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Composição e ocorrência da assembléia de mamíferos de médio e grande porte em Áreas Protegidas sob distintos impactos humanos na Amazônia Central, Brasil.

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Sinopse

Avaliei a riqueza, composição da assembléia de mamíferos terrestres de médio e grande porte e a ocorrência de algumas espécies em três reservas sob distintos impactos na Amazônia Central, buscando entender a influência do impacto humano sobre tal assembléia. Para isso, utilizamos um conjunto de 30 armadilhas fotográficas/reserva. Relacionei a ocorrência das espécies com variáveis antrópicas e ambientais medidas em cada ponto/armadilha.

Palavras-chave: Armadilha fotográfica, mamíferos amazônicos, ocorrência, Reservas Florestais do INPA, modelos hierárquicos, impacto humano, estrutura do habitat, conservação de mamíferos.

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Resumo: As Áreas Protegidas (AP's) são consideradas ferramentas essenciais na conservação da biodiversidade, porém próximo a aglomerações humanas ainda se questiona sua eficiência em manter as espécies e seus papéis ecológicos, a exemplo dos mamíferos terrestres de médio e grande porte, considerados sensíveis a impactos humanos e foco deste estudo. Este trabalho avaliou a riqueza, composição e ocorrência da comunidade de mamíferos terrestres, utilizando armadilhagem fotográfica, em três AP's próximas ao maior centro urbano da bacia Amazônica, Manaus com ~ 1.8 milhões de habitantes. As AP's estudadas apresentam distintos impactos humanos e restrições de fiscalização. Avaliamos a riqueza e composição para comparar a estrutura da comunidade entre as áreas. Ainda, estimamos as ocorrências das espécies (>5 registros/reserva) é relacionamos com fatores antrópicos e ambientais, através de análises de máxima verossimilhança. As reservas apresentaram riquezas similares, por outro lado a similaridade na composição foi menor na área limítrofe a cidade de Manaus, a reserva Ducke (mais alterada). Indiferentemente da reserva, as ocorrências de algumas espécies foram influenciadas por variações espaciais na heterogeneidade da floresta, representada aqui basicamente pelo gradiente topográfico. Confirmando nossas expectativas quanto ao impacto humano, espécies mais sensíveis responderam negativamente a distância das estradas (índice de acessibilidade) e proximidade das bordas das reservas, sendo que a Ducke teve uma maior contribuição. Indicamos que, apesar da proximidade urbana afetar tanto a composição, quanto a ocorrência de algumas espécies, mesmo áreas mais próximas de centros urbanos, como a Ducke, ainda conservam a comunidade de mamíferos. Nossos resultados reforçam a necessidade da manutenção de conexões dessas áreas com florestas adjacentes e maior proteção/fiscalização em áreas próximas a aglomerações humanas, assegurando a persistência dos mamíferos e de outras espécies em longo prazo.

Keywords: Amazônia Central, Composição da assembléia, Modelos hierárquicos, Armadilhagem fotográfica, Mamíferos neotropicais.

Abstract

Composition and occurrence of midsized to large-bodied mammals in Protected Areas under different human impacts in Central Amazonia, Brazil.

Protected Areas (PAs) are considered essential tools for biodiversity conservation, but their efficiency in maintaining species and their ecological roles has been questioned when such areas are close to human settlements. This critique is especially frequent for taxa considered highly sensitive to human impacts, including many species of medium- and large-sized terrestrial mammals, the target group of this study. Using camera trapping, the current study evaluated site-by-site richness and composition of three PAs (with distinct suites of human impacts and protection issues) near the largest urban center in the Amazon Basin – the city of Manaus (1.8 million inhabitants). We analyzed species occurrence and compared assemblage structure between areas for medium- and large-sized terrestrial mammals, and related these to anthropogenic and environmental factors. For some species, occurrence was most influenced by spatial variations in forest heterogeneity: confirming predictions regarding human impact, the most sensitive species responded negatively to road proximity (accessibility index) and to reserve edges (indicative of higher hunting pressure and forest disturbance). The most compositionally altered was the Ducke Reserve, where these effects were most marked. The reserves had similar richness, though assemblage composition varied. Hence, even though urban proximity influences proportional composition, PAs close to urban centers, such as Ducke, still retain a complete regional mammalian assemblage. Our results emphasize the need to ensure that such areas continue to be connected with adjacent forests, and indicate the need for increased protection and surveillance so that conservation of mammals and other forest species is ensured over the long term.

Keywords: central Amazon, assemblage composition, hierarchical models, camera traps, Neotropical mammals.

Sumário

Apresentação

Esta dissertação foi elaborada como parte dos requisitos para a obtenção do título de Mestre em Biologia (Ecologia) pelo Instituto Nacional de Pesquisas da Amazônia- INPA. O estudo avaliou a riqueza composição e ocorrência da assembleia de mamíferos terrestres de médio e grande porte em florestas de terra-firme na Amazônia Central. As áreas de estudo compreendem três Áreas Protegidas situadas próximas ao município de Manaus, Amazonas, Brasil. Estas têm diferentes impactos humanos e restrições quanto à fiscalização. Durante os anos de 2010 a 2012, foram amostrados 90 pontos, 30 por reserva. A amostragem foi realizada por meio de armadilhas fotográficas que permaneceram nas reservas por 30 dias. A riqueza e composição foram avaliadas para verificar possíveis mudanças na estrutura das assembleias entre as Reservas. Em seguida foi utilizada uma abordagem de máxima verossimilhança, que considera a detecção imperfeita das espécies para obter as ocorrências das espécies mais abundantes e relacioná-las com fatores ambientais e antrópicos baseados em hipóteses *a priori* do que se tem de conhecimento sobre as espécies na literatura.

A dissertação é composta de um capítulo em forma de artigo. O artigo avalia a riqueza, composição da assembléia de mamíferos terrestres de médio e grande porte e a ocorrência das espécies mais registradas entre as três reservas estudadas e sua relação com o impacto humano. Além disso, foi avaliado a influencia de algumas variáveis ambientais para tais espécies a fim de contribuir para o conhecimento do uso do habitat pelas mesmas.

O artigo aqui apresentado segue as normas de formatação da revista *Biological Conservation*. As legendas das figuras, os gráficos e as tabelas são apresentadas junto às mesmas, dispostos ao fim do texto corrido do artigo.

Objetivo Geral

Avaliar a composição e ocorrência da assembleia de mamíferos terrestres de médio e grande porte em florestas de terra firme amazônica sob distintos impactos humanos, utilizando dados de presença e ausência obtidos através de armadilhagem fotográfica.

Objetivos específicos

1) Avaliar a riqueza e composição da assembleia desses mamíferos em cada área amostral: Reserva Florestal Adolpho Ducke; Estação Experimental de Silvicultura/Reserva Florestal Cuieiras e Reservas do Projeto Dinâmica Biológica de Fragmentos Florestais.

2) Estimar as taxas de ocorrência e detecção para as espécies que apresentarem maior número de registros fotográficos, utilizando modelos hierárquicos que consideram a detecção imperfeita

3) Avaliar a influência de fatores ambientais e antrópicos sobre os padrões de ocorrência e detecção para tais espécies.

Capítulo 1

Gonçalves, A.L.S., da Silva, C.E.F., Barnett, A.A., Spironello, W.R., Ahumada, J. Composition and occurrence of midsized to large-bodied mammals in Protected Areas under different human impacts in Central Amazonia, Brazil. Manuscrito formatado para *Biological Conservation*.

Composition and occurrence of midsized to large-bodied mammals in Protected Areas under different human impacts in Central Amazonia, Brazil.

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Summary: Protected Areas (PAs) are considered essential tools for biodiversity conservation, but their efficiency in maintaining species and their ecological roles has been questioned when such areas are close to human settlements. This critique is especially frequent for taxa considered highly sensitive to human impacts, including many species of medium- and large-sized terrestrial mammals, the target group of this study. Using camera trapping, the current study evaluated site-by-site richness and composition of three PAs (with distinct suites of human impacts and protection issues) near the largest urban center in the Amazon Basin – the city of Manaus (1.8 million inhabitants). We analyzed species occurrence and compared assemblage structure between areas for medium- and large-sized terrestrial mammals, and related these to anthropogenic and environmental factors. For some species, occurrence was most influenced by spatial variations in forest heterogeneity: confirming predictions regarding human impact, the most sensitive species responded negatively to road proximity (accessibility index) and to reserve edges (indicative of higher hunting pressure and forest disturbance). The most compositionally altered was the Ducke Reserve, where these effects were most marked. The reserves had similar richness, though assemblage composition varied. Hence, even though urban proximity influences proportional composition, PAs close to urban centers, such as Ducke, still retain a complete regional mammalian assemblage. Our results emphasize the need to ensure that such areas continue to be connected with adjacent forests, and indicate the need for increased protection and surveillance so that conservation of mammals and other forest species is ensured over the long term.

Keywords: central Amazon, assemblage composition, hierarchical models, Neotropical mammals.

Highlights

► We evaluate Protected Areas (PAs) their current status and effectiveness in maintaining mammalian assemblage structure. ► Data from camera trap was used to model occurrence of mammals via hierarchical models. ►We identify key environment and anthropic elements for mammalian assemblage. ► Index of accessibility and disturbance impacted the occurrence of some mammal species. ►We suggest conservation actions to maintain mammals in PAs near human settlements.

1. Introduction

Recent exponential growth in global biodiversity loss has been attributed largely to human activities (Estes et al., 2011). As a counterpoint, Protected Areas (hereafter, PAs) have been seen as key tools in efforts to conserve biodiversity (Bruner et al., 2001; Peres, 2011). In the Brazilian Amazon, the PAs designated as Conservation Units (hereafter, CUs) (Bernard et al., 2014; Imazon and ISA, 2011) were created to reduce both deforestation rates and maintain the region´s exceptionally high biodiversity (Peres, 2005). But, even with the growing number of new CUs, there are still questions regarding the effectiveness of such areas in terms of conservation and maintenance of ecological roles of species, especially near human settlements (DeFries et al., 2010; Peres, 2011; Schulman et al., 2007).

In the Brazilian Amazon 70% of CUs have people residing within their boundaries (Bernard et al., 2014; Terborgh and Peres, 2002). Such areas can suffer from poaching, non-sustainable natural resource extraction and deforestation (Peres, 2011; Terborgh and Peres, 2002). Such impacts potentially alter the distribution of species and affect the dynamics of species assemblages (Galetti et al., 2009). In addition to anthropogenic factors, the structural characteristics of the habitat within CUs (e.g., soil conditions, topography, forest structure) are also of great importance, influencing both the dynamics and distribution of organisms (Licona et al., 2010; Negrões et al., 2011; Salvador et al., 2010). Given the plethora of negative impacts that such CUs confront, it is all too easy for them to become conservation law enforcement failures (Peres, 2011; Terborgh and Peres, 2002; Urquiza-Haas et al., 2009).

In the Neotropics, species of medium and large (> 600g; > 15kg, respectively: Emmons and Feer, 1997) mammals are often among the first to suffer the impacts of human pressure (Peres, 2000), even when other species benefit from these changes (Galetti et al., 2009). Such changes consequently alter the dynamics of tropical ecosystems (Cuarón, 2000; Michalski and Peres, 2007), since, by virtue of their high functional diversity, mammals play key ecological roles in such systems (Emmons, 1984). Because of this, medium and large terrestrial mammals are considered good indicators of forest integrity (Cuarón, 2000).

For these reasons, understanding how such mammals respond to environmental changes is essential for the conservation and effective management of their populations, as well as for the selection and maintenance of conservation areas (Dale et al., 1994; Galetti et al., 2009), and the development of efficient regional conservation strategies (Licona et al., 2011). Despite this, few studies have attempted to evaluate explicitly the ecological effectiveness of PAs in the Amazon, in terms of assessing their capacity to maintain biodiversity and representativeness of the sample preserved (Negrões et al., 2011; Sampaio et al., 2010).

Due to the great habitat diversity and size of the Amazon biome, ecological knowledge of the region´s medium- and large-sized mammals is still incipient and many assemblages remain poorly sampled (Michalski and Peres, 2007; Salvador et al., 2011). For Amazonian mammals, those groups with the most ample data on ecology, species richness and species distributions are primates (e.g., Mendes Pontes et al., 2012; Peres and Dolman, 2000) and top carnivorous predators (e.g., Michalski and Peres, 2005; Ramalho and Magnusson, 2008). For other orders, data on most aspects of species and community biology are still insufficient (e.g., Michalski and Peres, 2007; Munari, 2010).

