Natural factors but not anthropogenic factors affect native and non–native mammal distribution in a Brazilian National Park

R. A. Duarte Silveira, H. H. Marques da Rosa, A. A. Pereira, M. Passamani, R. D. Zenni

Abstract

Natural factors but not anthropogenic factors affect native and non–native mammal distribution in a Brazilian National Park. Protected areas, designed for biodiversity conservation, are currently affected by invasive species as most of them have documented biological invasions. This study aimed to test whether non–native mammal species richness influences the local distribution of native mammals and how distance from human settlement, elevation and vegetation characteristics influence native and non–native mammal richness in a national park in Brazil. We recorded 20 mammal species in the park, 17 native species and three non–native species. Native mammal richness was higher at intermediate elevations and in forests with lower tree densities and tree basal area. Non–native mammal richness was greater at higher elevations and in forests with low tree densities. Non–native mammals did not influence native mammal presence. In conclusion, the distribution of both native and non–native mammal species was affected by elevation and vegetation but not by distance from human settlements or non–native mammal presence.

Key words: Biological invasions, Domestic animals, Itatiaia National Park, Protected areas, Wild boar

Resumen

Son factores naturales y no antropogénicos los que afectan a la distribución de mamíferos autóctonos y alóctonos en un parque nacional del Brasil. En la actualidad, las zonas protegidas, que están concebidas para la conservación de la biodiversidad, se ven afectadas por especies invasoras, ya que en la mayoría de ellas se han documentado invasiones biológicas. Con el presente estudio tratamos de comprobar si la riqueza de especies de mamíferos alóctonos incide en la distribución local de mamíferos autóctonos y determinar la influencia de la distancia a asentamientos humanos, la altitud y las características de la vegetación en la riqueza de mamíferos autóctonos y alóctonos en un parque nacional del Brasil. Registramos 20 especies de mamíferos en el parque, de las que 17 eran autóctonas y tres, alóctonas. La riqueza de mamíferos autóctonos fue mayor en altitudes intermedias y en bosques poco densos y con escasa área basimétrica. La riqueza de mamíferos alóctonos fue mayor en altitudes intermedias y en bosques poco densos. Los mamíferos alóctonos no influyeron en la presencia de los mamíferos autóctonos. En conclusión, la altitud y la vegetación son los factores que afectaron a la distribución de las especies de mamíferos autóctonas y alóctonas, y no la distancia a asentamientos humanos.

Palabras clave: Invasiones biológicas, Animales domésticos, Parque Nacional de Itatiaia, Zonas protegidas, Jabalí

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Introduction

The introduction of non–native species is a cause of great concern among conservation biologists (Bellard et al., 2016; Seebens et al., 2017). Invasive species can have direct and indirect economic, environmental and social impacts (Charles and Dukes, 2007). Such impacts can threaten biological diversity through competition, predation, disease transmission, hybridization, physical disturbance of the environment, and destruction of crops and pastures (Doherty et al., 2015; Gompper, 2014; Paini et al., 2016; Rosa et al., 2019; Wyatt et al., 2008).

Among non–native species, mammals are one of the groups that cause the most damage to global diversity and their strong impact as an invasive species has already been demonstrated (Bellard et al., 2016; Blackburn et al., 2004; Doherty et al., 2015). Mammals such as dogs, cats, horses and cattle, wild boar, primates, opossums and hares (Long, 2003) have been introduced into new countries around the world for a number of reasons, such as for hunting game, for biological control, and for domestication and commercialization as livestock or pets (Long, 2003). Their high impact capacity, such as competition with native species, disease and pathogen transmission, hybridization, genetic changes, and damage to crops, may be the result of their high ecological plasticity and great capacity for habitat modification (i.e. ecosystem engineers) (Jones et al., 1994; Long, 2003).

The creation of protected areas is an important strategy to maintain habitat integrity and conserve biodiversity (Gray et al., 2016) but protected areas have also been affected by the introduction of invasive species. Invasive mammals worldwide have a history of impact in protected areas in relation to predation, competition, pathogen transmission, soil disturbance and exposure, vegetation damage, and non–native seed dispersal (Ballari et al., 2014; da Rosa et al., 2017; Lessa et al., 2016; Parsons et al., 2016). Moreover, the presence of non–native species in protected areas is often associated with human presence since most protected areas are either located near urban centers, or humans take non–native species to these places with them (Paschoal et al., 2018). As the presence of these animals in protected areas may then reduce the effectiveness of biodiversity conservation strategies, knowing their distribution across those areas is fundamental in order to manage biological invasion.

