Do visitors attract or repel vertebrates in an urban park in the Brazilian Atlantic Forest?

Visitantes atraem ou afastam vertebrados em um parque urbano na Floresta Atlântica Brasileira?

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ABSTRACT

Ecotourism is an important tool for biodiversity conservation in protected areas. However, high visitation rates and intensive public use can affect the wildlife. The present study aimed to evaluate vertebrate foraging in areas under different levels of human influence in the Tijuca National Park, a protected area within the metropolitan area of Rio de Janeiro, Brazil. We used baits to attract vertebrates in areas with and without visitor facilities, at distances of 5, 35, and 100 meters from the road. We have analyzed the removal of bait by vertebrates in such treatments and identify higher consumption associated to greater human presence. The presence of visitors and visitor facilities (e.g., parking lots, barbecue pits, picnic tables, and playgrounds) significantly increases bait consumption. Park managers should consider the negative impacts of tourism on wildlife searching for ways to minimize them.

KEYWORDS: Management of Protected Areas; Public Use; Tijuca National Park; Ecotourism; Edge Effects.

RESUMO

O ecoturismo é uma importante ferramenta para a conservação da biodiversidade em áreas protegidas. No entanto, as altas taxas de visitação e uso público intensivo podem afetar a fauna em áreas protegidas. O objetivo deste estudo foi avaliar o forrageamento de vertebrados em áreas sob diferentes influências antrópicas no Parque Nacional da Tijuca: uma unidade de proteção integral dentro da metrópole do Rio de Janeiro, Brasil. Foram usadas iscas em áreas com e sem infraestrutura para visitantes, em distâncias de 5, 35 e 100 metros das margens da estrada, dentro de cada sítio de estudo. Análises apontaram que em áreas onde a presença humana é menos constante, o consumo de iscas de bananas foi menos intenso. A interferência causada por visitantes do parque sobre a intensidade do consumo de isca é significativa e influenciada por estruturas de visitação como estacionamento, churrasqueiras, mesas de piquenique e playground. Gestores de parques devem considerar tais impactos do turismo, visando minimizar influências negativas sobre a fauna.

PALAVRAS-CHAVE: Gestão de Unidade de Conservação; Uso Público; Parque Nacional da Tijuca; Ecoturismo; Efeito de Borda.

Introduction

The Brazilian Atlantic Forest is one of the richest and most threatened ecosystems in the world (MYERS *et al.*, 2000; BROOKS *et al.*, 2006). Currently, with approximately 11.7% of its original area, most of its remnants are isolated and disturbed (RIBEIRO *et al.*, 2009). Habitat fragmentation causes biotic and abiotic changes, which are more pronounced near the forest edge (MURCIA, 1995; LAURANCE *et al.*, 2002). These abiotic and biotic changes increase the risk of cascade effects in ecological interactions (MURCIA, 1995), which are among the least studied edge effects, and can alter the structure of the local community (LAURANCE *et al.,* 2002).

The expansion of disturbed forests results in the loss of habitats for many plant and animal species that need intact or extensive rainforests to survive (LAURANCE, 1999). Evidence shows higher fruit removal on forest edges than in the interior of forest fragments (e.g. RESTREPO *et al.*, 1999; DONOSO *et al.*, 2003; KOLLMANN and BUSCHOR, 2002). Some studies found low abundance of frugivores (KIRIKA *et al.*, 2008) within small forest fragments or edges. However, species with different levels of habitat specialization may respond differently to forest fragmentation and disturbance (DEVICTOR *et al.*, 2008). These changes are likely to affect specialist more than generalist species (KIRIKA *et al.*, 2008), as the former usually have smaller home ranges than the latter and prefer a closed forest canopy (HARRIS; PIMM, 2008). Generalist forest species and visiting species forage and reproduce in secondary forests of disturbed habitats (DRANZOA, 1998) and forest edges, and, therefore, are more common in these environments (BORGHESIO, 2008).