Even within this paucity, there is considerable sample bias in the geographical distribution of our knowledge of the Amazonian mammal fauna: the best known-sites are often those closest to regional population centers (Michalski and Peres, 2007). These well-sampled sites may be contributing disproportionately to the conservation theory used in management planning and also, since many CUs are located near urban centers, to on-ground conservation efforts. Given this, it is important to ascertain if mammal assemblages near tropical forest conurbations are representative of those in the broader milieu or whether they are depauperate. This is especially important given the tendency to employ medium- and large-sized mammals as flagship species (Walpole and Williams, 2002).

In this context, the current study sought to evaluate the effectiveness and current state of conservation within CUs located near Manaus, and to understand how species of medium- and large-sized terrestrial mammals relate to the environment and any changes within in. Manaus is the largest urban center in the Brazilian Amazon Basin (1.8 million inhabitants: IBGE, 2010), and has within a 100 km radius fourteen CUs. The study used data from the "Tropical Ecology Assessment and Monitoring Network - TEAM" project which, within the Manaus region, works in three CUs. All have similar environmental conditions (habitat, rainfall, drainage), but have differing levels of human impact and management intensity.

We had the following objectives: (1) to assess whether richness and composition of the medium- and large-sized terrestrial mammal assemblages differed between areas; (2) estimate the rates of occurrence and detection of such mammal species; (3) assess the influence of anthropogenic factors on the patterns of occurrence and detection of such species.

Additionally, we investigated whether factors associated with habitat can influence patterns of species occurrence. We used camera trapping methods to assess these ecological parameters. Estimates of occurrence and detection were generated using presence and absence data and hierarchical models of occurrence that, while considering problems of imperfect detections, allowed modeling of species habitat use via multiple variables (Mackenzie et al., 2006; O'Connell et al., 2011).

Studies have shown that human population density and urbanization can either positively or negatively influence the species richness and composition of mammalian assemblages (Galetti et al., 2009; Urquiza-Haas et al., 2009). Moreover, larger and more specialized species have larger home ranges, and so are likely to be more vulnerable to hunting and other human disturbance (Michalski and Peres, 2007; Peres, 2000), while some generalist species may expand their ranges as a result of human impacts (Ahumada et al., 2011; Jerozolimski and Peres, 2003). Thus we predicted: (1) the mammal assemblage structure will vary across sites, with perturbations being proportional to the degree of exposure to human influence; (2) larger and more specialized species will be less frequent as human impacts increase; and (3) generalist species will show an inverse pattern, either increasing in relation to human impact intensity or being indifferent to human disturbance levels.

2. Materials and methods

2.1. Study area

We conducted the study in three PAs, each with different levels of human impacts and environmental protection (Fig. 1). The first, Adolpho Ducke Forest Reserve (**Ducke**), is a 10 000 ha area located on the outskirts of the city of Manaus, Amazonas, Brazil (02º 55' to 03º 01' S, 59º 53' to 59º 59' W) (Oliveira et al., 2008). Due to rapid urban expansion, city suburbs now fringe the southern and western borders of the reserve. Ducke has a constant environmental supervision. The second site, **ZF-2**, combined the Cuieiras Forest Reserve and Tropical Forestry Experimental Station into a single area. ZF-2 is located some 60 km northwest of Manaus (02º 37' to 02º 38' S, 60º 09' to 60º 11' W). It has an area of approximately 38 000 ha, and is delimited by the BR-174 highway and the Cuieiras River basin (Higuchi, 1981). Environmental protection enforcement consists of a single forest service post on an unpaved road, the only access-by-road to the reserves. The third study site, **ZF-3**, consists of two experimental forest reserves, Cabo Frio and Km 37, also treated by the current study as a single area. Both form part of the Biological and Dynamics of Forest Fragments Project (Laurance et al., 1998). Located some 80 km from Manaus (02º 30' S**,** 60º 00' W), these reserves together have an area of around 35 000 ha, which includes primary forest, abandoned cattle pasture, active farms and some smallholdings. The approach is via two local roads (ZF-3 and ZF-7), which connect to the two asphalt-paved highways (the BR-174 and AM-010, respectively). The region has no environmental supervision.

We classified the level of human disturbance in each area by adapting the TEAM Human Ecosystem Interaction Protocol (Defries et al., 2010; TEAM Network, 2010) for calculating the percentage of anthropically-disturbed area around each set of camera traps. Using the remote sensing, surrounding forest within a 10-km radius of areas containing camera traps were classified as *Continuous habitat, Partially* and *Highly Fragmented* if human settlement was considered, respectively, to occupy 0-20 %, 20-50 % or 50-100 % of the land around them (Ahumada et al., 2011). We quantified this percentage using the Prodes program, referring data to 2012 (Prodes-INPE; see http://obt.inpe.br/prodes). Our calculations showed that the appropriate percentages were 16.8 %, 18% and 69.2% for ZF-2, ZF-3 and Ducke, respectively (Fig. 1).

The natural unmodified vegetation in the three areas is considered similar floristically (Baker et al., 2014; Oliveira and Amaral, 2010), and they share the same species of medium- and large-sized mammals (Emmons and Feer, 1997; Wilson and Reeder, 2005). Natural, unmodified, habitat is upland terra firme forest, with a relatively open understory and a dense uniform canopy some 30-39 m tall, with emergents to 55 m (Castilho et al., 2006). Soils are nutrient-poor sandy and clayey oxisols. The topography is undulating, with the average elevation varying between 40-160 m above sea level (m.a.s.l.) (Prance et al., 1990). This variation has great influence on forest structure, with visibly different vegetation formations being associated with hill-tops, and slopes of varying inclination. Additionally, occasionally flooded bottomland swamps may occur in areas where plateaus are dissected by streams (Oliveira et al., 2008). The average temperature is 26ºC, and the seasons are well defined, with most rain falling from December to May (211-300 mm monthly average), and a marked dry season occurring from June to November (42-162 mm monthly average) (Ribeiro and Adis, 1984).

2.2. Sampling design

We used regional data from the Tropical Ecology Assessment and Monitoring Network Project (TEAM). This project conducts long-term biodiversity monitoring of 17 tropical forests around the globe, including two sites in the Brazilian Amazon (Caxiuanã, Pará and Manaus). Terrestrial mammals are among the biodiversity components studied by this network, and are monitored using a standardized camera trap methodology (TEAM Network, 2011). In Manaus, TEAM has three sample areas (Fig. 1).

For this study, we undertook six sampling campaigns. These were conducted between July 2010 and October 2012 (Table 1). We used 30 camera traps (model RM45, Reconyx Inc.) per reserve, a total of 90 camera traps overall. The Reconyx RM45 is triggered by infra-red and does not use flash. In each reserve, the trap array covered 60 km^2. Sampling followed standard TEAM protocol (TEAM Network, 2011), with traps arranged in a regular grid, each sampling an area of 2 km^2. During each field campaign, traps remained in position for 30 consecutive days, with the same positions repeated in each campaign. Traps were positioned some 30-50 cm above the forest floor. We programmed the traps to register images without pause and remain active 24 hours a day. At the end of sampling, we removed the images from memory cards with DeskTEAM software (TEAM Network, 2011). Bait response is not uniform across medium- and large-mammal species (O'Connell et al., 2011), so, to avoid disproportionate increases in the frequency of some species, we did not use bait.

2.3. Data analysis

2.3.1. Richness and composition of the mammal community

We evaluated sample area mammal richness with species accumulation curves, using the non-parametric Jackknife first order index (Magurran, 2004). For each curve we performed 1000 sample order randomizations. We considered richness between reserves distinct when the confidence intervals did not overlap curves (Magurran, 2004).

We analyzed image capture rates to evaluate medium- and large-mammal assemblage composition. First, we considered image records of species as independent, setting a minimum interval of 24h between images of the same species from the same trap. We then calculated capture rates for each species per reserve (no. independent records/1000 camera* days: Tobler et al., 2009). We used capture rates to compare mammal assemblage composition between areas using the Multi-Response Permutation Procedure (MRPP: Legendre and Legendre, 1998), based on the Bray-Curtis similarity index. The Sørensen index was used when calculating similarity based on presence/absence data.

We used the MRPP test statistic, with an R value to determine the degree of similarity between treatments (reserves). This value can vary from -1 to 1: the more positive the value, the smaller the difference between treatments. Subsequently, we verified the dispersion within the study areas via a multivariate dispersion index, which allowed us to check whether treatments genuinely differed in species composition, or if observed differences resulted from greater within-group heterogeneity. The values resulting from such analysis reveal average distance within groups/treatments in relation to the core of the analysis in a multivariate space (Legendre and Legendre, 1998). The composition of the medium- and large-size mammal assemblages in three reserves was plotted using non-metric multi-dimensional scaling ordinations (Legendre and Legendre, 1998). We conducted all analyses in R software (R Development Core Team, 2010), using the *Vegan* package (Oksanen et al., 2012).

2.3.2. Estimates of occurrence (Ψ) and detection (p) of the species

2.3.2.1. Characterization of variables

Nine variables were used in modeling mammal species occurrence and detection. The variables were characterized as two related to sampling, five to anthropogenic and two to environmental factors. We tested the sampling variables *Year* and *Occasion* respectively, modeling probability of occurrence and detection of species in order to determine whether there was heterogeneity between years and days sampled. For each sample point, we also measured the anthropogenic variables, *Road Distance*, an index of accessibility to areas related to hunting and other human impacts (being, for each point, the linear distance to nearest road: Lake and Peres, 2003); *Edge Distance,* used here as an indicator of possible habitat disruption, and of hunting (being, for each point, linear distance to nearest human-made habitat edge: Rovero et al., 2012). *Domestic Animals,* the occurrence of which can affect populations of native species and also related with hunting (being, records of dogs in camera traps images: Peres, 2000). We also included two categorical variables, *Block* (for each block of 15 traps/reserve), and *Reserve* (Ducke, ZF-2 and ZF-3). The arrangement of camera traps was based on previous TEAM studies, so that within reserves ZF-3 and ZF-2, the set of traps 30 are arranged in two blocks of 15 cameras (Fig. 1). Consequently, the variable *Block* was put in place to determine whether there were different probabilities of species occurrence in each of these four arrays. The variable *Reserve* was used to analyse whether sample areas had different relative probabilities of occurrence, and was also used as an indication of the influence of urban proximity on species occurrence.

The two environmental variables were: *Density Drainage* and *Elevation*. Choice of these variables is based on *a priori* assumptions and existing literature concerning study species habitat requirements (Anderson et al., 2001). In the study areas, slope and elevation greatly influence forest structure (Oliveira et al., 2008). Accordingly, and following such studies as Bodmer (1997) and Keuroghlian et al. (2004), we assumed that the presence of more specialized herbivorous mammals (e.g., Red-brocket deer, Brazilian tapir) would be positively influenced by topography and waterway density and proximity, while that of more generalist herbivores (e.g., red-rumped agouti, red acouchy) would not be associated with any of the studied variables (Emmons and Feer, 1997; Eisenberg and Redford, 1999).

We extracted all variables, except for *Domestic Animals*, from remote sensing data using ArcGIS 10 software (ESRI, Redlands, California). For *Drainage Density* we created a buffer of 500 m (equivalent to ~78 ha) around each camera trap point. This was done to avoid overlap between point coverage. We measure linear meters of stream extent within the buffer and divided it by area. Hydrological network data was obtained from the Brazilian Institute of Geography and Statistics (IBGE), and refined using the HAND algorithm (see Noble et al., 2011). For *Elevation,* we used Topodata database values (see http://dsr.inpe.br/topodata/), corrected for 30 m resolution from SRTM (Shuttle Radar Topography Mission) radar images.

We assessed co-linearity between variables using a Pearson correlation. Following Legendre and Legendre (1998), we considered variables to be correlated when coefficient values were > 0.50. The variable *Elevation* was negatively correlated with *Drainage Density* ($r = -0.69$, $p = < 0.001$). We did not include correlated variables that influenced the same parameter in the same model. Subsequently, we verified whether reserves had distinct contributions in relation to median values of continuous variables, by applying an analysis of variance (One-way ANOVA) followed by a post-hoc Tukey's test to discriminate difference between pairs. According to the analyses, values for continuous variables did not differ between reserves, with the exception of *Edge Distance*, which was higher at Ducke (Table 2). Consequently, we did not include *Edge Distance* and *Reserve* in the same analysis.