To determine the distribution of these mammals across areas we can use environmental factors, human occupation, and vegetation traits (Ahumada et al., 2011; Dias et al., 2019; Lyra–Jorge et al., 2009; Pereira, 2017; Sampaio et al., 2010). Regarding environmental factors, the structure of the landscape is an important variable for mammal communities (Lyra–Jorge et al., 2010; Sampaio et al., 2010). There is less species richness and functional diversity and higher dominance in highly fragmented sites than in partially fragmented sites and continuous forest landscapes (Ahumada et al., 2011). It has been observed that forest cover and management intensification affect the distribution of mammals in a cacao agroforestry system (Cassano et al., 2014). However, regarding human occupation, probability of occupancy of carnivores can be influenced by the distance to forest, human infrastructure, watercourses, and the proportion of anthropized areas (e.g pasture, crops) (Cruz et al., 2019; Dias et al., 2019). It has also been seen that areas with higher human occupancy had lower species richness, with omnivorous and insectivorous species being the most common species (Bogoni et al., 2016). Vegetation traits can also influence mammal communities. Focal tree connectivity and canopy cover are most likely the most important predictors of occupancy for the arboreal community whereas forest loss and canopy height are the strongest predictors for the terrestrial mammal community (Whitworth et al., 2019).

Information about non–native mammal distribution across protected areas and environmental and other factors affecting their distribution is necessary so as to develop effective control and management measures. The aim of this study was to test whether distance from human settlements, elevation, absolute tree density, absolute tree coverage, mean tree basal area, mean tree height, and mean tree canopy cover affected the richness of native and non–native mammals in a protected area in Brazil, the Itatiaia National Park. We sought to answer the following questions: (a) do non–native mammals in the Park affect native mammal presence?; (b) does non–native mammal richness decrease the greater the distance from human settlements?; (c) does native mammal richness increase the greater the distance to these settlements?; and (d) which environmental variables influence native and non–native mammal distribution?

Material and methods

Study area

We conducted the study in the Itatiaia National Park (22° 22' 31'' S 44° 39' 44'' W, fig. 1), a strict protection conservation area, meaning only the indirect use of its natural resources is allowed and it cannot be inhabited by humans (Brasil, 2011). Inserted in the Atlantic forest hotspot domain, in the Mantiqueira Complex, the Itatiaia National Park was created in 1937. It was the first area in Brazil to be given protected status. It comprises four municipalities, Bocaina de Minas and Itamonte in Minas Gerais State, and Resende and Itatiaia in Rio de Janeiro State. The Park is non–officially divided in two main parts, the highland and the lowland. The highland has about 16,395 ha, with an altitude ranging from 1,500 m to 2,791 m a.s.l., a type of climate *Cwb* (temperate climate with dry winter and warm summer), mean temperature ranges from 8.2 °C to 13.6 °C, and annual precipitation of about 2,600 mm. There are small rural producers living within the boundaries of the Park. The lowland, where the Park administration is located has an area of 6,414 ha. The altitude ranges from 540 m to 1,500 m a.s.l., and the climate is *Cwa* type (temperate with dry winters
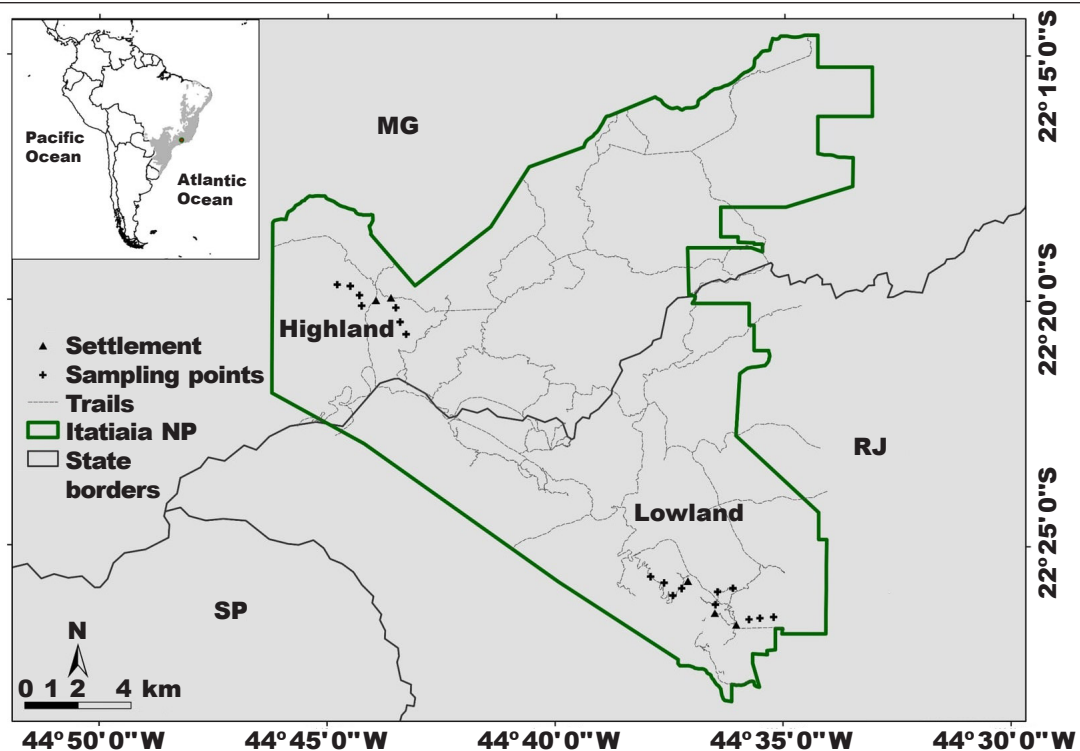
Fig. 1. Location of sampling points (black crosses) in two trails of the highland and three trails of the lowland of the Park. Black triangles indicate the nearest human settlement from the first camera–trap in each trail. The highland has about 16,395 ha, with an altitude range from 1,500 m to 2,791 m a.s.l., a *Cwb* type of climate (temperate climate with dry winter and warm summer), mean temperature ranges from 8.2 ºC to 13.6 ºC, annual precipitation is about 2,600 mm, and there are small rural producers living within the boundaries of the Park. The lowland, where the Park administration is located, has about 6,414 ha, with an altitude range from 540 m to 1,500 m a.s.l., a type of climate *Cwa* (temperate climate with dry winter and hot summer), mean temperature ranges from 20 ºC to 24 ºC, the annual precipitation is about 1,800 mm and the main occupation is related to cottages available for holidays and weekends and summer houses.