Environmental changes caused by human disturbances, such as sports activities (CREEL *et al.*, 2002) and tourism (BARJA *et al.*, 2007; VAN METER, et al., 2009), can also influence the wildlife. However, the actual effect of human disturbance on animal populations is poorly known (FRID; DILL, 2002; BÉCHET *et al.*, 2004; PROAKTOR *et al.*, 2007; BEKESSY *et al.*, 2009). Ecotourism and recreational activities are growing worldwide, especially in protected areas (BALMFORD *et al.*, 2009) and it can even contribute to the biodiversity conservation (ZAÚ, 2014). However, the effects of such activities on wildlife have raised concern among park managers. The increasing number of roads for tourists within forests expands the edge effects (LAURANCE *et al.*, 2009). The edge effect is a consequence of increased exposure to abiotic conditions of the forest outside, such as a higher incidence of sun and wind, decreasing humidity and increasing temperature (MURCIA, 1995). These situations modifies the forest dynamics (LAURANCE *et al.*, 2009) changing animal behavior (CIUTI *et al.*, 2012). We hypothesize that, in protected areas cut by roads, the edges associated with human agglomerations (e.g., parking lots, barbecue pits, picnic tables, and playgrounds) provide more food possibilities for animals. Such an increase in food availability may be related to the food provided directly by visitors or indirectly by their waste.

We assumed that these conditions work synergistically by attracting generalist animals and the ones that are used to the human presence. Thus, we assessed the intensity of consumption of baits by vertebrates. We chose sites with different levels of human activity and with linear edge effects

created by narrow paved roads that cut the Tijuca National Park, an urban remnant of Brazilian Atlantic Forest.

Methods

Study area

The study area is a relevant remnant of Brazilian Atlantic Forest (MORELLATO and HADDAD, 2000), located in a scarped relief at 400 m a.s.l. in the Tijuca National Park (22°57'S and 43°17'W), southeastern Brazil (Figure 1). The park has approximately 4.000 ha and is cut by paved roads (< 10 m wide). The city of Rio de Janeiro, with 6,200,000 inhabitants, surrounds the park (IBGE, 2011).
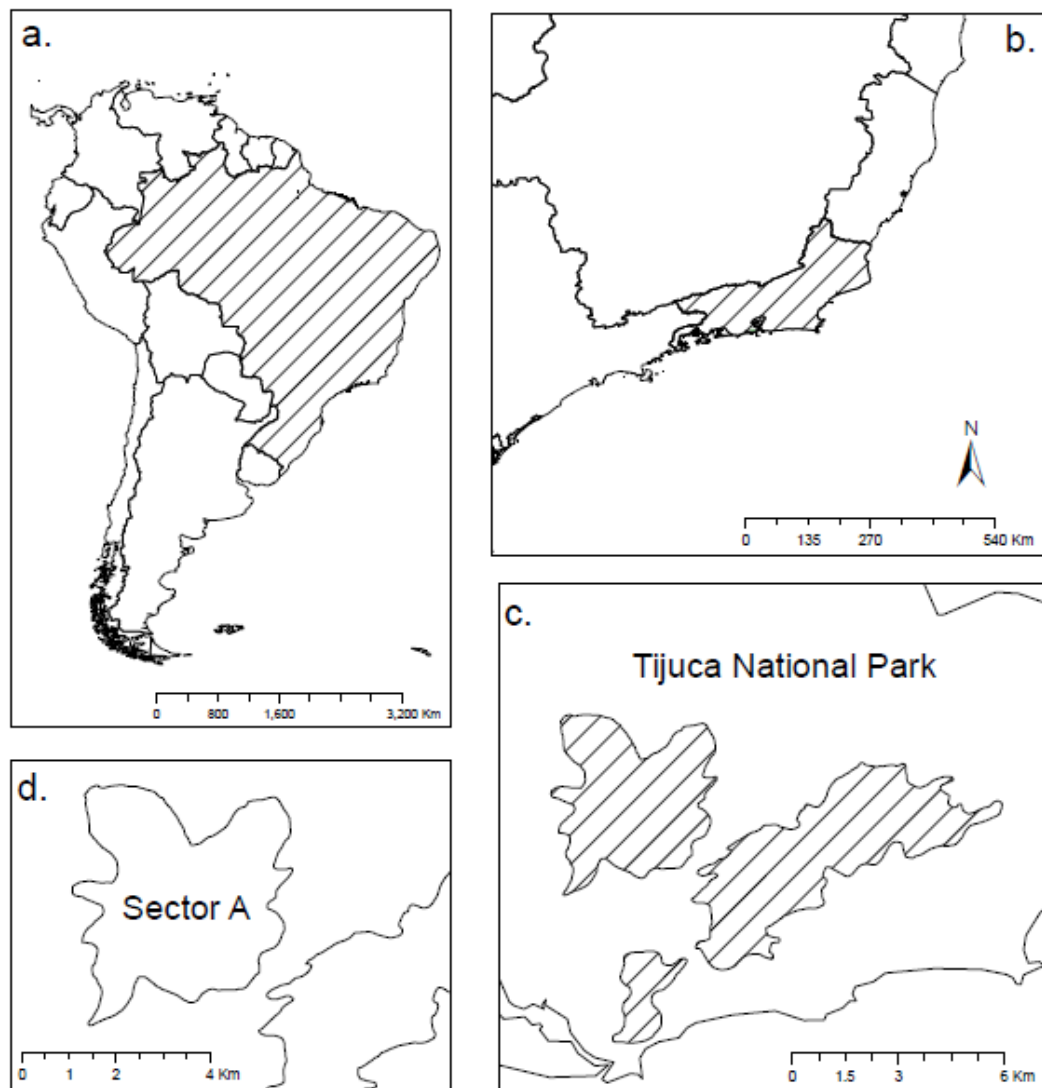