2.3.2.2. Model building and selection for occurrence and detection

We used records of the most abundant species, wich were herbivores (Table 3) to estimate occurrence (Ψ, probability that a species would occur in a particular location) and detection (*p*, probability of detection of species conditional on its occurrence) (Mackenzie et al., 2006). This method uses binary data for detection (1's), and non-detection (0's), for the species in a set of locations, and allows a history of detection to be built for each species at each sampling point. In order to increase detection probability for each sampling period, we divided the 30 sampling days in each reserve into six sampling units (*Occasions*), each composed of five days (Tobler et al., 2009).

Before running occurrence analysis, we checked data from each species for spatial autocorrelation. Failure to do so can lead to errors in conclusions with regard to the relative importance of variables determining species occurrence (Legendre and Legendre, 1998). Data correlograms were generated using the *spline correlog* from the R program *ncf* package (Bjornstad, 2008). We did not detect spatial autocorrelation among the species analyzed (Online Appendix A, Figure A1).

For occurrence analysis, we employed multi-season single-species models. These assume that occurrence probability is dynamic, i.e., can switch between two seasons or primary periods (open population), but not between visits or secondary periods within a season (Mackenzie et al., 2006). We used these models to assess changes in both occurrence and detection between the two years of sampling. In the models, the dynamic process is governed by changes in occurrence (Ψ), colonization (γ), extinction (ε) and detection (p). First, we modeled parameters considering the influence of *year*: Ψ [**year**] γ [**year**] ε [**year**] p [**year**], then we evaluated the influence of sampling *Occasions* on species detection: Ψ [.] γ [.] ε [.] p [**occasion**]. Results showed that the processes of colonization (γ) and extinction (ε) were not significant, and that detection was similar for both sampling years for all species. In addition, detection did not vary between sampling occasions. Therefore, since the parameters remained constant between years, we assumed the premise of closed populations was valid, so permitting a combined data analysis (Table 4).

Subsequently, we modeled occurrence with environmental and anthropogenic variables (e.g., Ψ [**variable**] ε [.] γ [.] p [.]) as covariates for each sampling unit. Two variables influencing species detection were simultaneously inserted when modeling occurrence, *Edge Distance* and *Domestic Animals* (e.g., Ψ [**variable**] γ [.] ε [.] p [**variable**]). These variables were included because we predicted that species were likely to become more elusive near edges and in the presence of domestic animals, i.e., where human disturbance is higher (Michalski and Peres, 2007; Peres, 2000). We tested 20 model combinations, first a null and global model, as well as the influence of each variable and multivariate combinations.

We selected the best combination of variables to describe the data of occurrence and species detection, using the Akaike Information Criterion (AIC), Akaike weight (AIC ω) and delta AIC (Δ AIC) (Burnham and Anderson, 2004). We considered only models with Δ AIC values ≤ 2, as those with best data fit and having variables with best support for predicting the occurrence and detection of species. AIC ω was used to determine the relative importance of each variable. Unless a single model had ωi ≥ 0.90, we made inferences about other models of the analyzed data by summing, for each species, the ωi weight values between models whose variables had values up to 90%. We estimated the final occurrence of each species with Model-Averaging (Burnham and Anderson, 2004). We tested the relevance of each parameter analyzing β (i.e., regression coefficient) within the top ranking models for significance of effect (i.e., 95% confidence intervals (CI) excluding zero (Mackenzie et al., 2006). We conducted all analyses in R, package *Unmarked* (Fiske and Chandler, 2010).

3. Results

3.1. Richness and composition of community

With the 90 sampling points combined we achieved a total sampling effort of 5400 traps*day. The 30 sampling points per forest reserve provided a sampling effort of 1800 traps per reserve*day (Table 1). Based on existing literature (Emmons and Feer, 1997; Wilson and Reeder, 2005), 28 species of medium- and large-sized terrestrial mammals are present in the study area. Of these, we recorded 21 (75 %). We obtained 2040 independent records of medium- and large-sized terrestrial mammals, ranging from 1 grison (*Galictis vitatta*) to 774 records of red acouchy (*Myoprocta acouchy*) (Table 3). In general, areas showed no differences in species richness (Fig. 2 and Table 3). However, mammalian assemblage composition between reserves showed significant dissimilarities, with Ducke having the lowest similarity (Fig. 3; MRPP, $p = 0.03$; $R_{ZF3\ x\ ZF2} = 0.61$; $R_{ZF3\ x\ DUCKE} = 0.50$; $R_{ZF2\ x\ DUCKE} = 0.51$). For dispersal within treatments we found no difference between reserves (mean values of 0:49, 0:50 and 0:50 for Ducke, ZF-2 and ZF-3, respectively).

3.2. Modeling probability of occurrence (Ψ)

For analyses of occurrence, species with <5 records/reserve were excluded from the final analyses, due to low detection that generates fail in convergence of models (Table 3). This cut-off left nine species: three rodents, *Myoprocta acouchy*, *Dasyprocta leporina* and *Cuniculus paca*; four ungulates, *Mazama americana*, *Mazama gouazoubira*, *Tapirus terrestris* and *Tajacu peccary*; one xenarthan, *Dasypus novemcinctus*; and the marsupial, *Didelphis marsupialis*. We investigated the occurrence and the relationship of these species with anthropogenic and environmental variables in the sampled areas. Except for red-rumped agouti (*D. leporine*) and red acouchy (*M. acouchy*), no single model emerged as the best model (i.e., ωi> 0.90), allowing the use of more than one model for all the other seven species (Table 5, Online Appendix A, Table A1).

3.2.1. Anthropic variables

The variable *Distance to Road* had the greatest influence on species occurrence (Σω = 2.60), followed by *Reserve* (Ducke, ZF-2 and ZF-3) (Σω = 2.46) (Table 6). Of the nine species analyzed, five had relationship with *Distance to Road* (Table 5, Online Appendix A, Table A1). Red brocket deer (*M. americana*), nine-banded armadillo (*D. novemcinctus*) and collared peccary (*P. tajacu*) showed an increased occurrence with greater distances from roads, while grey brocket deer (*M. gouazoubira*) and commom opossum (*D. marsupialis*) showed the inverse pattern (Fig. 4, and Table 6).

For *Reserve*, we observed a significant difference in occurrence of *M. gouazoubira*, being higher at Ducke (*Ψ* Reserve = 0.80 ± SE 12:16), when compared to ZF-2 (*Ψ* Reserve = 0.47 ± 0.16 SE) and ZF-3 (*Ψ* Reserve = 0.41 ± 0.16 SE). In contrast, the occurrence of *P. tajacu* was lower at Ducke (*Ψ* Reserve = 0 0.11 ± 0.07 SE), compared to ZF-2 (*Ψ* Reserve = 0.51 ± 0.16 SE) and ZF-3(*Ψ* Reserve = 0.60 ± 0.16 SE). The agouti, *D. leporina*, was most frequent at Ducke (*Ψ* Reserve = 0.86 ± 0.10 SE), compared to the other reserves (Fig. 5).

We did not observe any relationship between *Edge Distance* and species occurrence, but did find that *Edge Distance* was among the top ΔAIC ≤ 2 models influencing detection of five species (Σω = 4.95) (Table 6), indicating its specific importance for these species.

3.2.2. Environmental variables

Both *Elevation* (Σω = 2.97) and *Drainage Density* (Σω = 2.52) were important in influencing occurrence of some species (Table 6, Online Appendix A, Table A1). *M. gouazoubira*, *M. acouchy* and *D. novemcinctus* occurrence was positively related to terrain elevation, while *M. americana* has a negative relation to drainage density (being recorded less frequently in poorly drained areas). This occurred in all ΔAIC ≤ 2 models for *M. americana*, indicating its importance as an occurrence predictor for the species. For these three species, values at 95% confidence intervals of models including the environmental variables, and β coefficients, did not overlap zero (Online Appendix A, Table A1).

4. Discussion

4.1. Richness and composition of mammal community between reserves

Richness estimates obtained by this study (21 species, 75%) were similar to those for other forest regions of Amazonia: e.g., Maffei (2002: Bolivian chaco, 23 species, 82 %), Negrões (2011: southeastern Amazonia, 20 species, 71 %) and Tobler (2008: Peruvian Amazon, 24 species, 86 % of current sample). Accumulation curves for the three study areas did not reach an asymptote, indicating increased sampling would add additional as-yet unregistered taxa (O'Connell et al., 2011). However, the camera trapping method was effective in recording elusive species with large home ranges and/or low densities, e.g., jaguar (*Panthera onca*), white-lipped peccary (*Tayassu peccary*), tapir (*Tapirus terrestris*) and grison (*Galictis vitatta*).

Contrary to our expectations based on the extent and nature of human impacts at the sites, all three reserves had similar species richness: a result indicating that assemblages of medium- and large-sized terrestrial mammals have persisted in the reserves in spite of the human-associated habitat changes. However, we did detect changes in mammalian assemblage composition between study sites. Ducke, the area closest to a large city (Manaus) was the most dissimilar, and was so in ways that supported our hypothesis regarding change in assemblage composition in response to human proximity (Fig. 3). Observed compositional changes were also consistent with other studies conducted in tropical forest protected areas (Ahumada et al., 2011; Carrillo, 2000; Peres and Lake, 2003). Such studies all indicate that the first changes to mammal assemblages within protected areas occur to species on which hunting generally focuses, such as ungulates and medium-sized rodents.

4.2 Human impacts and relation with mammal occurrence

Five species were influenced by distance from roads, regardless of reserve sampled, though the effect form differed between species. Species subjected to strong hunting pressure, such as *M. americana*, *D. novemcinctus,* and *P. tajacu* (Jerozolimski and Peres, 2003), showed higher occurrence in areas farther from roads, while the opposite was true for *M.*

gouazoubira and *D. marsupialis* – two rarely hunted species (Jerozolimski and Peres, 2003; Sampaio et al., 2010).

Our results indicate that even a small decrease in access to areas (< 5-7 km) increases the occurrence probability of the first three species, and decreases that of the latter two (Fig. 4). Indeed, previous studies have shown that areas ~ > 6 km distant from a large river or road are effectively protected against extractive activities and hunting simply by virtue of distance limitation (Licona et al., 2011; Peres and Lake, 2003). In parallel, we observed a tendency for some species to be less detectable nearer to reserve edges (Table 5). This effect was especially marked at Ducke, where distance to the forest border was less than at the other two reserve sites (Table 2). These results indicate that complex interactions may determine the species distribution: interactions may occur between hunting (due to greater accessibility: Jerozolimski and Peres, 2003; Peres and Lake, 2003), border proximity (within which the structure of vegetation may be altered: Laurance et al., 1998), and species habitat preferences (Cuarón, 2000).

Such effects may not impact equally on all members of the mammalian assemblage, so that some may be negatively impacted while others benefit (Galetti et al., 2009; Peres and Dolman, 2000). In other areas this may manifest as trophic cascade, causing small carnivores to increase in numbers when larger ones are removed (e.g., Ahumada et al., 2011; Galleti et al., 2009; Michalski and Peres, 2005). In the current study, an inverse pattern of occurrence and detection was recorded for the two brocket deer species (*M. americana* and *M. gouazoubira*) in relation to roads and edges, respectively (Online Appendix A, Figure A2). We hypothesized this may have been caused by the compensatory effect of reciprocal densities and competition (Peres and Dolman, 2000). Certainly *M. gouazoubira,* a resilient species (Bodmer, 1997), seems to benefit from the decrease in abundance, or even absence, of *M. americana* near roads and forest edges. This result is consistent with previous studies of these species in areas impacted by hunting pressure and human-induced changes in vegetation structure (Di Bitetti et al., 2008; Hurtado-Gonzales and Bodmer, 2004).

The presence and proximity of roads influenced some species in every reserve. However, we observed that, overall, Ducke was the most impacted site when species occurrence was analyzed with the categorical variable *Reserve* (Fig. 1). This accounted for the observed patterns of occurrence of three species: *D. leporina, M. gouazoubira* and *P. tajacu*.