Fig. 1. Ubicación de los puntos de muestreo (cruces negras) en dos pistas en la Parte Alta y tres pistas en la Parte Baja del Parque. Los triángulos negros indican la construcción antrópica más cercana a la primera trampa en cada pista. La Parte Alta tiene alrededor de 16.395 ha, un rango de altitud de 1.500 m a 2.791 m s.n.m. y un tipo de clima Cwb *(clima templado con invierno seco y verano cálido). La temperatura media varía de 8,2 ºC a 13,6 ºC y la precipitación anual es de unos 2.600 mm. Asimismo, hay pequeños productores rurales que viven dentro de los límites del Parque. La Parte Baja, donde se ubica la administración del Parque, tiene alrededor de 6.414 ha, con un rango de altitud de 540 m a 1.500 m s.n.m. y un tipo de clima* Cwa *(clima templado con invierno seco y verano caluroso), la temperatura media varía de 20 ºC a 24 ºC, la precipitación anual es de unos 1.800 mm y el principal tipo de ocupación son cabañas para vacaciones y fines de semana y casas de veraneo.*

and hot summers). Mean temperature ranges from 20 ºC to 24 ºC and the annual precipitation is about 1,800 mm. The main occupation is related to weekend and holiday accommodation (Barreto et al., 2014; Köppen, 1936; Tomzhinski, 2012). The Park has various phytophysiognomies, ranging from high altitude grasslands (above 2,000 m), dense ombrophilous forest (submontane, montane and high–montane), montane mixed ombrophilous forest (with the presence of Araucaria trees) and montane semideciduous forest

(Barreto et al., 2014). An issue of concern in Itatiaia National Park is related to land tenure regularization. This is a problem not only in the this park but also in many strict protection conservation areas (Cheade, 2015; INEA, 2010). Only 51 % of the Park area was regularized until 2016 (ICMBio, 2016). Some private landowners still have properties and even live within the boundaries of the Park. This is because they did not receive compensation for the land by the federal government. In the remaining 49 % of non–regularized

areas, there are summer houses and hotels, mainly in the lowlands, and small rural producers with grazing being the main economic activity in the highlands (Barreto et al., 2014).

Mammal data collection

To survey the mammals of the Itatiaia National Park we installed camera–traps in the forest at 17 sampling points, 50 m perpendicular to man–made trails in the highland and lowland. Each sampling point was positioned at a minimum distance of 150 m from the closest human settlement and at a distance of 500 m from each other in a straight line (fig. 1). Human settlements in the highland consisted of inhabited houses without large crops but with backyards covered in grasses. In the lowland, these settlements are touristic points. There is a hotel with high human traffic, and an abandoned hotel with low or no human traffic. Seven camera–traps were installed along two trails (Picu and Araucárias trails) in the highland, whereas in the lowland we installed ten camera–traps in three trails (Três Picos, Rui Braga and Hotel Donati). These cameras remained in the field from September 2018 to December 2018 in the highland and from December 2018 to March 2019 in the lowland sites. Each sampling point had one camera–trap (Bushnell©, Digital Hunting Camera© or Trail Camera©) placed on trees larger than 15 cm in diameter and approximately 45 cm from the ground (Srbek–Araujo et al., 2012). The cameras were active day and night and were set up to take three pictures every 30 seconds, whenever the motion sensor was triggered. To avoid selection of species we did not use baits (Srbek–Araujo et al., 2012). Every 45 days approximately we revisited the cameras to collect data, adjust equipment and replace batteries. After the collection period, the photos were analyzed. To avoid repetition of data with the same individual when the individualization was not possible, we considered all the photographs with intervals of at least one hour as new independent records (Srbek–Araujo et al., 2012). We included all mammals able to be photographed and identified. We therefore included some unrestricted arboreal mammals, such as the Southeastern four–eyed opossum *Philander frenatus* and the Southeastern squirrel *Guerlinguetus ingrami.* It is important to mention that the records of species frequency can depend on various factors at a site. The location of the cameras can have a strong influence on this variable and even bias the probability of detection of species (Di Bitetti et al., 2014). However, we followed a pattern among our sampling sites, installing camera traps within the forests and near animal–made trails only, trying to equalize detection probability between sites.

