



## NON-VOLANT MAMMALS OF THE SERRA DA MACACA PARK ROAD (SP-139), SOUTHEASTERN BRAZIL

*Francisco de Assis Alves<sup>1\*</sup>, Carlos Roberto Teixeira<sup>1</sup>, Luciano Barbosa<sup>2</sup> & Jairo Alves Júnior<sup>3</sup>*

<sup>1</sup> Universidade Estadual Paulista, Faculdade de Medicina Veterinária e Zootecnia, Departamento de Cirurgia Veterinária e Reprodução Animal, Rua Prof. Doutor Walter Mauricio Correa, s/n, CEP: 18618-681, Botucatu, SP, Brasil.

<sup>2</sup> Universidade Estadual Paulista, Instituto de Biociências, Departamento de Bioestatística, Rua Prof. Dr. Antônio Celso Wagner Zanin, 250, CEP: 18618-689, Botucatu, SP, Brasil.

<sup>3</sup> Muriqui Consultoria Ambiental, Rua dos Bandeirantes, nº 461, Jardim Lemense, CEP: 13610-639, Leme, SP, Brasil.

E-mails: francisco.alves@unesp.br; cr.teixeira@unesp.br; luciano.barbosa@unesp.br; alves.jairo.jr@gmail.com.

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**Abstract:** The objective of this study was to survey non-volant mammals at Serra da Macaca Park Road (SP-139), particularly during road daily closure. Visual searches and camera traps were used to record mammals, and estimator Jackknife to estimate the expected richness. Differences in diversity were calculated using the Shannon-Wiener index ( $H'$ ). In total, 12 species of non-volant mammals, four of them considered threatened, were sampled. Additionally, roadkills of the non-volant mammals were recorded too. The absence of some predominantly nocturnal species from the list of the roadkilled non-volant mammals was noticeable. The results highlight the importance of the temporary road closures, during periods of high mammal activity.

**Keywords:** Atlantic Forest; mammals; protected areas; roadkill; road closures.

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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.* 2012) and about 18% are officially considered threatened species (ICMBio 2018). 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).

Mammal surveys have a wide range of applications (Tobler *et al.* 2008). The most widespread techniques for studies of this nature include linear transections, direct observations,