For ZF-2 and ZF-3 we did not find significantly different values for the occurrence for any species.

The gray brocket deer, *M. gouazoubira*, was more common at Ducke than at ZF-2 and ZF-3, a trend also shown (more weakly) by *D. leporina*. In contrast, *P. tajacu* occurred less at Ducke than the other two sites (Fig. 5). These three species are known to be tolerant to habitat changes, such as hunting and deforestation (Jerozolimski and Peres, 2003; Michalski and Peres, 2007; Sampaio et al., 2010). They also have high intrinsic reproduction rates (Bodmer et al., 1997), allowing populations to persist in impacted environments (Hurtado-Gonzales and Bodmer, 2004; Peres and Lake, 2003). However, even disturbance-tolerant species such as *P. tajacu* may have reduced populations in areas where the combination of negative environmental factors (habitat area effects) and overhunting (Peres, 1996; Peres, 2000) is overwhelming. In the case of Ducke, despite its 10 000 ha area, we suggest that low *P. tajacu* occurrence is due to persistent low-levels of hunting and deforestation that have been operating consistently since before the protected gazetting of the area in the 1950´s (Oliveira et al., 2008). In addition, Ducke currently has low connectivity to adjacent forests (Fig. 1), complicating re-colonization by individuals of hunted species even if these possess disturbance-tolerant characteristics. This result is consistent with other studies in Amazonian forests (e.g., Dale et al., 1994; Novaro et al., 2000), that have reported on dynamic source–sink systems driven principally by hunting off-take.

4.3 Environmental effects in occurrence of mammals

Three species (*D. novemcinctus*, *M. acouchy* and *M. gouazoubira*) were recorded more frequently in higher relief areas (plateaus). Small variations in relief can have great influence on forest structure (Oliveira et al., 2008), with studies in the Manaus region showing plateaus possess higher productivity and greater tree biomass than areas of lower elevation (Castilho et al., 2006). The greater availability of resources on plateaus may therefore explain the higher occurrence there of such frugivorous species as *M. gouazoubira* and *M. acouchy* (Bodmer, 1997; Dubost and Henry, 2006). The nine-banded armadillo (*D. novemcinctus*) was also recorded more frequently on plateaus. Higher densities of ants (Oliveira et al., 2009) and termites (Ackerman et al., 2009), the main prey of *D. novemcinctus* (Emmons and Feer, 1997), have been recorded on plateaus at Ducke. Consequently, our results appear to indicate a preference of these species for areas where availability of preferred food is greatest.

However, refugia provision may also be a factor, as plateaus have denser understory vegetation (Cintra et al., 2005), and so may provide more shelter. This is relevant since all these species use dense vegetation for concealment (Bodmer, 1997; Dubost, 1988).

The red brocket deer (*M. americana*) showed lower occurrence in poorly drained areas (Table 6). This result is consistent with a study by Tobler et al. (2009) at Tambopata, Peru, who reported higher occupancy rates of this species in terra firme forests, compared to floodplain forests. Besides, we believe this result reflects the influence of greater availability of resources favored by *M. americana* in well-drained areas, in this case, near plateaus (Castilho et al., 2006; Gayot et al., 2004).

The results of this study demonstrate the efficacy of camera trapping as a means of analyzing investigate-to-study patterns of species distribution when combined with maximum likelihood analyses that account for imperfect detections (Mackenzie et al., 2006; O'Connell et al., 2011). This allows for unbiased indicator estimation, making camera trap surveys extremely useful for monitoring programs aimed at measuring progress towards biodiversity conservation targets (Ahumada et al., 2013), i.e., as a proxy for population trends in areas where data on species abundance and habitat use are not available). Besides, inclusion of relevant variables in our analysis can allow management further insight into the key threats faced by species in PAs and thus assist in management decisions.

Even with a sampling effort of 5400 traps*day, many species had low detection rates, and so could not be included in the analysis and some were not registered (Table 3). For some of the species in the regional medium- and large-sized mammalian assemblage (e.g., carnivores), low detection is a predictable feature, due to cryptic and elusive habits (Pimenta, 2012; Ramalho and Magnusson, 2008). In addition, central Amazonia has one of the lowest mammalian densities in the Neotropics (Emmons, 1984). O'Brien et al. (2010) note that we need to consider a trade-off between detection probability, extent of area, effort and number of samples. Therefore, in order to increase detection rates and hence investigatory precision, we suggest increased sampling to a minimum of 60 days. Such an increase in sampling effort should result in hard-to-detect species being registered and species detected but with low registers (Table 3). However, if the goal of a survey is not only to produce a species inventory, but also to analyze community parameters involving diversity, occurrence and distribution, complementary methods are recommended, (Michalski and Peres, 2007;

O'Connell et al., 2011) such as baits associated with camera traps for carnivores, and the general deployment of live-traps, line transects and spoor searches as joint methodologies.

4.4 Management implications

In this study we have shown that, despite detecting human impact-induced changes in composition and occurrence of species, all tested reserves still possessed the same assemblage of medium- and large-sized terrestrial mammals. We believe this confirms the effectiveness of the reserves as conservation units, and highlights the importance of maintaining CUs even when, like Ducke, they are near very large human settlements. If, like Ducke, they remain partially connected to adjacent forests, then it appears that such forests are still able to maintain the assemblage of medium- and large-sized mammals in its entirety. This result is consistent with other studies (e.g., Michalski and Peres 2007), that have shown that forest isolates the size of Ducke (10 000 ha) can sustain the same mammal community richness as found in fully continuous forest, and so have strong conservation value.

In the long term, however, it is likely that anthropogenic effects will increase in all areas studied, due to the growth of Manaus, as well as increasing pressure from deforestation/fragmentation and hunting. Given this scenario, if no conservation measures are taken in the short term, some species of mammals will suffer drastic population reductions and may become extinct locally. Large ungulates and carnivores are the most likely to be affected in this way.

Protected areas in Brazilian Amazon covered about 2 197 485 km^2 or 43.9% of the region (Imazon and ISA, 2011). However, PAs alone will not be able to safeguard all species, so we emphasize that maintaining connectivity with less impacted forests, usually privately owned landscapes, will determine long-term persistence of mammals within and around these PAs (Peres, 2005; Sampaio et al., 2010). Even then, the degree of effectiveness in conserving biodiversity in such areas will depend on funding for implementing such basic management activities as monitoring, area demarcation and the encouragement of direct local community involvement (Bruner et al., 2001; DeFries et al., 2010). Effective government participation is also important, of which locally-relevant examples include laws mandating the creation and maintenance of connectivity corridors in areas under urban pressure (National System of Conservation Units Law No. 9985 of 2000), and the maintenance of 80% of native vegetation on private property for areas designated legal reserves (Brazilian Forest Law No. 12651 of 2012). Given this perspective, we remain cautiously optimistic when this is considered as a possible future scenario for Amazonia.

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LIST OF TABLES

Table 1. Sampling area, dates and numbers of camera stations for six 30-d camera trap surveys carried out at three sites in central Amazonia, Brazil. Camera*days are the number of survey days multiplied by the number of camera stations.

Reserve	**Sampling Period**	**Trap stations**	**Effort (camera*days)**
ZF-3	07/06/2010 to 08/06/2010	30	900
ZF-3	08/23/2011 to 09/23/2011	30	900
ZF-2	08/26/2010 to 09/26/2010	30	900
ZF-2	07/05/2011 to 08/05/2011	30	900
Ducke	09/12/2011 to 10/12/2011	30	900
Ducke	08/06/2012 to 09/ 06/2012	30	900
Total		**180**	**5400**

Table 2. Continuous variables used for the occurrence analyses, evaluated via *one way* ANOVA and a *post-hoc* Tukey test, to verify differences between reserves. * Indicates significant values p<0.05.

	ANOVA		**Tukey *p***		
	F	*p*	DUCKE x ZF-2	DUCKE x ZF-3	ZF-3 x ZF- 2
Drainage density	2.57	0.08	0.97	0.16	0.1
Elevation	2.18	0.11	0.51	0.09	0.59
*Distance Edge**	**3.12**	**0.05**	**0.5**	**0.06**	**0.11**
Distance Road	1.8	0.17	0.96	0.19	0.28

Table 3. Number of captures and (in parentheses) capture frequency (number of captures / 1000 trap*days) for medium-sized to large-bodied terrestrial mammals observed in three forest reserves in central Amazonian Brazil. Overall, 21 species were registered of 28 expected.

Species	Common name	DUCKE	ZF-2	ZF-3	Total
Artiodactyla					
Mazama americana	Red brocket deer [a]	27(15.0)	45(25.0)	26(14.4)	98(18.1)
Mazama gouazoubira	Gray brocket deer [a]	49(27.2)	28(15.5)	22(12.2)	99(18.3)
Pecari tajacu	Collared peccary [a]	9(5.0)	43(23.8)	47(26.1)	99(18.3)
Tayassu pecari	White-lipped peccary	4(2.2)	1(0.5)	-	5(0.9)
Perrisodactyla					
Tapirus terrestris	Brazilian tapir [a]	11(6.1)	6(3.3)	10(5.5)	27(5.0)
Xenarthra					
Tamandua tetradactyla	Collared anteater [b]	-	5(2.7)	1(0.5)	6(1.1)
Myrmecophaga tridactyla	Giant anteater [c]	7(3.8)	9(5.0)	2(1.1)	18(3.3)
Priodontes maximus	Giant armadillo	-	-	-	-
Dasypus novemcinctus	Nine-banded armadillo [a]	33(18.3)	67(37.2)	53(29.4)	153(28.3)
Dasypus kappleri	Seven-banded armadillo	-	-	-	-
Cabassous unicinctus	Southern naked-tailed armadillo	-	1(0.5)	-	1(0.1)
Rodentia					
Dasyprocta leporina	Red-rumped agouti [a]	108(60.0)	84(46.6)	113(62.7)	305(56.4)
Myoprocta acouchy	Red acouchy [a]	342(190.0)	146(81.1)	286(158.8)	774(143.3)
Cuniculus paca	Spotted paca [a]	50(27.7)	34(18.8)	58(32.2)	142(26.2)
Lagomorpha					
Sylvilagus brasiliensis	Brazilian rabbit	-	-	-	-
Marsupialia					
Didelphis marsupialis	Commom opossum [a b]	109(60.5)	90(50.0)	34(18.8)	233(43.1)
Carnivora					
Nasua nasua	Coati [b c]	2(1.1)	2(1.1)	5(2.7)	9(1.6)
Procyon cancrivorus	Crab-eating raccoon	-	-	-	-
Eira barbara	Tayra [b c]	2(1.1)	5(2.7)	8(4.4)	15(2.7)
Galictis vittata	Greater Grison	1(0.5)	-	-	1(0.1)
Panthera onca	Jaguar [c]	3(1.6)	4(2.2)	5(2.7)	12(2.2)
Puma concolor	Puma	4(2.2)	3(1.6)	-	7(1.2)
Leopardus pardalis	Ocelot	2(1.1)	7(3.8)	7(3.8)	16(2.9)
Leopardus tigrinus	Oncilla [b]	-	-	-	-
Herpailurus yaguarondi	Jaguarundi	1(0.5)	2(1.1)	1(0.5)	4(0.7)
Leopardus wiedii	Margay [b c]	10(5.5)	2(1.1)	4(2.2)	16(2.9)
Speothos venaticus	Bush dog	-	-	-	-
Atelocynus microris	Short-eared dog	-	-	-	-
Species Totals		**19**	**20**	**17**	**21**

[a] Denotes species analyzed using occurrence models (Mackenzie et al., 2006)
[b] Terrestrial and arboreal
c Species likely to be analyzed if a 60-day sampling effort were to be considered.

Table 4. Model comparison for determining the effects of year on probability of occurrence (*Ψ*), colonization (*γ*), extinction (*ε*), detection (*p*) and effect of detection occasion (*p*) for combined mammal species records from camera trapping data in three forest reserves, central Amazonian Brazil.

