| Cuniculidae |  |  |  |  |  |
|  *Cuniculus paca* Linnaeus, 1766 | Agouti | Af | Af, Bv |  | Bv |
| **Records in visual searches** |  | **5** | **8** | **4** | **4** |
| **Records in camera traps** |  | **4** | **6** | **1** | **4** |
| **Species total** |  | **8** | **10** | **4** | **8** |

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| Table 2. Shannon-Wiener Diversity Index calculated for the communities of non-volant mammals observed at the Serra da Macaca ParkRoad (SP-139). |
| Sampling Campaign | Shannon-Wiener (H') Index |
| 1st C | 1.859 |
| 2nd C | 1.865 |
| 3rd C | 1.220 |
| 4th C | 1.876 |