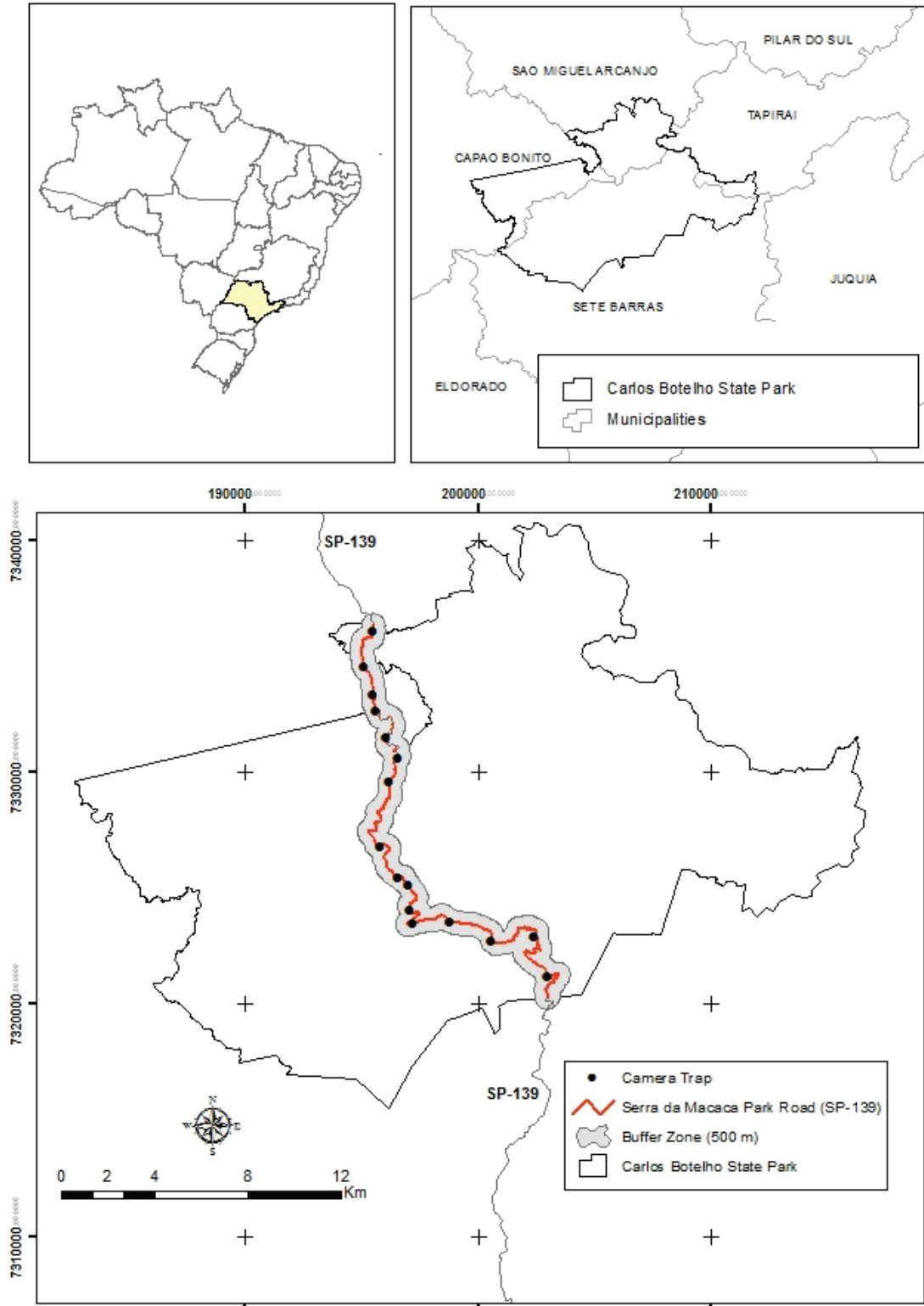
track search (tracks, fur, feces), captures and interviews (Voss & Emmons 1996). On the other hand, the use of camera traps has gained popularity in the last decades (Tobler *et al.* 2008).

In this study, we aimed to perform a survey of mammals to obtain a list of species that use the Serra da Macaca Park Road, which is the popular name for the 33 km stretch of the SP-139 road crossing the Carlos Botelho State Park (PECB), focusing particularly during the period when the road is closed. The SP-139 was constructed in 1942 as an unpaved two-way highway linking the highlands (São Miguel Arcanjo, State of São Paulo, in the Alto Paranapanema region) with the coastal plains (Sete Barras, State of São Paulo, in the Vale do Ribeira do Iguape region). This road crosses the

PECB, an integral protected area for the Atlantic Forest (Figure 1), that holds several rare endemic species (Beisiegel 1999).

The project to pave and make improvements on the Serra da Macaca Park Road (SP-139) was defined

at management plan for the Park. The paving used was ecological (constituted by interlocked concrete blocks that allow better rainwater drainage and store less heat), installed a drainage system, guard rails and regularized hillside protections. A



**Figure 1.** Study site and the location of the 16 points (black dots) sampled through the camera trap method along the Serra da Macaca Park Road (SP-139). In yellow, São Paulo state, Brazil.

series of preventive measures were implemented to avoid roadkills, such as 16 canopy bridges, 12 underpasses (bridges and culverts), speed limits of 40 km/h, nocturnal closure (between 8 p.m. and 6 a.m. of the following day) and two OCRs (Optical Character Recognition), at the entrance and exit of the PECB.

Data collection occurred between 2018 and 2019 during four 10-days campaigns: March 2018, July 2018, November 2018 and February 2019. Thus, a campaign was carried out in each season of the year. We used “R” v. 3.5.1 (R CORE TEAM, 2020) to conduct all the analyses.