Species	***Models***	***K***	**Δ *AIC***	***Ψ (SE)***	***Ψ t+1(SE)***	***p (SE)***
	Ψ(.) *p*(.)	4	0.00	0.45(0.08)	0.43(0.05)	0.18(0.02)
M. americana	*Ψ*(year) γ(year) ε(year) *p*(year)	8	1.65	0.43(0.08)	0.46(0.08)	0.20(0.04)
	Ψ(.) *p*(occasion)	16	3.49	0.41(0.07)	0.45(0.10)	0.24(0.07)
M. gouazoubira	*Ψ*(.) *p*(.)	4	0.00	0.57(0.12)	0.57(0.11)	0.13(0.03)
	Ψ(year) γ(year) ε(year) *p*(year)	8	1.67	0.63(0.18)	0.53(0.11)	0.11(0.04)
	Ψ(.) *p*(occasion)	16	14.3	0.61(0.17)	0.52(0.07)	0.09(0.04)
P. tajacu	*Ψ*(.) *p*(.)	4	0.00	0.38(0.09)	0.52(0.15)	0.16(0.02)
	Ψ(year) γ(year) ε(year) *p*(year)	8	2.04	0.40(0.11)	0.54(0.18)	0.14(0.04)
	Ψ(.) *p*(occasion)	16	21.02	0.40(0.11)	0.57(0.20)	0.13(0.06)
T. terrestris	*Ψ*(.) *p*(.)	4	0.00	0.29(0.13)	0.37(0.12)	0.08(0.03)
	Ψ(year) γ(year) ε(year) *p*(year)	8	2.23	0.31(0.19)	0.35(0.14)	0.07(0.05)
	Ψ(.) *p*(occasion)	16	21.76	0.29(0.17)	0.29(0.11)	0.03(0.04)
D. leporina	*Ψ*(.) *p*(.)	4	0.00	0.73(0.05)	0.76(0.06)	0.31(0.02)
	Ψ(year) γ(year) ε(year) *p*(year)	8	0.99	0.71(0.05)	0.78(0.07)	0.34(0.03)
	Ψ(.) *p*(occasion)	16	15.38	0.71(0.05)	0.77(0.06)	0.37(0.06)
M. acouchy	*Ψ*(.) *p*(.)	4	0.00	0.81(0.04)	0.75(0.06)	0.55(0.01)
	Ψ(year) γ(year) ε(year) *p*(year)	8	1.59	0.81(0.04)	0.75(0.06)	0.53(0.02)
	Ψ(.) *p*(occasion)	16	5.82	0.81(0.04)	0.75(0.06)	0.61(0.05)
C. paca	*Ψ*(.) *p*(.)	4	0.00	0.44(0.07)	0.52(0.06)	0.23(0.02)
	Ψ(year) γ(year) ε(year) *p*(year)	8	0.93	0.48(0.09)	0.50(0.05)	0.19(0.03)
	Ψ(.) *p*(occasion)	16	10.02	0.47(0.08)	0.49(0.04)	0.30(0.08)
D. marsupialis	*Ψ*(.) *p*(.)	4	0.00	0.52(0.06)	0.58(0.07)	0.31(0.02)
	Ψ(year) γ(year) ε(year) *p*(year)	8	1.27	0.54(0.06)	0.57(0.06)	0.28(0.03)
	Ψ(.) *p*(occasion)	16	9.01	0.53(0.06)	0.56(0.06)	0.31(0.07)
D. novemcinctus	*Ψ*(.) *p*(.)	4	0.00	0.57(0.06)	0.49(0.08)	0.27(0.02)
	Ψ(year) γ(year) ε(year) *p*(year)	8	2.19	0.56(0.07)	0.49(0.07)	0.27(0.03)
	Ψ(.) *p*(occasion)	16	13.79	0.56(0.06)	0.49(0.08)	0.29(0.06)

Note: *K*: number of parameters; *ΔAIC*: difference in Akaike Information Criterion values between each model and the best model; *Ψ(SE)*: mean occupancy estimates; *Ψt+1(SE)*: mean occupancy estimates in next year; *ρ*(SE): mean detection probability estimates. Values in parentheses represent standard error of estimates.

Table 5. Occupancy model selection (ΔAIC<2) for the nine most frequent species in combined mammal species records from camera trapping data in three forest reserves, central Amazonian Brazil.

Species	*Models*	*K*	*ΔAIC*	*AICω*	*^Ψ (SE)*	*^p (SE)*
M. americana	*Ψ*(Drainage +Road)	6	0.00	0.45	0.58(0.15)	0.16(0.02)
	Ψ(Drainage+Block) *p*(edge)	7	0.34	0.38	0.63(0.17)	0.15(0.02)
	Ψ(Drainage)	5	1.64	0.17	0.53(0.12)	0.16(0.02)
	Model-averaged				**0.58(0.15)**	**0.16(0.02)**
M. gouazoubira	*Ψ*(Elevation)	5	0.00	0.42	0.69(0.11)	0.11(0.02)
	Ψ(Elevation+Road) *p*(edge)	7	0.20	0.38	0.71(0.19)	0.11(0.02)
	Ψ(Elevation+Reserve)	7	1.51	0.20	0.55(0.16)	0.13(0.02)
	Model-averaged				**0.65(0.15)**	**0.12(0.02)**
P. tajacu	*Ψ*(Reserve)	6	0.00	0.31	0.40(0.07)	0.15(0.02)
	Ψ(Road) *p*(edge)	6	0.21	0.28	0.36(0.08)	0.16(0.02)
	Ψ(Reserve)	7	0.56	0.23	0.40(0.06)	0.15(0.02)
	Ψ(Reserve+Drainage) *p*(edge)	7	1.06	0.18	0.40(0.06)	0.15(0.02)
	Model-averaged				**0.39(0.07)**	**0.15(0.02)**
T. terrestris	*Ψ*(.)	4	0.00	0.44	0.29(0.13)	0.08(0.03)
	Ψ(Road)	5	0.66	0.32	0.28(0.12)	0.08(0.03)
	Ψ(Road+Drainage) *p*(edge)	7	1.24	0.24	0.30(0.15)	0.07(0.01)
	Model-averaged				**0.29(0.13)**	**0.08(0.02)**
D. leporina	*Ψ*(Reserve)	6	0.00	1.00	0.74(0.09)	0.31(0.02)
	Model-averaged				**0.74(0.09)**	**0.31(0.02)**
M. acouchy	*Ψ*(Elevation)	5	0.00	1.00	0.86(0.04)	0.55(0.01)
	Model-averaged				**0.85(0.04)**	**0.55(0.01)**
C. paca	*Ψ*(.)	4	0.00	0.60	0.44(0.07)	0.23(0.02)
	Ψ(Drainage)	5	0.82	0.40	0.43(0.07)	0.23(0.02)
	Model-averaged				**0.44(0.07)**	**0.23(0.02)**
D. marsupialis	*Ψ*(Reserve+Drainage)	7	0.00	0.38	0.58(0.11)	0.31(0.02)
	Ψ(Block+Drainage+Road)	7	0.27	0.33	0.52(0.07)	0.31(0.02)
	Ψ(Block+Road) *p*(edge)	7	0.55	0.29	0.52(0.06)	0.31(0.02)
	Model-averaged				**0.54(0.08)**	**0.31(0.02)**
D. novemcinctus	*Ψ*(Elevation)	5	0.00	0.32	0.77(0.07)	0.23(0.02)
	Ψ(Elevation+Road)	6	0.08	0.31	0.80(0.08)	0.23(0.02)
	Ψ(Elevation)	5	0.97	0.20	0.70(0.13)	0.24(0.02)
	Ψ(Elevation+Reserve)	7	1.32	0.17	0.65(0.12)	0.23(0.02)
	Model-averaged				**0.73(0.10)**	**0.23(0.02)**

Note: Only models with AIC weight (ω) > 0.1 and ΔAIC<2 are shown. *K*: number of parameters; *ΔAIC*: difference in Akaike Information Criterion values between each model and the best model; AIC ω: model weight; Ψ(SE): mean occupancy estimates; ρ(SE): mean detection probability estimates. Values in parentheses represent standard error of estimates. Drainage = drainage density; Road = distance of road; Edge = distance of edge; Elevation = terrain elevation.

Table 6. Sum of AIC weights (ω) based on weight of top-ranked occurrence and detection models ($\Delta AIC \leq 2$) for environmental and anthropogenic variables. The direction of the relationship for continuous variables and the condition with the occurrence for categorical variable (de=DUCKE, z2= ZF-2, z3= ZF-3) are indicated in parentheses.

Parameter	**Type**	**Variable**	***Ma***	***Mg***	***Pt***	***Tt***	***Dl***	***Ma***	***Cp***	***Dm***	***Dn***	$\sum\omega$ **covariate**
ψ	Environmental	Elevation		**0.99(+)***				**0.99(+)***			**0.99(+)***	2.97
		Drainage	**0.99(-)***		0.18 (+)	0.24(-)			0.40(+)	0.71(-)		2.52
	Anthropogenic	Road	**0.45(+)***	**0.38(-)***	**0.28(+)***	0.56(+)				**0.62(-)***	**0.31(+)***	2.60
		Edge										0.00
		Block	0.38(-)							0.62(-)		1.00
		Reserve		**0.20 (-z2)(-z3)***	**0.72 (-de) (+z2)(+z3)***		**0.99(+de)**§			0.38 (-)	0.17(+)	2.46
p	Anthropogenic	Edge	0.99(-)	0.99(-)	0.99(-)	0.99(+)				0.99(+)		4.95
		Domestic										0.00

Species abbreviations: Ma = *Mazama americana*; Mg = *M. gouazoubira*; Pt = *Pecari tajacu*; Tt = *Tapirus terrestris*; Dl = *Dasyprocta leporina*; Ma = *Myoprocta acouchy*; Cp = *Cuniculus paca*; Dm = *Didelphis marsupialis*; Dn = *Dasypus novemcinctus*.

Variables abbreviations: Drainage = drainage density; Road = distance to road; Edge = distance to edge; Elevation = terrain elevation; Domestic = domestic animals.

$\sum\omega_{\text{covariate}}$ is the sum of model weights for well-supported models ($\Delta AIC<2$) containing each covariate across species.

[*] Indicates confidence intervals of β coefficients that did not overlap zero.

[§] Indicates a weak effect (intervals of β coefficients that did overlap zero).

FIGURE CAPTIONS

FIGURE 1. Location in macro- and micro-scales of study areas, with State of Amazonas, central Amazon, Brazil, in the top right corner. Detailed map shows studied forest reserves: DUCKE, ZF-2 and ZF-3, all located near Manaus city. The black points show the locations of 90 camera stations installed in the three forest reserves, with 30 cameras per reserve.

FIGURE 2. Accumulation curves for species of mid- to large-bodied mammals in each forest reserves. Vertical bars represent 95% confidence intervals.

FIGURE 3. Non-metric ordination of mammal assemblage composition, with groups divided by reserve. Results showed the average distance within groups/treatments in relation to the core of the analysis in a multivariate space. The Ducke Reserve was significantly different ($p < 0.03$) from the other groups.

FIGURE 4. Mean occurrence estimates of five species as a function of distance to roads, using all sites combined. The occurrences of species *M. americana, P. tajacu* and *D. novemcinctus* were greater as distance to roads increased, while *M. gouazoubira* and *D. marsupialis* showed the opposite pattern. Dashed lines represent standard errors.

FIGURE 5. Point estimates of occurrence for the nine most-frequent medium- and large-bodied terrestrial mammals in each forest reserves. Bars represent standard errors. [*] indicates species with significant differences in occurrence between reserves. Species abbreviations: Ma: *Mazama americana*; Mg: *M. gouazoubira*; Pt: *Pecari tajacu*; Tt; *Tapirus terrestris*; Dl; *Dasyprocta leporina*; Ma: *Myoprocta acouchy*; Cp; *Cuniculus paca*; Dm: *Didelphis marsupialis*; Dn: *Dasypus novemcinctus*.