Figure 1: Location of the Tijuca National Park, Rio de Janeiro, southeastern Brazil. a) location of Brazil within South America; b) location of the state of Rio de Janeiro within Brazil; c) location of Tijuca National Park within Rio de Janeiro; d) study area, located in the sector "A" of Tijuca National Park.

Figura 1: Localização do Parque Nacional da Tijuca, Rio de Janeiro. a) localização do Brasil na América do Sul; b) localização do Estado do Rio de Janeiro, no Brasil; c) localização do Parque Nacional da Tijuca, no Município do Rio de Janeiro; d) área de estudo, localizada no setor "A" do Parque Nacional da Tijuca.

The park provides water to approximately 30,000 people and protects part of the city against floods and landslides. The Tijuca National Park is an extremely important area for tourism, sport, and leisure, which receives over two million visitors each year (ICMBIO, 2008).

In 2009 approximately 316,000 people visited the sector "A" (Figure1), known as the Tijuca Forest (ICMBio, unpublished data on visitation referred to 2009). On average, 26,326 ± 4,885 people visit the Tijuca Forest each month (ICMBio, *op. cit.*). Assuming that visitation is equally distributed through weekdays and weekends and holidays (FREITAS et al., 2002), we can estimate that approximately 880 people visited the park each day in 2009. Approximately 100,000 vehicles cross the roads that cut through the sector "A" each year. There are, on average, 8,250 (± 1,155) vehicles driving in those roads each month, which represents approximately 275 vehicles/day (ICMBio., *op. cit.*). The impacts of these vehicles on park roads, as well as the impact of visitors, are unknown.

The regional climate is classified as 'tropical rainforest (Af)' in the Köppen system (KÖPPEN, 1948; MATTOS, 2006). The average annual rainfall is 2,300 mm (over 100 mm/month). The average annual temperature is 21.5°C, and the average maximum and minimum temperatures are 26.2 °C and 17.9°C, respectively (MATTOS, 2006).

Logging and coffee plantations led to the removal of the original vegetation over centuries. The remaining forest is formed by high trees up to 20 to 25 meters, as well as epiphytes, lianas, shrubs, and herbs. The studied forest is well preserved and forms a continuous canopy at a late secondary or local climax stage in 35% of the area of the Tijuca Massif (112 km^2) (COELHO-NETTO *et al.*, 2007). This scenario results from conservation actions to protect forest remnants, which started in the mid 19th century (reforestation and faunal reintroduction), as well as natural ecological succession (OLIVEIRA *et al.*, 1995). It is still possible to find the ruins of ancient farms within the forest.