Visual searches on the road consisted in a slow car travel (approximately 20 km/h) in both directions by two observers in the morning (6 a.m. to 9:30 a.m.) and night (8 p.m. to 10:30 p.m.), totaling 5.280 km travelled. For the sampling with camera traps, 16 sampling points were selected in the studied area (Figure 1). The points were on average 2 km apart, approximately. A digital camera trap (Bushnell® Modelo ZT820) was placed at each point for five consecutive nights, always after the road was closed for traffic, totaling a sampling effort of 320 cameras\*night. The equipments were fixed on vertical traffic signs at a height of 40 cm from the ground and were programmed to obtain 10-sec videos, with an interval of 10 seconds between triggers. Every day the cameras were removed in the morning and replaced at night to avoid the risk of equipment theft. We did not use any type of bait.

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 estimator, performing 1.000 randomizations. The diversity of non-volant mammals observed during the four sampling campaigns was compared by the Shannon-Wiener Index ( $H'$ ).

Also, we recorded mammal roadkills data during the campaigns, while in parallel, the State Forestry Foundation disclosed roadkills data collected by the fiscalization service of the Park, since the inauguration of the revitalized stretch of the road in November 2015 (Table 3).

The scientific names followed Abreu *et al.* (2021) 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 (São Paulo 2018) and Brazilian Red List for Endangered Species (ICMBio 2018).

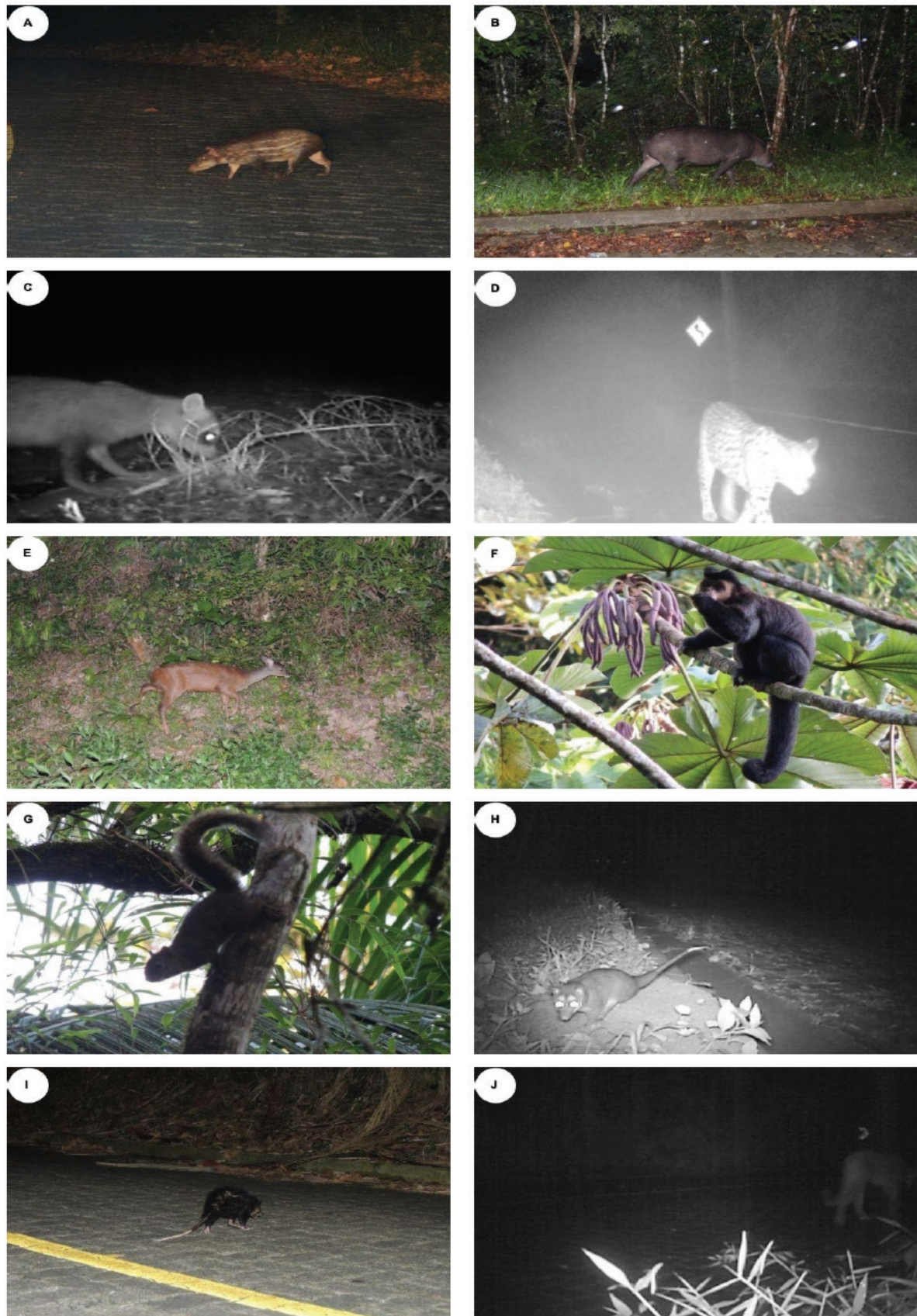
We obtained 79 records belonging to 12 different species of non-volant mammals during the study (Table 1 and Figure 2). The species accumulation curve did not show the tendency towards complete stabilization with the sampling effort undertaken (Figure 3). This result indicates that a greater sampling effort would certainly result in the addition of some species that were not sampled.