FIGURES

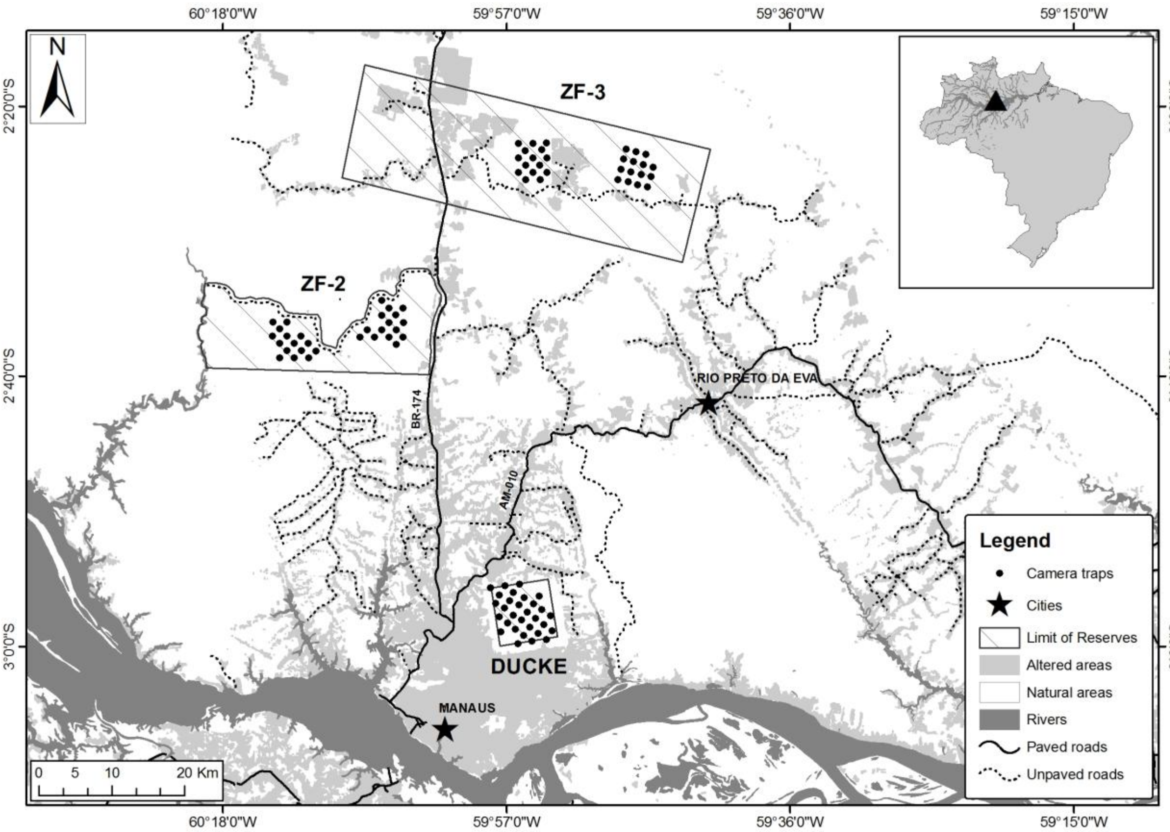
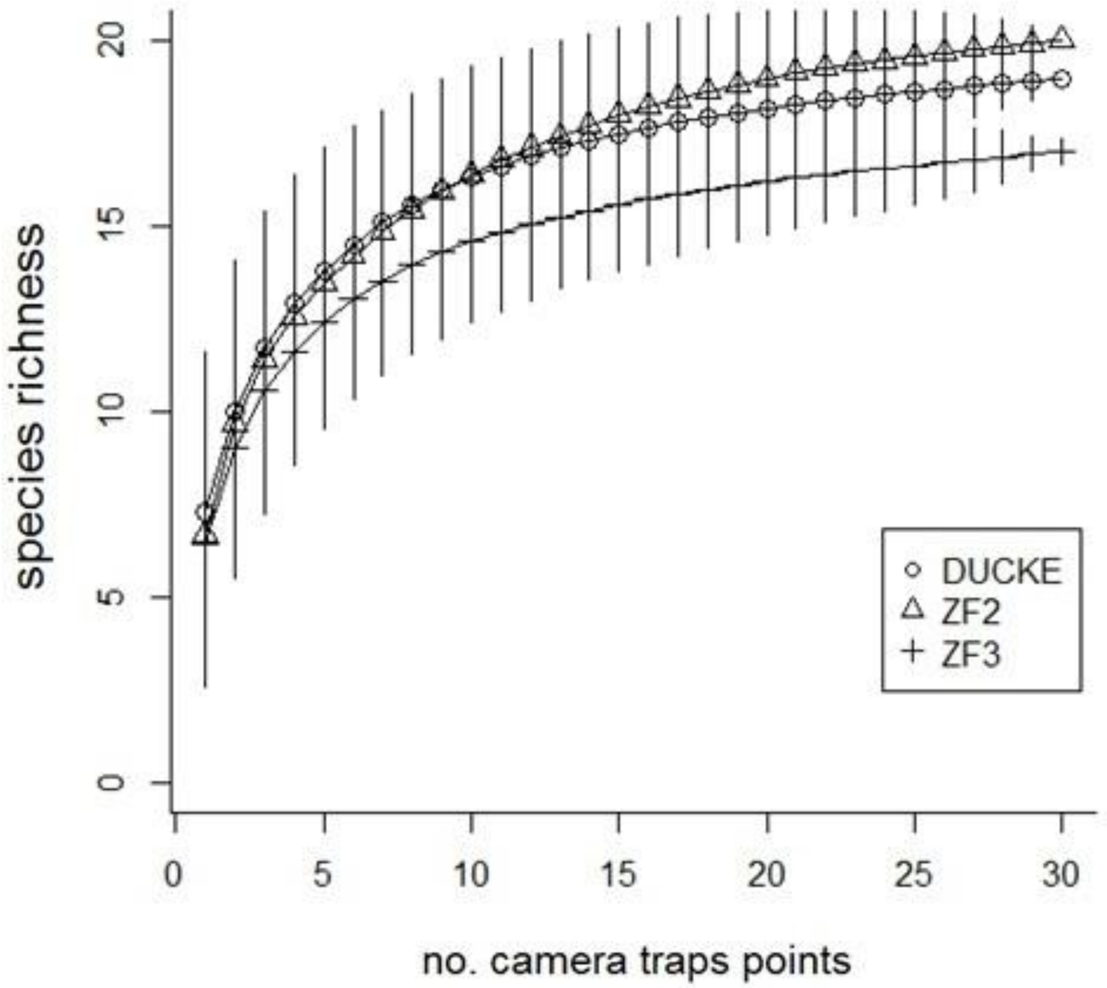


FIGURE 1


species richness
0
5
10
15
20
0
5
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25
30
no. camera traps points
DUCKE
ZF2
ZF3

FIGURE 2

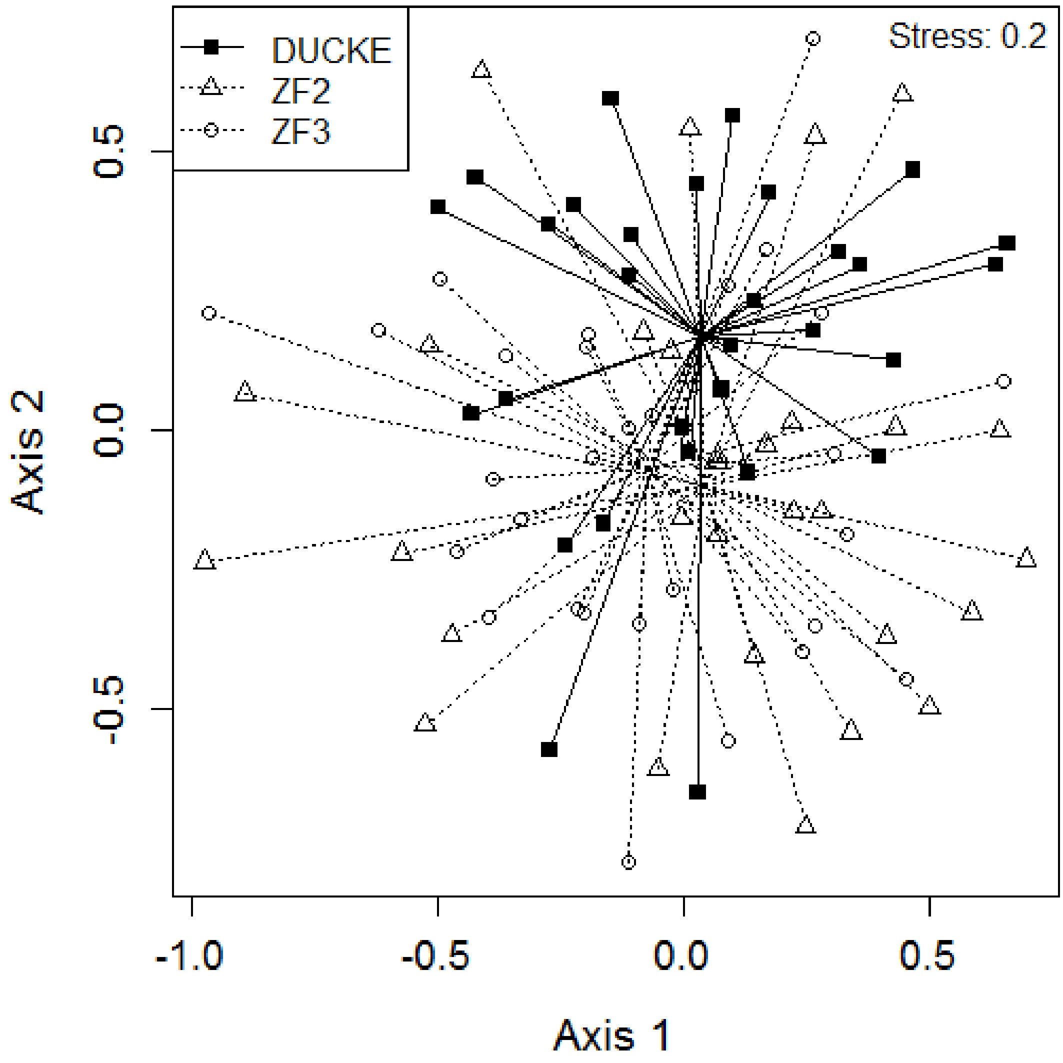

FIGURE 3

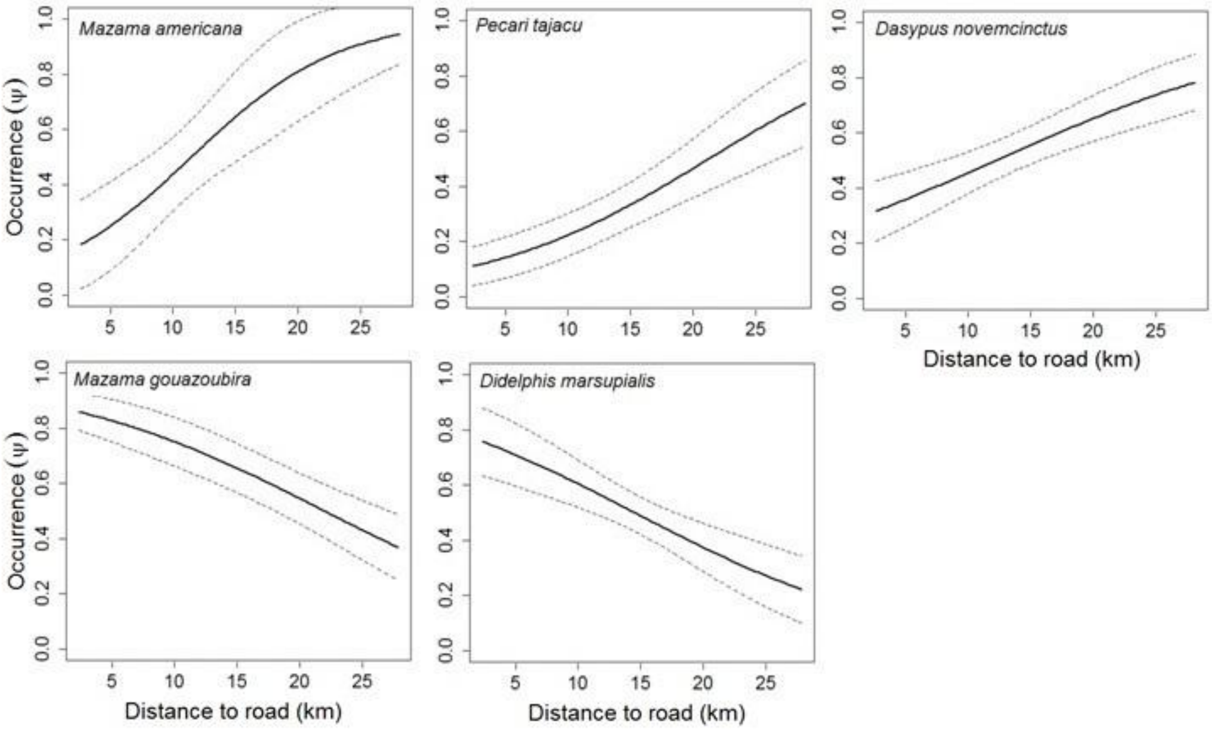
Mazama americana
Pecari tajacu
Dasypus novemcinctus
Mazama gouazoubira
Didelphis marsupialis
Occurrence (ψ)
0.0
0.2
0.4
0.6
0.8
1.0
5
10
15
20
25
Distance to road (km)