Environmental data collection

To test whether environmental factors and other factors influenced native and non–native mammal distributions, we measured elevation, absolute tree density, absolute tree coverage, mean tree basal area, mean tree height and mean tree canopy cover at each sampling point (table 1). To measure the proportion of tree canopy cover, we made a 50 m transect in the north–south direction from the camera trap and measured the percentage of canopy every 10 m using the CanopyApp © version 1.0.4. We used the average proportion of tree canopy cover as a predictor variable for each sampling point. Elevation was obtained using a Garmin 62s GPS and the distance from the sampling point was measured to the nearest human settlement using the ruler function in Google Earth Pro software version 7.3. To obtain the predictor variables absolute tree density, absolute tree coverage, mean tree basal area and mean tree height, we used the point–centered quarter method (Mitchell, 2007). For this method, we formed a circle divided into four quadrants using the sampling point as center. The four–quadrants were divided followed the main cardinal points (North, South, East and West). For each quadrant, we found the closest tree from the sampling point and measured the height, the circumference at breast height and the distance from the tree to the center. We repeated this procedure for the other three quadrants. Using these measures, we calculated absolute tree density, absolute tree coverage, mean tree basal area, mean tree height and mean tree canopy cover based on the methodology described in Mitchell (2007).

Data analysis

To test if non–native mammals had influenced the presence of native mammals in the Park, we ran a generalized linear model (GLM) with Quasipoisson error distribution using the response variable native mammal richness and the predictor variable non–native mammal richness. We ran a set of GLM with Quasipoisson error distribution to test how the non–native and native mammal richness related to each of the environmental variables. First, in order to see how mammals responded to anthropogenic influence, we performed two GLM considering non–native mammal richness and native mammal richness as response variables and distance to the nearest human settlement as a predictor variable (table 1). Second, we ran another two GLM with Quasipoisson error distribution using the same response variables of the first set of analyses to see if they responded to the environmental factors. Predictor variables were investigated together in the models; these were elevation, absolute tree density, absolute tree coverage, mean tree basal area, mean tree height, and mean tree canopy cover. Spearman's correlation matrix was used to identify the variables with a strong correlation, i.e. $\rho > 0.7$. Absolute tree density and mean tree canopy cover were strongly correlated, the latter being excluded from the analysis because tree diversity appears to be more important for mammals (Pereira, 2017). Next, we performed model selections using the Akaike information criterion modified for small samples (AICc), considering equally plausible those models with AICc < 2 to compare the relative importance of environmental variables (Burnham and Anderson, 2002). If we had more than one selected model with AICc < 2 explaining the response variables and more than one variable in each model,

Table 1. Environmental variables collected at each sampling point in the highland and lowland of the Itatiaia National Park: L, location; T, trail (3P, 3 Picos; RB, Rui Braga; HD, Hotel Donati; PI, Picu; AR, Araucárias); D, distance from human settlement (in m); E, elevation (in m); Atd, absolute tree density (tree/ha, number of trees per area); Atc, absolute tree coverage (m^2/ha, occupied area by trees per unit area); Mtba, mean tree basal area (cm^2, transversal area of the tree trunk); Mth, mean tree height (in m); Mtcc, mean tree canopy cover (%, overlapping proportion of tree branches and leaves).

Tabla 1. Variables ambientales determinadas en cada punto de muestra de la Parte Alta y la Parte Baja del Parque Nacional de Itatiaia: L, ubicación; T, pista (3P, 3 Picos; RB, Rui Braga; HD, Hotel Donati; PI, Picu; AR, Araucárias); D, distancia del asentamiento humano (en m); E, altitud (en m); Atd, densidad absoluta de árboles (tree/ha, número de árboles por hectárea); Atc, cobertura absoluta de árboles (m^2/ha, superficie ocupada por árboles por hectárea); Mtba, área basal media de los árboles (cm^2, promedio de la sección transversal del tronco); Mth, altura media de los árboles (en m); Mtcc, cubierta media del dosel (%, proporción de superposición de las ramas y las hojas de los árboles).

L	T	D (m)	E (m)	Atd (tree/ha)	Atc (m²/ha)	Mtba (cm²)	Mth (m)	Mtcc (%)
Lowland	HD	1,075.64	1,082	5,548.44	6.67	12.02	4.45	79.35
Lowland	HD	598.38	1,012	5,175.71	102.2	197.46	9.25	67.42
Lowland	HD	165.45	954	12,075.84	33.83	28.01	5.25	58.72
Lowland	3P	329.45	1,108	5,548.47	33.54	60.45	5.75	63.04
Lowland	3P	827.54	1,220	779.16	15.72	201.77	7.75	45.19
Lowland	3P	1,166.95	1,228	11,138.88	129.85	116.57	5.75	62.08
Lowland	RB	298	1,159	2,148.32	230.72	1073.94	2.38	51.66
Lowland	RB	779.11	1,178	5,327.93	85.12	159.76	6.38	59.84
Lowland	RB	898.63	1,365	7,901.23	38.04	48.14	4.5	61.22
Lowland	RB	1,407.67	1,501	4,643.48	6.09	13.12	3.25	56.6
Highland	PI	199.95	1,903	3,894.07	5.98	15.35	3.5	57.82
Highland	PI	672.69	1,893	1,242.02	7.33	59	5.68	37.49
Highland	PI	1,112.1	1,896	783.53	8.3	106.01	6.88	38.36
Highland	PI	1,588.33	1,973	2,246.13	23.32	103.83	5.75	32.94
Highland	AR	162.77	1,977	5,590	28.56	51.09	4.88	59.6
Highland	AR	992.77	2,212	4,549.99	11.2	24.62	5.38	56.87
Highland	AR	1,474.39	2,236	4,772.69	39.38	82.51	6.5	42.7