The most abundant tree families in the area are Myrtaceae, Arecaceae, Fabaceae, Lauraceae, Rubiaceae, Euphorbiaceae, Nyctaginaceae, Meliaceae, and Melastomataceae. Spontaneous and planted exotic species, such as the jaqueira (*Artocarpus heterophyllus* Lam), dracena (*Dracaena fragrans* (L.) Ker Gawl.), and eucalipto (*Eucalyptus robusta* Sm.), are also frequent in some areas (ZAÚ, 2010).

The fauna of Tijuca National Park is poor due to historical human impacts. However, we found some typical Atlantic Forest species in the area. Passeriform birds are relatively diverse, and mammals include mainly the quati (*Nasua nasua* (L., 1766)), macaco-prego (*Cebus apella* L., 1766), sagui mico-estrela (*Callithrix spp.* Erxleben, 1777), caxinguele (*Sciurus aestuans* L., 1776), cutia (*Dasyprocta leporine* L., 1758), gambá (*Didelphis marsupialis* L., 1758), preguiça (*Bradypus tridactylus* L., 1758), tapiti (*Sylvilagus brasiliensis* (L., 1758)), cachorro-do-mato (*Cerdocyon thous* (L., 1706), guaxinim (*Procyon cancrivorus* (G.[Baron] Cuvier, 1798)), and porco-espinho (*Sphiggurus insidiosus* (Lichtenstein, 1818). The park also harbors several species of bats and small rodents (ICMBIO, 2008). Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio) research permit: SISBIO 15160.

Sampling design

We set up 100 meters long transects in five sites, starting at the roadside and ending at the uphill forest interior. Three transects were located in heavily visited areas (V1, V2, V3), which harbor large human agglomerations (i.e., parking lots, barbecue pits, picnic tables, and playgrounds). The other two transects were located in isolated areas subjected to low human disturbance (D1 and D2; Figure 2). The distance between sites varied from 500 to 1,000 m. We installed 0.5 x 0.5 meters plots within each transect, at distances of 5, 35, and 100 m. We previously prepared these plots by removing the litter, flattening the microrelief, and adding local sand.

Figure 2: Study sites in Tijuca National Park, Rio de Janeiro, southeastern Brazil (modified from Google Earth 2014). In detail: V1, V2, and V3 - sites that are heavily used by visitors; D1 and D2 - sites that are distant from visitor facilities and so receive fewer visitors.

Figura 2: Locais de estudo no Parque Nacional da Tijuca, Rio de Janeiro (modificado a partir do Google Earth, 2014). Em detalhe: V1, V2 e V3 – locais que são muito utilizados pelos visitantes; D1 e D2 – locais que estão distantes de instalações para visitantes.

We used bananas as bait due to their low market cost and also because they can be easily transported, handled, and prepared. Besides, bananas are widely accepted by the local fauna. We placed banana pieces in each testing site every two weeks and checked the sites 24 h later to record food consumption, in a total of 15 events.

Data analysis

In the lack of data normality, after the identification and extraction of outliers, and even after the transformation of the data, we used the nonparametric analysis of variance (Kruskal-Wallis test), followed by Dunn test. We used that analysis to test for possible differences between bait consumption intensity within and between sites.

For the ordination of plots and sites, we used a non-metric multidimensional scaling analysis (NMDS) based on Euclidean distances of bait consumption (abundance), based on the method of paired groups (MCCUNE and GRACE, 2002). In order to analyze the data with the same coefficient and algorithm, we used an analysis of similarities (ANOSIM) and a non-parametric MANOVA (NPMANOVA). We grouped the last two analyses (D1 and D2) to test for differences between this group (D) and the heavily visited areas (V), considering different distances from road edges (5, 35, and 100 m).