There was a methodological flaw in the planning of the campaigns. More samples were taken in the wet season than in the dry season. This failure did not allow us to reliably compare the results in terms of seasonality.

The estimated species richness, by the non-parametric estimator Jackknife, was 14.92 species ( $\pm 1.7$ ), and campaign three presented the lowest diversity (Table 2). The species richness observed in the Serra da Macaca Park Road (SP-139) corresponded to 22% of the species of PECB (Brocardo *et al.* 2012).

Among the species recorded, some are notable due to their conservation statuses (Table 1), including felines such as puma (*Puma concolor*) and ocelot (*Leopardus pardalis*), as well as lowland tapir (*Tapirus terrestris*), which occurs naturally in low densities in the wild (Saranholi, 2013; Affonso, 1998). The lowland tapir (*Tapirus terrestris*) was the second most abundant mammal during the sampling, just below the black-eared opossum (*Didelphis aurita* Wied-Neuwiedi, 1826). The largest non-volant mammal in Brazil (lowland tapir) was more commonly spotted on the higher parts of the road. It is noteworthy too the presence of the small red brocket deer (*Mazama bororo*), endemic to Brazil and possibly the deer species with the smallest geographic distribution among all neotropical deers (Duarte *et al.* 2017).

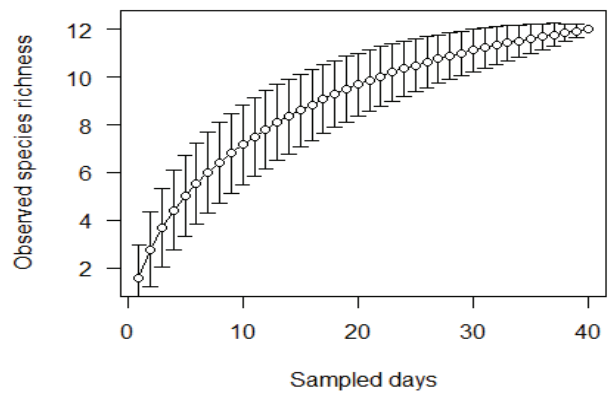
In turn, 21 carcasses of mammals belonging to 13 different species were recorded through the survey of roadkilled non-volant mammals (Table 3). Among these, the southeastern four-eyed opossum (*Philander quica* Temminck, 1824) had the highest relative frequency (19.05%). Furthermore, we recorded a carcass of the giant anteater (*Myrmecophaga tridactyla* Linnaeus, 1758). This species is considered vulnerable to the



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

risk of extinction, and was not sampled through visual searches, nor trap cameras.