we performed the Relative Importance of Regressors in Linear Models, using the package 'relaimpo' version 3.5.3. This analysis quantifies which of these predictor variables of the selected models were more important, based on the higher percentage of explanation to the response variable. All analyses were performed in R version 3.5.0, using packages 'ggplot2', 'MuMIn', 'lme4' and 'relaimpo'. The tests were considered significant at $p < 0.05$.

Results

With a sampling effort of 1,543 trap–days, we recorded 20 mammal species, three non–native and 17 native species. In the highland we recorded seven native mammals (Brazilian common opossum *Didelphis aurita*, spotted–paca *Cuniculus paca*, striped hog–nosed skunk *Conepatus semistriatus*, tayra *Eira barbara*, lesser grison *Galictis cuja*, southern tiger cat *Leopardus guttulus*, tapeti *Sylvilagus brasiliensis*) and three non–native mammals, one wild and two domestic animals (wild boar *Sus scrofa*, domestic dog *Canis lupus familiaris* and domestic cattle *Bos taurus*) In the lowland, we recorded 17 native (*D. aurita*, *C. paca*, *C. semistriatus*, *E. barbara*, *G. cuja*, *L. guttulus*, *S. brasiliensis*, white–lipped peccary *Tayassu pecari*, southeastern squirrel *Guerlinguetus ingrami*, nine–banded armadillo *Dasypus novemcinctus*, crab–eating fox *Cerdocyon thous*, ocelot *Leopardus pardalis*, South American coati *Nasua nasua*, collared peccary *Pecari tajacu*, southeastern
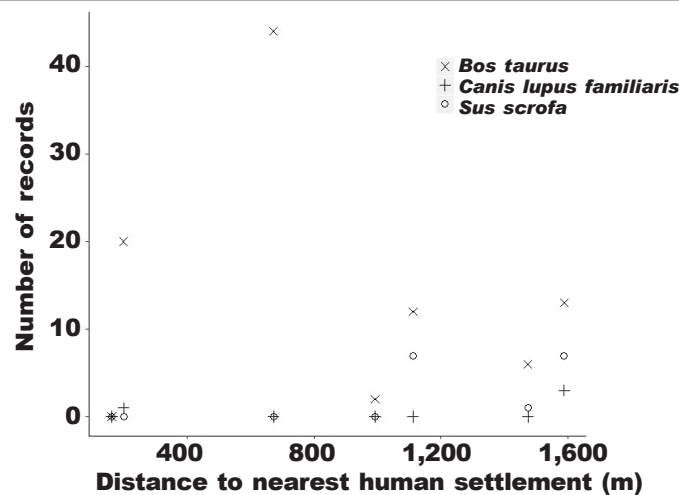
Fig. 2. Number of records of wild boar *Sus scrofa*, domestic cattle *Bos taurus* and domestic dogs *Canis lupus familiaris* in relation to distance of camera–traps from human settlement in the highland in the Itatiaia National Park. The points, crosses and x represent the sampling points where we installed the camera–traps.

Fig. 2. Numero de registros de jabalíes Sus scrofa, *ejemplares de ganado doméstico* Bos taurus*, y perros domésticos* Canis lupus familiaris*, en relación con la distancia de las trampas fotográficas situadas en las construcciones antrópicas en el Parque Nacional de Itatiaia. Los puntos, los triángulos y los cuadrados representan los puntos de muestreo donde se instalaron las cámaras.*

four–eyed opossum *Philander frenatus*, Paraguayan hairy dwarf porcupine *Coendou spinosus*, *Leopardus* sp.) and no non–native species (appendix 1s and 3s). Non–native mammals did not affect the presence of native mammals ($p = 0.3$).

We only had records of the non–native *S. scrofa* at distances of 1 km or more from human settlements (fig. 2). The same did not happen for *B. taurus* and *C. lupus familiaris*. We recorded *B. taurus* near and far from human settlements (fig. 2) whereas *C. lupus familiaris* were found at distances of 200 and 1,500 m only (fig. 2). Despite these differences, distances to human settlements did not influence either native ($p = 0.6$) or non–native mammal richness ($p = 0.1$).