Results

The areas with the highest human activity (V1 and V2) had more baits removed, whereas the areas where human presence was low (D1 and D2) showed low bait removal (Figure 3). We also observed differences in bait removal between distant sites (D) and sites near road edges, which were heavily visited by humans (V5 and V35; Tables 1 and 2; ANOSIM: R = 0.3827; p = 0.0087; NPMANOVA: F = 2.23; p = 0.0058).
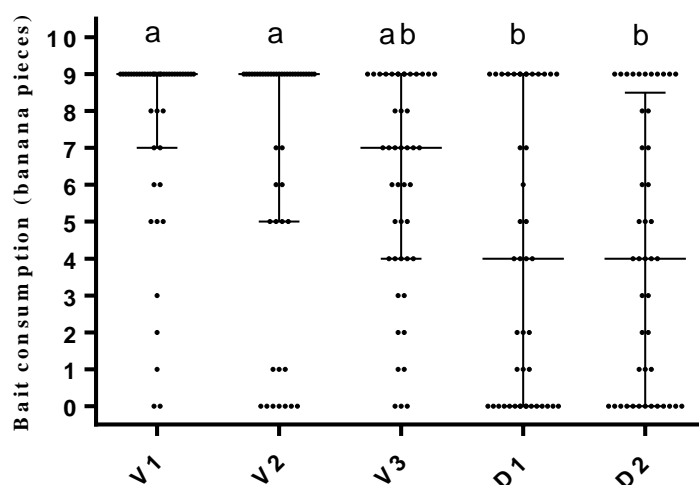

Figure 3: Comparative distribution of bait consumption (n = 45 records of 0 to 9 banana pieces per site). V1, V2, and V3: sites that are heavily used by visitors; D1 and D2: sites that are distant from visitor facilities and so receive fewer visitors; in Tijuca National Park, Rio de Janeiro, Brazil. K-W = 32.06; P < 0.0001. Horizontal lines (median with interquartile range). Different letters indicate significant differences.

Figura 3: Distribuição comparativa do consumo de isca (n = 45 registros de 0 a 9 pedaços de banana por local). V1, V2 e V3: locais que são muito utilizados pelos visitantes; D1 e D2: locais que estão distantes de instalações para visitantes e, por isso, recebem menos visitantes. Parque Nacional da Tijuca, Rio de Janeiro, Brasil. K-W = 32,06; P < 0,0001. Linhas horizontais representam a mediana e o intervalo interquartílico. Letras diferentes indicam diferenças significativas.

Table 1: Analysis of similarities (ANOSIM). R = 0.3827; P = 0.0087. Uncorrected P-value, based on Euclidean distances of bait consumption (abundance based on n = 45 records of 0 to 9 banana pieces per site). 9,999 permutations. V: sites that are heavily used by visitors; D: sites that are distant from visitor facilities and so receive fewer visitors, located at 5, 35, and 100 m from road edges in Tijuca National Park, Rio de Janeiro, southeastern Brazil.

Tabela 1: Análise de similaridade (ANOSIM). r = 0,3827; P = 0,0087 (valor de p não corrigido), com base em distâncias euclidianas do consumo de isca (abundância em n = 45 registros de 0 a 9 pedaços de banana por local). 9.999 permutações. V: locais que são muito utilizados pelos visitantes; D: locais que estão distantes de instalações para visitantes. Trechos localizados a 5, 35 e 100 m das margens de estradas no Parque Nacional da Tijuca, Rio de Janeiro.

	V-35	V-100	D
V-5	0.4030	0.2044	*0.0098*
V-35		0.6006	*0.0105*
V-100			0.1316

Table 2: Non-parametric MANOVA (NPMANOVA) analysis. F = 2.23; P = 0.0058. Uncorrected P-value based on Euclidean distances of bait consumption (abundance based on n = 45 records of 0 to 9 banana pieces per site). 9,999 permutations. V: sites that are heavily used by visitors; D: sites that are distant from visitor facilities and so receive fewer visitors; located at 5, 35, and 100 m from road edges in Tijuca National Park, Rio de Janeiro, southeastern Brazil.

Tabela 2: Análise não-paramétrica MANOVA (NPMANOVA). F = 2,23; P = 0,0058. Valor de P não corrigido, com base nas distâncias euclidianas de consumo de isca (abundância em n = 45 registros de 0 a 9 pedaços de banana por local). 9.999 permutações. V: Locais que são muito utilizados pelos visitantes; D: locais que estão distantes de instalações para visitantes. Trechos localizados a 5, 35 e 100 m das bordas da estrada no Parque Nacional da Tijuca, Rio de Janeiro.