FIGURE 4

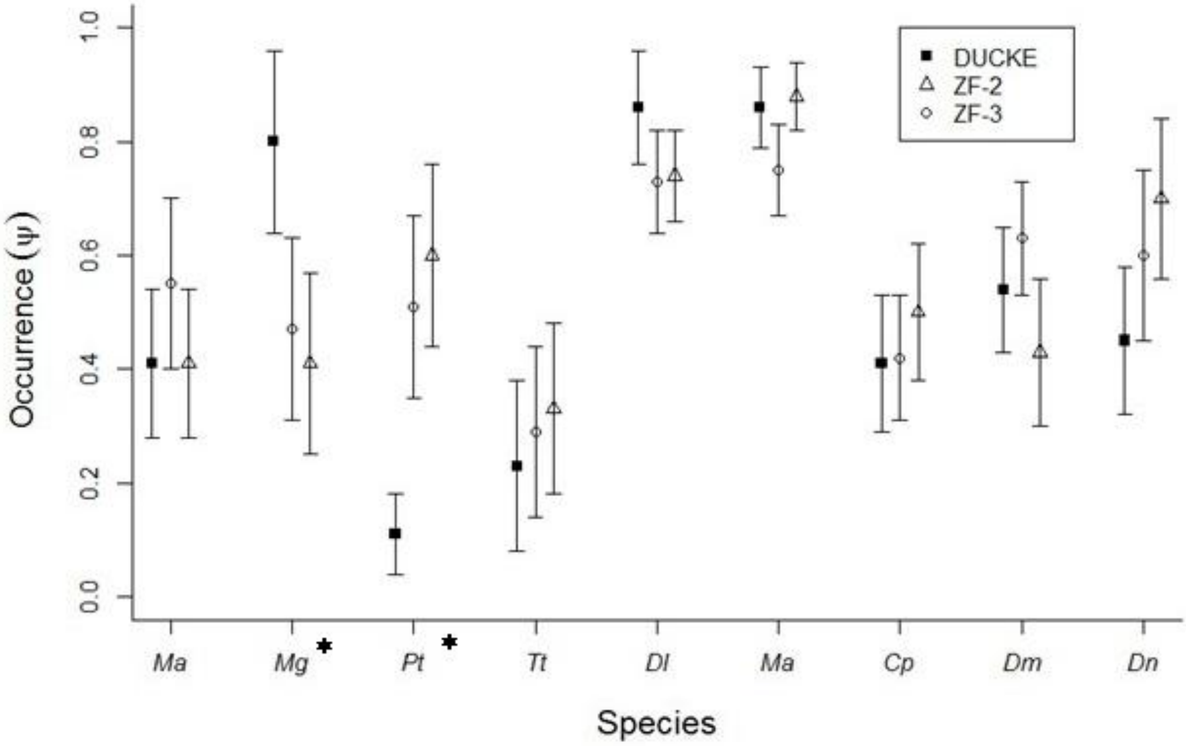
Occurrence (ψ)
1.0
0.8
0.6
0.4
0.2
0.0
DUCKE
ZF-2
ZF-3
Ma
Mg
Pt
Tt
Dl
Ma
Cp
Dm
Dn
Species

FIGURE 5

Conclusões

Este trabalho forneceu informações a respeito da riqueza e composição da assembléia de mamíferos terrestres de médio e grande porte e a relação do uso do habitat e impacto humano para nove espécies, dentre as 28 presentes nesta assembléia, em florestas de terra-firme na Amazônia Central. Em relação à estrutura do habitat, o veado-cinza (*Mazama gouazoubira*), cutiara (*Myoprocta acouchy*) e o tatu (*Dasypus novemcinctus*) responderam positivamente a altitude. A maior ocorrência destes mamíferos nos relevos mais altos, indica um relação dos platôs como ambientes mais produtivos em relação aos baixios. Sugerimos que tal efeito seja testado em estudos futuros. Áreas com maior riqueza de corpos d'água foram menos utilizadas veado-vermelho (*Mazama americana*). Estes resultados também reforçam a preferência por ambientes distantes dos baixos, os quais são menos produtivos.

Por fim, não detectamos diferenças na riqueza de mamíferos entre áreas com distintos impactos. Por outro lado ocorreram mudanças na composição da assembléia, além de detectarmos alterações nos padrões de ocorrência para algumas espécies consideradas como cinegéticas validando as hipóteses deste estudo. A distância de estradas afetou de forma distinta a ocorrência de cinco espécies. O veado vermelho, cateto e tatu tiveram menores ocorrências próximas às estradas, indicando um efeito negativo relacionado à proximidade urbana, principalmente a acessibilidade às áreas. Por outro lado o veado-cinza e a mucura apresentaram um padrão inverso, indicando um efeito indireto das mesmas. Possivelmente, esse resultado reflita um processo de compensação da comunidade, já reportando em estudos anteriores. A variável borda também esteve presente entre os melhores modelos influenciando a detecção para quatros espécies, indicando uma tendência para as mesmas. Apesar de todas as reservas apresentarem algum grau de perturbação humana, a Ducke de fato foi a área com maior impacto. Segundo os resultados encontrados neste estudo, o veado cinza teve maior ocorrência na Ducke, hipotetizada como mais impactada, enquanto o contrário foi verdadeiro para o cateto. Enquanto outras espécies consideradas cinegéticas mantiveram ocorrências similares entre as reservas. Esses resultados refletem o impacto humano causado sobre essas espécies, onde acreditamos que a caça oportunista nas reservas possa estar causando tais diferenças. Mesmo assim, apesar de haver uma alteração na composição e ocorrência de algumas espécies da assembléia, acreditamos que as três áreas estudadas, mesmo em locais mais próximos de centros urbanos, como a Ducke, ainda sejam capazes de manter a assembléia de mamíferos assim como outras espécies. A manutenção da conectividade com florestas menos impactadas, além do reforço de atividades básicas de gestão, como envolvimento direto das comunidades próximas, demarcação das divisas e execução das leis, poderá assegurar dessa forma a viabilidade das populações de mamíferos terrestres de médio e grande porte em longo prazo, mantendo assim as áreas efetivas para conservação.

APÊNDICES

Apêndice 1. Ata da Aula de Qualificação.

PG·ECO·INPA
PÓS-GRADUAÇÃO EM ECOLOGIA

INPA
INSTITUTO NACIONAL DE PESQUISAS DA AMAZÔNIA

GOVERNO FEDERAL
BRASIL
PAÍS RICO É PAÍS SEM POBREZA

AULA DE QUALIFICAÇÃO

PARECER

Aluno(a): ANDRÉ LUIS SOUSA GONÇALVES
Curso: ECOLOGIA
Nível: MESTRADO
Orientador(a): WILSON ROBERTO SPIRONELLO

Título:

"Influência de fatores antrópicos e ambientais na ocorrência de mamíferos terrestres em três reservas florestais de terra firme, AM"

BANCA JULGADORA:

TITULARES:
Albertina Pimentel Lima (INPA)
Paulo Estefano Bobrowiec (INPA)
Ronis da Silveira (UFAM)

SUPLENTES:
José Luis Campana Camargo(INPA/PDBFF)
Fernando Rosas (INPA)

	PARECER		ASSINATURA
Albertina Pimentel Lima (INPA)	(X) Aprovado	( ) Reprovado	[assinatura]
Paulo Estefano Bobrowiec (INPA)	(X) Aprovado	( ) Reprovado	[assinatura]
Ronis da Silveira (UFAM)	(X) Aprovado	( ) Reprovado	[assinatura]
José Luis C Camargo (INPA/PDBFF)	( ) Aprovado	( ) Reprovado	
Fernando Rosas (INPA)	( ) Aprovado	( ) Reprovado	

Manaus(AM), 30 de março de 2012

OBS: A aluno apresentou no tempo regulamentar, e respondeu satisfatoriamente à arguição da Banca Examinadora

INSTITUTO NACIONAL DE PESQUISAS DA AMAZÔNIA INPA
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site: http://pg.inpa.gov.br e-mail: pgecologia@gmail.com

Apêndice 2. Pareceres da Banca do Trabalho Escrito.

Instituto Nacional de Pesquisas da Amazônia - INPA
Programa de Pós-graduação em Ecologia

Avaliação de dissertação de mestrado

Título: Ocorrência de mamíferos terrestres de médio e grande porte em florestas de terra firme sob distintos impactos humanos na Amazônia Central

Aluno: André Luis Sousa Gonçalves

Orientador: **Wilson Spironello** Co-orientador: -----

Avaliador: **Darren Norris**

Por favor, marque a alternativa que considerar mais apropriada para cada item abaixo, e marque seu parecer final no quadro abaixo

	Muito bom	Bom	Necessita revisão	Reprovado
Relevância do estudo	( )	(X)	( )	( )
Revisão bibliográfica	( )	( )	(X)	( )
Desenho amostral/experimental	( )	(X)	( )	( )
Metodologia	( )	( )	(X)	( )
Resultados	( )	( )	(X)	( )
Discussão e conclusões	( )	( )	(X)	( )
Formatação e estilo texto	( )	(X)	( )	( )
Potencial para publicação em periódico(s) indexado(s)	( )	( )	(X)	( )

PARECER FINAL

( ) **Aprovada** (indica que o avaliador aprova o trabalho sem correções ou com correções mínimas)

(X) **Aprovada com correções** (indica que o avaliador aprova o trabalho com correções extensas, mas que não precisa retornar ao avaliador para reavaliação)

( ) **Necessita revisão** (indica que há necessidade de reformulação do trabalho e que o avaliador quer reavaliar a nova versão antes de emitir uma decisão final)

( ) **Reprovada** (indica que o trabalho não é adequado, nem com modificações substanciais)

Macapa **14 de junho 2013**

Local, Data, Assinatura

Comentários e sugestões podem ser enviados como uma continuação desta ficha, como arquivo separado ou como anotações no texto impresso ou digital da tese. Por favor, envie a ficha assinada, bem como a cópia anotada da tese e/ou arquivo de comentários por e-mail para pgecologia@gmail.com e flaviacosta001@gmail.com ou por correio ao endereço abaixo. O envio por e-mail é preferível ao envio por correio. Uma cópia digital de sua assinatura será válida.

Endereço para envio de correspondência:

Flavia Costa
DCEC/CPEC/INPA
CP 478
69011-970 Manaus AM
Brazil

Instituto Nacional de Pesquisas da Amazônia - INPA
Programa de Pós-graduação em Ecologia

Avaliação de dissertação de mestrado

Título: Ocorrência de mamíferos terrestres de médio e grande porte em florestas de terra firme sob distintos impactos humanos na Amazônia Central

Aluno: André Luis Sousa Gonçalves

Orientador: **Wilson Spironello** Co-orientador: -----

Avaliador: **Maria Luisa da Silva Pinto jorge**

Por favor, marque a alternativa que considerar mais apropriada para cada item abaixo, e marque seu parecer final no quadro abaixo

	Muito bom	Bom	Necessita revisão	Reprovado
Relevância do estudo	( )	( )	(x)	( )
Revisão bibliográfica	( )	(x)	( )	( )
Desenho amostral/experimental	(x)	( )	( )	( )
Metodologia	( )	(x)	( )	( )
Resultados	( )	(x)	( )	( )
Discussão e conclusões	( )	( )	(x)	( )
Formatação e estilo texto	( )	( )	(x)	( )
Potencial para publicação em periódico(s) indexado(s)	( )	( )	(x)	( )

PARECER FINAL

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( ) **Reprovada** (indica que o trabalho não é adequado, nem com modificações substanciais)

Rio Claro, 28/07/2013,
Local Data **Assinatura**

Comentários e sugestões podem ser enviados como uma continuação desta ficha, como arquivo separado ou como anotações no texto impresso ou digital da tese. Por favor, envie a ficha assinada, bem como a cópia anotada da tese e/ou arquivo de comentários por e-mail para pgecologia@gmail.com e flaviacosta001@gmail.com ou por correio ao endereço abaixo. O envio por e-mail é preferível ao envio por correio. Uma cópia digital de sua assinatura será válida.