Visual searches recorded five species that were not filmed by camera traps: the southern tamandua (*Tamandua tetradactyla* Linnaeus, 1758), the black-horned capuchin (*Sapajus nigritus*), the tapeti (*Sylvilagus brasiliensis* Linnaeus, 1758), the small red brocket deer (*Mazama bororo*) and ingram's squirrel (*Guerlinguetus brasiliensis* Gmelin, 1788). Puma (*Puma concolor*) was detected exclusively by the camera traps, and the remaining non-volant mammals by both methods. The results corroborate the importance of combining complementary methods.



**Figure 3.** Species accumulation curve for the richness of non-volant mammals recorded through visual searches and camera traps at the Serra da Macaca Park Road (SP-139).

**Table 1.** Non-volant mammals recorded at the Serra da Macaca Park Road (SP-139). Types of records: CT = camera trap; VS = visual search. Conservation status in the State of São Paulo (São Paulo, 2018) and Brazil (ICMBio, 2018): EN = Endangered; VU = Vulnerable; NT = Near Threatened; DD = Data Deficient.

Taxon	Common Name	Status		1 <sup>st</sup> C	2 <sup>nd</sup> C	3 <sup>rd</sup> C	4 <sup>th</sup> C
		SP	BR				
<b>Didelphimorphia</b>							
Didelphidae							
<i>Didelphis aurita</i> Wied-Neuwied, 1826	black-eared opossum			VS	CT/VS	VS	VS
<i>Philander quica</i> Temminck, 1824	southeastern four-eyed opossum			VS	CT/VS	VS	VS
<b>Pilosa</b>							
Myrmecophagidae							
<i>Tamandua tetradactyla</i> Linnaeus, 1758	southern anteater			VS			
<b>Primates</b>							
Cebidae							
<i>Sapajus nigritus</i> Goldfuss, 1809	black-horned capuchin			VS	VS		VS
<b>Lagomorpha</b>							
Leporidae							
<i>Sylvilagus brasiliensis</i> Linnaeus, 1758	tapeti	DD				VS	
<b>Carnivora</b>							
Felidae							
<i>Leopardus pardalis</i> Linnaeus, 1758	ocelot	VU		CT/VS	CT		CT
<i>Puma concolor</i> Linnaeus, 1771	puma	VU	VU		CT		CT
Procyonidae							
<i>Procyon cancrivorus</i> Cuvier, 1798	crab-eating raccoon			CT	VS		CT

**Table 1.** Continues on next page...

Table 1. ...continued

Taxon	Common Name	Status		1 <sup>st</sup> C	2 <sup>nd</sup> C	3 <sup>rd</sup> C	4 <sup>th</sup> C
		SP	BR				
<b>Perissodactyla</b>							
Tapiridae							
<i>Tapirus terrestris</i> Linnaeus, 1758	low-land tapir	EN	VU	CT/VS	CT/VS	CT/VS	CT
<b>Cetartiodactyla</b>							
Cervidae							
<i>Mazama bororo</i> Duarte, 1996	small red brocket deer	VU	VU		VS		
<b>Rodentia</b>							
Sciuridae							
<i>Guerlinguetus brasiliensis</i> Gmelin, 1788	ingram's squirrel				VS		
Cuniculidae							
<i>Cuniculus paca</i> Linnaeus, 1766	agouti	NT		CT	CT/VS		VS
<b>Records in visual searches</b>				<b>12</b>	<b>29</b>	<b>11</b>	<b>7</b>
<b>Records in camera traps</b>				<b>4</b>	<b>6</b>	<b>2</b>	<b>8</b>
<b>Species total</b>				<b>8</b>	<b>10</b>	<b>4</b>	<b>8</b>

Table 2. Shannon-Wiener Diversity Index calculated for the communities of non-volant mammals observed at the Serra da Macaca Park Road (SP-139).