	V-35	V-100	D
V-5	0.4029	0.2047	*0.0131*
V-35		0.6021	*0.0126*
V-100			0.2400

Nonetheless, some studies indicate that birds and small mammals are generally more abundant in the forest interior (WILLIS, 1979; CARVALHO and VASCONCELOS, 1999; COSSON *et al.*, 1999; ANDERSEN, 2003), as some animals adjust their home ranges in response to predation in more exposed environments (KOTLER *et al.*, 1991). This hypothesis, though, does not explain our results, because the main frugivorous terrestrial vertebrates do not have natural predators in the park, and they are used to human presence.

The NMDS (2D; stress = 0.2076) showed a significant representation of the axis 1 (r^2 axis 1 = 0.52, r = 0.72; r^2 axis 2 = 0.19, r = 0.44), which points out to a gradient associated with the proximity to visitor facilities (Figure 4). This gradient comprises from sites distant from visitor facilities (D, on the right) to heavily visited areas (V, on the left). Considering the trend of the gradient from D to V, we also adjusted the polygons that represent the

distances from road edges to the observed gradient. There was some overlap among polygons. The polygon formed by the plots located at V100 m from road edge was close to D. The polygon formed by plots located at V35 m was on an intermediate position. Finally, the polygon formed by plots located at V5 m from road edge, was on the left side of the graph (Figure 4). That indicates a gradient impact of visitor's on the fauna, which is greater near the visitor area facilities, comparing to distant ones.
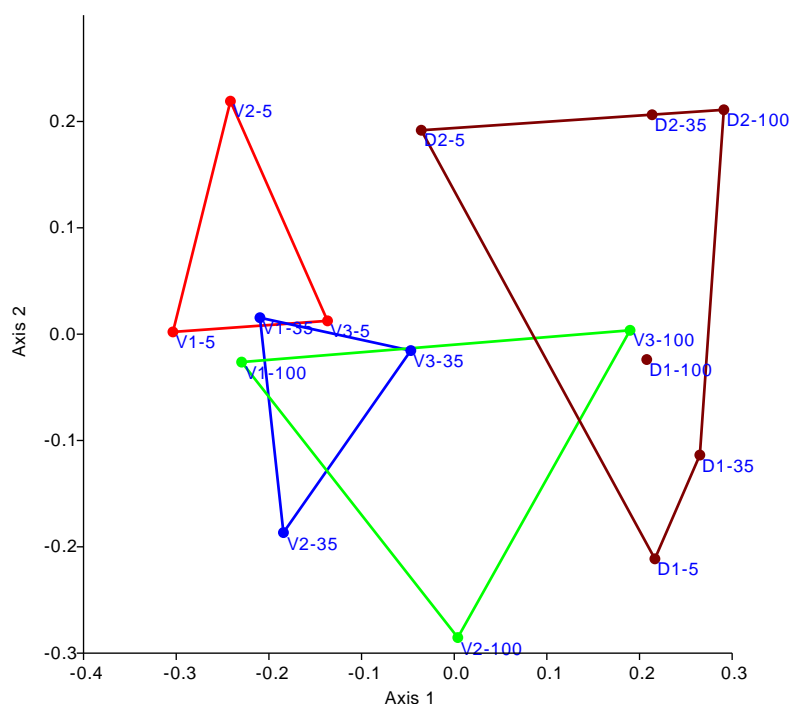

Figure 4: Non-metric multidimensional scaling (NMDS) based on Euclidean distances of bait consumption (abundance), according to the method of paired groups (2D; stress = 0.2076) (r^2 axis 1 = 0.52, r = 0.72; r^2 axis 2 = 0.19, r = 0.44) (n = 45 records of 0 to 9 banana pieces per site). V1, V2, and V3: sites that are heavily used by visitors; D1 and D2: sites that are distant from visitor facilities and so receive fewer visitors; located at 5, 35, and 100 meters from road edges in Tijuca National Park, Rio de Janeiro, Brazil.