Native mammal richness decreased from eight to four, six to four, eight to zero and four to zero species as elevations increased (1,178 to 1,501 m; 1,082 to 1,501 m; 1,178 to 2,236 m; 1,903 to 2,236 m, respectively). Native mammal richness also decreased, from eight to four and four to zero in forests where mean tree basal area (159.76 to 201.77 cm² and 15.35 to 1,073.94 cm²) was higher, and from eight to four and four to one in forests where absolute tree density (5,327.93 to 7,901.23 tree/ha and 2,246.13 to 12,075.84 tree/ha) and mean tree height (6.38 to 7.75 m and 3.5 to 9.25 m) were also higher ($p < 0.001$). In addition, native mammal richness increased from one to five in forests with greater absolute tree coverage (33.83 to 129.85 m²/ha; $p < 0.001$). The AICc test selected three models that best explained native mammal richness (appendix 2s).

However, according to the relativeimportance of regressors in linear models (relaimpo), elevation had more than half of the influence (61%) in native mammal richness followed by mean tree basal area (32%) and absolute tree density (7%, fig. 3). Non–native mammal richness decreased from three to zero species with an increase in tree density (3,894.07 to 5,590.0 tree/ha) and in forests with higher trees (3.5 to 6.5 m; $p < 0.001$) and increased from zero to three species with an increase in elevation (954 to 1,973 m; $p < 0.001$). The AICc test selected two models that better explained non–native richness (appendix 2s). However, according to the relaimpo package, elevation influenced 81% whereas absolute tree density influenced only 19% in non–native richness (fig. 3).

Discussion

Native mammal richness did not increase the greater distance to human settlements. Also, non–native mammal richness did not increase the closer to these settlements. The way it is written is different from the original question. It was expected to increase native mammal richness and decrease non-native mammal richness the further from human settlements. These results may be explained by the fact that these species have more extensive home range sizes than the distance we analyzed, moving long distances in search of resources (Kasper et al., 2016; Pereira, 2017). Moreover, most of the recorded species are capable
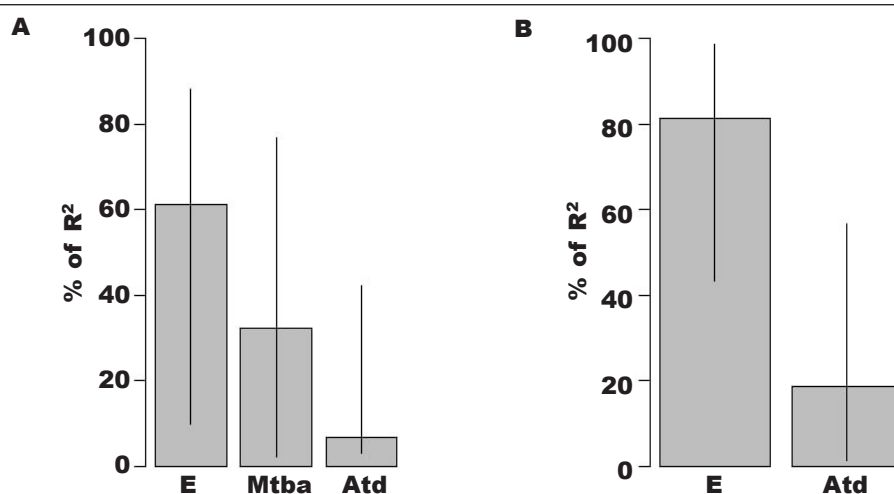
Fig. 3. Relative importance of environmental variables for native (A) and non–native (B) mammal richness at Itatiaia National Park. Bar plots of method Img were built with 95 % bootstrap confidence interval (lines in the bars). Variables are elevation (E), mean tree basal area (Mtba) and absolute tree density (Atd).

Fig. 3. Importancia relativa de las variables ambientales para la riqueza de mamíferos nativos (A) y exóticos (Ba) en el Parque Nacional de Itatiaia. Las barras del método Img se construyeron con un intervalo de 95 % de confianza 'bootstrap'. Las variables son la altitud (E), el promedio del área basal media de los árboles (Mtba) y densidad absoluta de árboles (Atd).

of living both in native environments and in those with some kind of anthropogenic influence (Zanzini et al., 2018). We found more native mammal richness in intermediate elevations in the Park (954–1,501 m) as has also been reported in other studies (Brown, 2001; Geise et al., 2004; Moreira et al., 2009; Rosa et al., 2014). Native mammal richness was also higher in forests where mean basal area was low. Mammal occupancy patterns in line with our findings in relation to vegetation structure have been observed previously. For instance, *Pecari tajacu* occupancy patterns were found to be negatively related with low basal area of fruiting trees, indicating low productivity of these trees, and, consequently, few available resources (Thornton et al., 2011). Occupational patterns of other species were negatively associated with the basal area of small trees, which could indicate difficulty in moving and foraging in these areas (Thornton et al., 2011). However, other studies have found that vegetation traits such as vertical structure index, tree species diversity, percentage of forest and grassland (Andrade–Núñez and Aide, 2010), and forest cover (Ferreira et al., 2020) have influenced mammal species richness. Based on these studies and the fact that the occurrence of mammals can be influenced by tree fructification, we can assume that one of the reasons for the negative association between native mammals in Itatiaia National Park and mean tree basal area was due to the fact that we did not consider only fruiting trees in this study. Other factors may also have influenced the study.