Sampling Campaign	Shannon-Wiener (H') Index
1 <sup>st</sup> C	1.890
2 <sup>nd</sup> C	1.865
3 <sup>rd</sup> C	1.220
4 <sup>th</sup> C	1.876

Table 3. List of non-volant mammals found dead in the Serra da Macaca Park Road (SP-139), number of records (N) and relative frequency (%). Data Collection: VS = Visual Search; FF = Forestry Foundation. Conservation status in the State of São Paulo (São Paulo, 2018) and Brazil (ICMBio, 2018): EN = Endangered; VU = Vulnerable; NT = Near Threatened; \* = Exotic.

Taxon	Common Name	N	%	Data Collection		Status	
				VS	FF	SP	BR
<b>Didelphimorphia</b>							
Didelphidae							
<i>Didelphis aurita</i> Wied-Neuwied, 1826	black-eared opossum	3	14.28	X	X		
<i>Philander quica</i> Temminck, 1824	southeastern four-eyed opossum	4	19.05	X	X		
<b>Pilosa</b>							
Myrmecophagidae							
<i>Myrmecophaga tridactyla</i> Linnaeus, 1758	giant anteater	1	4.76		X	VU	VU

Table 3. Continues on next page...

Table 3. ...continued

Taxon	Common Name	N	%	Data Collection		Status	
				VS	FF	SP	BR
<i>Tamandua tetradactyla</i> Linnaeus, 1758	southern anteater	1	4.76		X		
<b>Cingulata</b>							
Dasypodidae							
<i>Dasyus novemcinctus</i> Linnaeus, 1758	nine-banded armadillo	2	9.52		X		
<b>Cetartiodactyla</b>							
Cervidae							
<i>Mazama bororo</i> Duarte, 1996	small red brocket deer	1	4.76		X	VU	VU
<b>Primates</b>							
Cebidae							
<i>Sapajus nigritus</i> Goldfuss, 1809	black-horned capuchin	2	9.52		X		
<b>Carnivora</b>							
Procyonidae							
<i>Nasua nasua</i> Linnaeus, 1766	south american coati	1	4.76		X		
Mustelidae							
<i>Eira barbara</i> Linnaeus, 1758	tayra	1	4.76		X		
<b>Rodentia</b>							
Cricetidae							
<i>Oligoryzomys flavescens</i> Waterhouse, 1837	yellow pygmy rice rat	1	4.76	X			
Cuniculidae							
<i>Cuniculus paca</i> Linnaeus, 1766	agouti	1	4.76		X	NT	
Sciuridae							
<i>Guerlinguetus brasiliensis</i> Gmelin, 1788	ingram's squirrel	2	9.52		X		
<b>Lagomorpha</b>							
Leporidae							
<i>Lepus europaeus</i> Pallas, 1778*	european hare	1	4.76		X		

Felines and ungulates were recorded moving along the road, particularly at nighttime. On the other hand, we recorded agouti (*Cuniculus paca*), the crab-eating raccoon (*Procyon cancrivorus*) and the black-horned capuchins (*Sapajus nigritus*) just crossing the road. The primates benefited from the forest canopy to cross the road where the treetops touched over it, as observed during visual searches, in all contacts.

We recorded zero roadkilled non-vollant nocturnal mammal species, indicating the effectiveness of the road-closure at night. However,

the volume of traffic on other roads with substantial rates of large and medium-sized mammal collisions may be too high to consider adopting this type of measure (Huijser & McGowen 2010). To our knowledge, Serra da Macaca Park Road (SP-139) is the only road in Brazil that closes to traffic, in order to avoid mammal roadkills.

#### ACKNOWLEDGEMENTS

We would like to thank the Department of Roads and Highways of the State of São Paulo (DER/

SP) for allowing the use of data collected from a road section under their jurisdiction, as well as the Foundation for Forest Conservation and Production of the State of São Paulo, the entity responsible for the management of the Carlos Botelho State Park. We would also like to thank Professor José Maurício Barbanti Duarte for the help in the identification of specimens of *Mazama bororo*.

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*Submitted: 16 April 2021*

*Accepted: 12 May 2022*

*Publisehd on line: 06 May 2022*

*Associate Editor: Maja Kajin*