Figura 4: Escalonamento Multidimensional Não Métrico (NMDS) com base na Distância Euclidiana do consumo de isca (abundância), de acordo com o método de grupos pareados (2d; estresse = 0,2076) (r2 eixo 1 = 0,52, r = 0,72; r2 eixo 2 = 0,19, r = 0,44) (n = 45 registos de 0 a 9 partes de banana por local). V1, V2 e V3: locais que são mais utilizados pelos visitantes; D1 e D2: locais que estão distantes de instalações para visitantes; parcelas amostrais localizadas a 5, 35 e 100 metros das margens de estradas no Parque Nacional da Tijuca, Rio de Janeiro.

Discussion

Bait removal was more strongly related to distance from visitor facilities than to distance from roads. The high light incidence on forest edges can facilitate the perception of baits by frugivores and result in high consumption (GALETTI *et al.*, 2003). However, road edges are old in the park, which usually leads to weak edge effects (TURTON; FREIBURGER,

1997). Additionally, canopies of the tallest trees on either sides of the road are very close to one another, which minimize abiotic edge effects (ZAÚ, 2010). It is also possible that similarities in bait consumption along the gradient result from uphill conditions, which are less prone to edge effects (e.g. FORMAN; ALEXANDER, 1998; FORMAN, 1998; RIBEIRO; ZAÚ, 2007). The floristic composition of the forest edges usually differs from that of the forest interior (HARPER *et al.*, 2005) and may influence the abundance and diversity of fruits (CAYUELA *et al.*, 2009). Some forest patches may have characteristics that make them distinct from others, even those located at short distances (POHLMAN *et al.*, 2009). This could exclude the hypothesis that only natural food attracts frugivores.

There are several studies on the relationship between fruit removal and edge effects, and most have reported increased fruit removal on forest edges (e.g. DONOSO *et al.*, 2003; TABARELLI and MANTOVANI, 1997; SANTOS; TELLERIA, 1997). This result is based on the following assumptions: (1) the high light incidence on forest edges can facilitate the spotting of fruits by animals (GALETTI *et al.*, 2003); (2) the number of omnivorous animals can increase on forest edges, and they are able to forage both in changed and preserved habitats (DONOSO *et al.*, 2003; MALCOLM, 1994); and (3) abrupt edges work like barriers, which makes animals move more frequently along them and increases fruit consumption (LÓPEZ-BARRERA, 2004).

The highest bait consumption in areas where recreation and leisure activities take place may be explained by the visitors' behavior. For example, we observed that some animals were attracted by food waste or food offered by visitors. Hence, the animals meet part of their food requirement through the visitors. Furthermore, the presence of generalist species, such as quati, which remove baits in areas under strong human influence and forest edges, may reflect their abundance in this environment (DRANZOA, 1998; BORGHESIO, 2008; MALCOLM, 1994).

The gradient of proximity to visitor facilities (e.g., parking lots, barbecue pits, picnic tables, and playgrounds) corroborates the hypothesis that visitors interfere with the fauna.

In spite of their vital role (e.g. MYERS *et al.*, 2000; MYERS, 2003), protected areas alone are not enough for conserving the biodiversity (PIMM *et al.*, 2014). The ecotourism board of a park plays a major role in promoting conservation awareness (ZAÚ, 2014). In addition, environmental education and management (e.g. ICMBIO, 2008; CID *et al.*, 2014) are essential to promote the sustainable ecotourism in protected areas. The inclusion of human food waste in the diet of wild animals, for example, may lead to changes in foraging behavior and community dynamics. To avoid that negative outcome, environmental education programs, with monitors and professionals trained, and management actions (e.g. increasing the number and remodeling of the informative signs) should be applied to minimize such impacts. Recently, barbecue places were drastically reduced and efficient locks were placed on trash bins, which prevent animals from opening them and consume food waste. However, given the scale and complexity of this process, it is clear that further studies are needed for a better management of ecotourism in protected areas.

Conclusion

Despite the bait removal wasn't strongly related to distance from roads, local factors related to stabilizing the edges and absence of predator of the main frugivorous terrestrial vertebrates in the park, can be related. The visitors are interfering with the foraging of vertebrate fauna, especially in the proximity of visitor facilities. Thus, although the ecotourism plays an important role in promoting conservation awareness, environmental education and management are essential to promote sustainable ecotourism. Visitor impact studies are needed to better ecotourism management in protected areas.

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