In Brazil, all but one of the 17 invasive mammal species reported in the literature for the country (Indian

sambar *Cervus unicolor*) are currently present in protected areas (da Rosa et al., 2017) and for the Itatiaia National Park we recorded three non–native mammal species: wild boar *Sus scrofa*, considered invasive in the Itatiaia National Park, domestic dogs *C. lupus familiaris*, and cattle *Bos taurus*, both considered casual in the Park (Ziller et al., 2020). Non–native mammal richness was greater at higher elevations and in forests with lower tree densities. Additionally, with the increase in elevation in the Park there is also a change in the vegetation's phytophysiognomy, from forest to native grasslands. Thus at higher elevations, forests are less dense, which may explain the increase of non–native richness in forests with lower tree density (Barreto et al., 2014). Moreover, the greater number of non–native mammal richness in high elevations can be due to being close to Itamonte neighborhoods, such as Fragária and Serra Negra. Some parts of these neighborhoods still share areas with the Park, facilitating access by domestic animals (Barreto et al., 2014). In addition, because of land tenure regularization issues, there are still residents living in this region within the Park (see methods). These residents have domestic animals such as dogs and cattle, which can range freely in the areas of the Park. Furthermore, we know that wild boar *S. scrofa*, prefer high elevations due to lack of sweat glands (Allwin et al., 2016), important in body thermoregulation. In this study, we recorded *S. scrofa* at minimum distances of 1 km from human settlements. This could be to avoid areas with human presence since hunting is still a current activity in the Park (Morais et al., 2019) and because this species is

wild and not directly related to humans (Long, 2003). The absence of non–native mammals in the lowland may be related to the type of occupation being mainly related to cottages available for holidays and weekends and the presence of summer houses. Furthermore, the Park administration located there controls the entrance of domestic animals in this area (Barreto et al., 2014; Rosa et al., 2014).

Domestic free–ranging animals are also an important issue for the conservation of biodiversity in the Park. The presence of domestic dogs *C. lupus familiaris* has also been reported in other protected areas (Paschoal et al., 2018). We found dogs were kept indoors in several residents' houses, which was a surprise as most dog owners allow them to roam freely (Gompper, 2014). Even so, as camera–traps have recorded some free–ranging dogs in the forest, the population needs to be aware of the consequences these animals can have on wildlife in the Park if they are released (Long, 2003) because the effects of a few individuals can be catastrophic, as in New Zealand, for example, where it was estimated that a single dog decimated approximately half of the North Island brown kiwi bird population (Taborsky, 1988). In addition to population consciousness, other measures such as vaccination and neutering could diminish the harm of free–ranging dogs to native communities (Lacerda et al., 2009). Domestic cattle *B. taurus*, which were found free ranging in the Park, have been identified elsewhere as a major cause of extinction of several native plants and animals (Gurevitch and Padilla, 2004). This is because the introduction of large herbivores into an environment imposes a new herbivore regime, especially due to different dietary patterns and body size (Hobbs and Huenneke, 1992), as well as degrading habitat due to grazing and trampling (Gurevitch and Padilla, 2004). The impact of domestic livestock can be negative, positive, or neutral, but with a tendency to negative impacts on vegetation, mainly related to conservation of vegetation structure, composition and dynamics (Mazzini et al., 2018). A study in a Patagonian forest showed that in places where cattle were alone, the impacts were higher than those caused by wild boar alone or than those in places where both were present (Ballari et al., 2020). Several studies have already shown that the impact of domestic animals can be significant. Therefore, as they are free ranging in the Park, they could cause disastrous consequences for native species as the impacts they have on this native community are as yet unknown.

Conclusion

The present study in the Itatiaia National Park showed that the diversity of mammal species was high, but it also revealed the presence of three non–native species. Although we found no evidence that non–native mammals influence the presence of native mammals at present, their potential threat to native biodiversity worldwide is well–known. The distribution of native and non–native mammals in the Park was affected by elevation and there were differences between wild and domestic free–ranging animals in the way they use the areas of the Park. In summary, elevation and vegetation, but not distance from human settlements or presence of non–native mammals, affect the distribution of both native and non–native mammal species in the Itatiaia National Park.

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Supplementary material

Appendix 1s. Native and non–native mammals recorded in the highland (HL) and lowland (LL) at Itatiaia National Park: Er, elevation range (in m); Trails: 3P, 3 Picos; RB, Rui Braga; HD, Hotel Donati; PI, Picu; AR, Araucárias; * non–native.