Endereço para envio de correspondência:

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Instituto Nacional de Pesquisas da Amazônia - INPA
Programa de Pós-graduação em Ecologia

Avaliação de dissertação de mestrado

Título: Ocorrência de mamíferos terrestres de médio e grande porte em florestas de terra firme sob distintos impactos humanos na Amazônia Central

Aluno: André Luis Sousa Gonçalves

Orientador: **Wilson Spironello** Co-orientador: ----

Avaliador: **Renata Pardini**

Por favor, marque a alternativa que considerar mais apropriada para cada item abaixo, e marque seu parecer final no quadro abaixo

	Muito bom	Bom	Necessita revisão	Reprovado
Relevância do estudo	( )	(x)	( )	( )
Revisão bibliográfica	( )	( )	(x)	( )
Desenho amostral/experimental	( )	(x)	( )	( )
Metodologia	( )	( )	(x)	( )
Resultados	( )	(x)	( )	( )
Discussão e conclusões	( )	(x)	( )	( )
Formatação e estilo texto	( )	(x)	( )	( )
Potencial para publicação em periódico(s) indexado(s)	( )	( )	(x)	( )

PARECER FINAL

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(x) **Aprovada com correções** (indica que o avaliador aprova o trabalho com correções extensas, mas que não precisa retornar ao avaliador para reavaliação)

( ) **Necessita revisão** (indica que há necessidade de reformulação do trabalho e que o avaliador quer reavaliar a nova versão antes de emitir uma decisão final)

( ) **Reprovada** (indica que o trabalho não é adequado, nem com modificações substanciais)

São Paulo, 12 de julho de 2013

Local **Data** **Assinatura**

Comentários e sugestões podem ser enviados como uma continuação desta ficha, como arquivo separado ou como anotações no texto impresso ou digital da tese. Por favor, envie a ficha assinada, bem como a cópia anotada da tese e/ou arquivo de comentários por e-mail para pgecologia@gmail.com e flaviacosta001@gmail.com ou por correio ao endereço abaixo. O envio por e-mail é preferível ao envio por correio. Uma cópia digital de sua assinatura será válida.

Endereço para envio de correspondência:

Flavia Costa
DCEC/CPEC/INPA
CP 478
69011-970 Manaus AM
Brazil

Apêndice 3. Ata da Defesa Pública.

INSTITUTO NACIONAL DE PESQUISAS DA AMAZÔNIA

PG·ECO·INPA PÓS-GRADUAÇÃO EM ECOLOGIA

GOVERNO FEDERAL BRASIL PAÍS RICO É PAÍS SEM POBREZA

ATA DA DEFESA PÚBLICA DA DISSERTAÇÃO DE MESTRADO DO PROGRAMA DE PÓS-GRADUAÇÃO EM ECOLOGIA DO INSTITUTO NACIONAL DE PESQUISAS DA AMAZÔNIA.

Aos 08 dias do mês de novembro do ano de 2013, às 09:00 horas, no auditório do Programa de Pós Graduação em Clima e Ambiente – PPG Cliamb/INPA, reuniu-se a Comissão Examinadora de Defesa Pública, composta pelos seguintes membros: o(a) Prof(a). Dr(a). **Adrian Barnett**, do Instituto Nacional de Pesquisas da Amazônia - INPA/Projeto TEAM, o(a) Prof(a). Dr(a). **Marcelo Gordo**, da Universidade Federal do Amazonas - UFAM e o(a) Prof(a). Dr(a). **Pedro Ivo Simões**, do Instituto Nacional de Pesquisas da Amazônia - INPA, tendo como suplentes o(a) Prof(a). Dr(a). Renato Cintra, do Instituto Nacional de Pesquisas da Amazônia – INPA e o(a) Prof(a). Dr(a). Fabricio Beggiato Baccaro, da Universidade Federal do Amazonas - UFAM, sob a presidência do(a) primeiro(a), a fim de proceder a argüição pública do trabalho de **DISSERTAÇÃO DE MESTRADO** de **ANDRÉ LUIS SOUSA GONÇALVES**, intitulado "Ocorrência de mamíferos terrestres de médio e grande porte em florestas de terra- firme sob distintos impactos humanos na Amazônia Central", orientado pelo(a) Prof(a). Dr(a). Wilson Spironello, do Instituto Nacional de Pesquisas da Amazônia - INPA.

Após a exposição, o(a) discente foi arguido(a) oralmente pelos membros da Comissão Examinadora, tendo recebido o conceito final:

[X] APROVADO(A) [ ] REPROVADO(A)

[X] POR UNANIMIDADE [ ] POR MAIORIA

Nada mais havendo, foi lavrada a presente ata, que, após lida e aprovada, foi assinada pelos membros da Comissão Examinadora.

Prof(a).Dr(a). Adrian Barnett ____________________

Prof(a).Dr(a). Marcelo Gordo ____________________

Prof(a).Dr(a). Pedro Ivo Simões ____________________

____
Coordenação PPG-ECO/INPA

Apêndice 4. Informações complementares

Figure A1-. Correlogram analysis of spatial data for the nine mammal species analyzed using the method of occurrence (ψ). The central horizontal lines represent the values of spatial correlation, while those on each side give 95% confidence intervals. The vertical dashed line shows the limit of autocorrelated values. Values above 1500 m (minimum distance between the camera traps in this study) were considered autocorrelated. No analyzed species showed spatial autocorrelation.

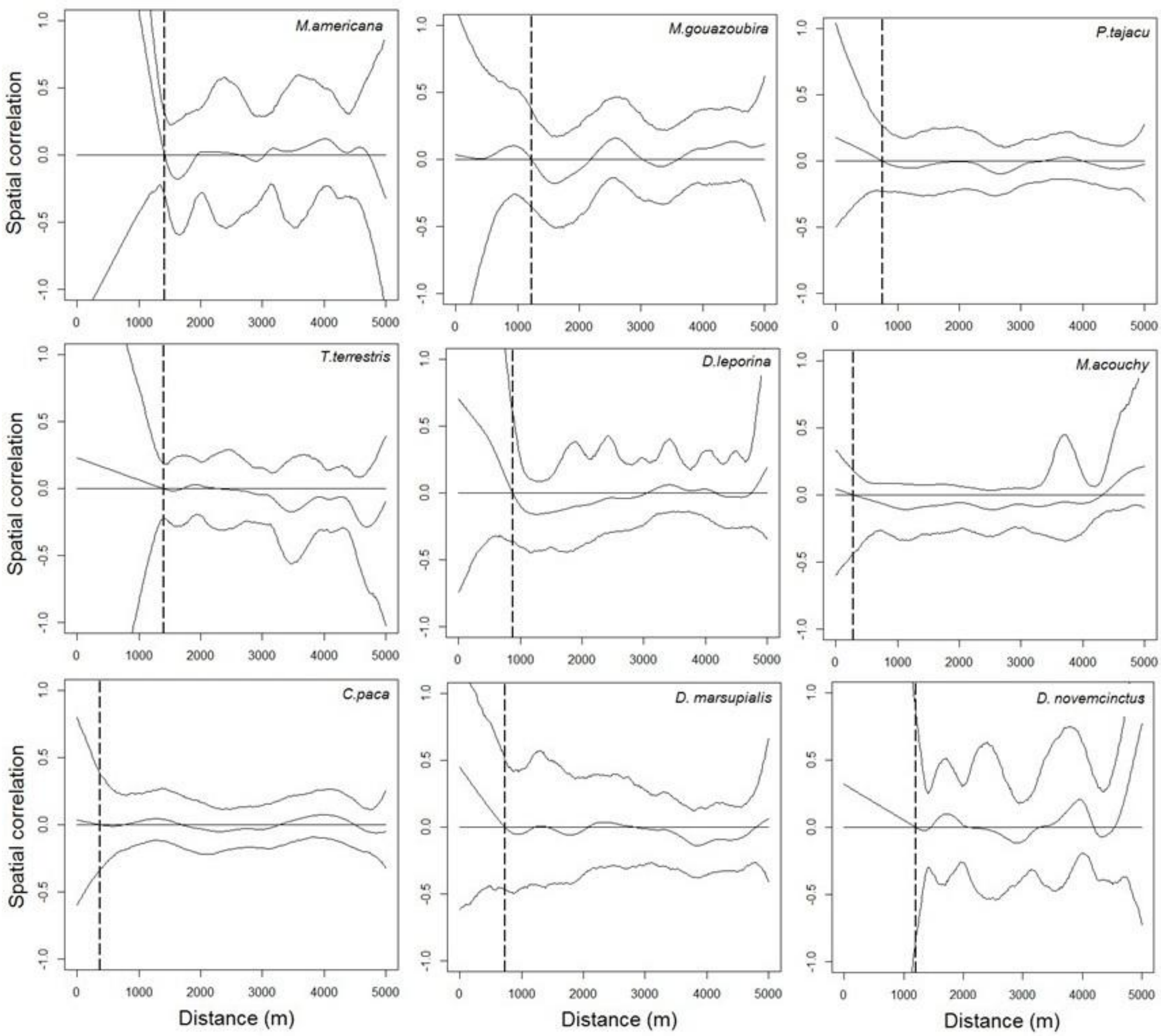

Table A1- Estimates of beta coefficients β in the logit scale and standard errors of predictor variables containing the best models of occurrence ($\Delta AIC \leq 2$) for the nine mammal species analyzed. [*] indicates the beta values that do not overlap zero.

	Intercept	Elevation	Drainage	Road	Edge	Block	ZF-2	ZF-3
Ma1	0.349 (0.616)		**-1.302 (0.697)***	**1.238(0.838)***				
Ma2	0.554(0.738)		**-1.137(0.644)***			-0.879(0.581)		
Ma3	0.149(0.514)		**-0.784(0.417)***					
Mg1	0.939(0.943)	**1.125(0.688)***						
Mg2	0.803(0.962)	0.987(0.874)		**-0.971(0.517)***				
Mg3	1.388(1.003)	0.775(0.575)					**-1.274(1.086)***	**-2.023(1.196)***
Pt1	**-2.143(0.772)***						**2.182(0.951)***	**2.532(0.981)***
Pt2	-0.618(0.371)			**0.865(0.365)***				
Pt3	**-2.312(0.781)***						**2.27(0.95)***	**2.981(1.142)***
Pt4	**-2.282(0.782)***		0.473(0.452)				**2.17(0.97)***	**2.941(1.133)***
Tt1	-0.864(0.635)							
Tt2	-0.907(0.623)			0.548(0.494)				
Tt3	0.242(1.304)		-1.395(1.094)	2.835(2.001)				
Dl1	**1.891(0.849)***						-1.67(0.932)	-0.354(1.047)
Ma1	1.862(0.414)	**0.861(0.336)***						
Ma2	1.697(0.361)	**0.876(0.356)***						
Cp1	-0.236(0.286)							
Cp2	-0.243(0.290)		0.316(0.271)					
Dm1	0.353(0.468)		-0.491(0.275)				0.315(0.652)	0.275(0.661)
Dm2	0.118(0.281)		-0.434(0.282)	**-0.684(0.360)***		-0.602(0.353)		
Dm3	0.095(0.265)			**-0.569(0.308)***		-0.490(0.305)		
Dn1	1.253(0.430)	**1.542(0.450)***						
Dn2	1.426(0.522)	**1.682(0.472)***		**0.588(0.359)***				
Dn3	0.865(0.638)	**1.305(0.510)***						
Dn4	0.649(0.568)	**1.753(0.537)***					1.526(0.900)	0.591(0.924)

Species abbreviations: Ma = *Mazama americana*; Mg = *M. gouazoubira*; Pt = *Pecari tajacu*; Tt = *Tapirus terrestris*; Dl = *Dasyprocta leporina*; Ma = *Myoprocta acouchy*; Cp = *Cuniculus paca*; Dm = *Didelphis marsupialis*; Dn = *Dasypus novemcinctus*.

Figure A2 – Spatial distribution of *M. gouazoubira* and *M. americana* influenced by roads and edges, showing inverse pattern of occurrence between these two species.