*Apéndice 1s. Registro de mamíferos nativos y exoticos en la Parte Alta (HL) y Parte Baja (LL) del Parque Nacional de Itatiaia. Er, rango de altitud (en m); Pistas: 3P, 3 Picos; RB, Rui Braga; HD, Hotel Donati; PI, Picu; AR, Araucárias; * exótico.*

Taxon	Common name	Location	Trail	Er (m)
Order Artiodactyla				
Family Bovidae				
Bos taurus (Linnaeus,1758)	Domestic cattle*	HL	PI, AR	1,893–2,236
Family Suidae				
Sus scrofa (Linnaeus,1758)	Wild boar*	HL	PI, AR	1,896–2,236
Family Tayassuidae				
Pecari tajacu (Linnaeus, 1758)	Collared peccary	LL	HD	1,082
Tayassu pecari (Link, 1795)	White–lipped peccary	LL	3P, RB, HD	1,012–1,501
Order Carnivora				
Family Canidae				
Canis lupus familiaris (Linnaeus, 1758)	Domestic dog*	HL	PI	1,903–1,973
Cerdocyon thous (Linnaeus, 1766)	Crab–eating fox	LL	3P	1,108
Family Felidae				
Leopardus sp.	–	LL	RB	1,178
Leopardus pardalis (Linnaeus, 1758)	Ocelot	HL, LL	HD	954–1,082
Leopardus guttulus (Hensel, 1872)	Southern tiger cat	HL, LL	HD, RB, PI	1,178–1,973
Family Mephitidae				
Conepatus semistriatus (Boddaert, 1785)	Striped hog–nosed skunk	HL, LL	3P, RB, PI	1,228–1,973
Family Procyonidae				
Nasua nasua (Linnaeus, 1766)	South American coati	LL	3P, RB	1,108–1,178
Family Mustelidae				
Eira barbara (Linnaeus, 1758)	Tayra	HL, LL	3P, RB, PI	1,108–1,973
Galactis cuja (Molina, 1782)	Lesser grison	HL, LL	PI, 3P	1,220–1,973
Order Cingulata				
Family Dasypodidae				
Dasypus novemcinctus (Linnaeus, 1758)	Nine–banded armadillo	LL	3P, RB	1,108–1,178
Order Didelphimorphia				
Family Didelphidae				
Didelphis aurita (Wied–Neuwied, 1826)	Brazilian common opossum	HL, LL	3P, RB, HD, PI	1082–1903
Philander frenatus (Olfers, 1818)	Southeastern four–eyed opossum	LL	HD, 3P	1082–1903

Appendix 1s. (Cont.)

Taxon	Common name	Location	Trail	Er (m)
Order Lagomorpha				
Family Leporidae				
Sylvilagus brasiliensis (Linnaeus, 1758)	Tapeti	HL, LL	PI, 3P	1,108–1,903
Ooder Rodentia				
Family Cuniculidae				
Cuniculus paca (Linnaeus, 1766)	Spotted–paca	HL, LL	PI, HD	1,082–1,903
Family Sciuridae				
Guerlinguetus ingrami (Thomas, 1901)	Southeastern squirrel	LL	3P, RB	1,178–1,501
Family Erithizontidae				
Coendou spinosus (F. Cuvier, 1823)	Paraguayan hairy dwarf porcupine	LL	3P	1,220

Appendix 2s. Akaike Information Criterion modified for small samples (AICc) for native and non–native mammal richness identified in the Itatiaia NP. GLM models selected include elevation (E), mean tree basal area (Mtba) and absolute tree density (Atd): WAICc, probability of the model being the best model in the set. (The relations of each dependent variable in the models are in superscript (positive '+' or negative '–').

Apéndice 2s. Criterio de información Akaiake (AICc) por la riqueza de los mamíferos nativos y exoticos identificados en el Parque Nacional de Itatiaia. Los modelos GLM seleccionados incluyen altitud (E), área basal promedio (Mtba) y densidad absoluta (Atd): WAICc, probabilidad de que el modelo sea el mejor modelo del grupo. (Las relaciones de cada variable dependiente en los modelos en superíndices (positivo '+' o negativo '–').

Dependent variable	Model	ΔAICc	WAICc
Native mammal richness	E^-, $Mtba^-$	0.00	0.257
	E^-	1.25	0.138
	E^-, $Mtba^-$, Atd^-	1.91	0.099
Non–native mammal richness	E^+, Atd^-	0.00	0.363
	E^+	1.65	0.159

Appendix 3s. Number of records and frequency of mammal species in the highland (HL) and lowland (LL) in the Itatiaia National Park: * non–native mammals.

*Apéndice 3s. Número de registros y frecuencia de especies de mamíferos en la Parte Alta (HL) y Parte Baja (LL) del Parque Nacional de Itatiaia: * mamíferos exóticos.*

Species	Number of records HL	Number of records LL	Species	Number of records HL	Number of records LL
*Bos taurus**	89		*Tayassu pecari*		127
*Canis lupus familiaris**	4		*Guerlinguetus ingrami*		25
*Sus scrofa**	15		*Dasypus novemcinctus*		10
Didelphis aurita	19	7	*Cerdocyon thous*		6
Cuniculus paca	8	1	*Leopardus pardalis*		5
Conepatus semistriatus	4	4	*Nasua nasua*		3
Eira barbara	4	7	*Pecari tajacu*		3
Galictis cuja	2	1	*Philander frenatus*		2
Leopardus guttulus	1	7	*Coendou spinosus*		1
Sylvilagus brasiliensis	1	7	*Leopardus* sp.		1