INSTITUTO NACIONAL DE PESQUISAS DA AMAZÔNIA – INPA
PROGRAMA DE PÓS GRADUAÇÃO EM ECOLOGIA

Resposta da mastofauna às atividades humanas: Avaliação do impacto de atividades de subsistência em uma Reserva de Desenvolvimento Sustentável, Amazônia Central.

Renata Ilha

Manaus
Junho 2016

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Nada é absoluto.

Tudo.

Tudo é momento.
Pra saber a qualidade de cada potência, é preciso calar

˜ entregar-se ao momento.

Respirar cada dúvida, cada medo

Respirar ~

O silêncio absoluto é Deus.
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Eu, nada sou.
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Resumo

A fauna da Amazônia está sendo ameaçada por diversas atividades humanas. Agricultura mecanizada e sobre-caça são duas das principais ameaças nos trópicos. A maior porção de floresta convertida para agricultura mecanizada está no "arco do desmatamento" na região de contato do bioma Amazônia com demais biomas do Brasil e em parte da Amazônia Oriental. Na Amazônia ocidental, no entanto, prevalecem pequenas porções de terras convertidas em plantações de subsistência. Caça de subsistência, por outro lado, é uma das formas mais comuns de extração de recursos não madeireiros nas florestas tropicais, sendo uma ameaça importante para a fauna, especialmente para espécies cinegéticas. As comunidades tradicionais da Amazônia têm a caça de subsistência e a agricultura familiar como principais fontes de alimento, juntamente com a pesca. Neste cenário, as Reservas de Desenvolvimento Sustentável, incorporadas em 2000 no Sistema Nacional de Unidades de Conservação, permite aos seus moradores realizar legalmente atividades de subsistência, como caçar e converter pequenas quantidades de terra para a agricultura familiar. Aqui, nós avaliamos como 16 espécies de mamíferos terrestres respondem aos efeitos de agricultura e caça de subsistência em uma Reserva de Desenvolvimento Sustentável na Amazônia Central. Para isso, nós monitoramos a atividade diária de caça por 13 anos através do Sistema de Monitoramento de Uso da Fauna (SMUF), amostramos mamíferos terrestres com armadilhas fotográficas em 160km^2, e mapeamos a atividade de agricultura de subsistência ao longo de 22 anos através de imagens de satélite. Nossos principais resultados mostraram que a maioria das espécies de caça estão negativamente relacionadas com a intensidade da caça, embora três espécies intensamente caçadas não respondam à caça. Embora com estabilidade espacial aparentemente menor do que a caça, a agricultura de subsistência parece ser menos importante para determinar a presença de espécies de mamíferos, sendo positivamente relacionada com a presença de duas espécies, e negativamente à três espécies. Nossos resultados destacam a importância de compreender o efeito das atividades de subsistência praticadas por comunidades tradicionais na Amazônia brasileira e indica a realização de planos de gestão integrados para manter o uso sustentável dos recursos florestais e a segurança alimentar destas populações a longo prazo. No segundo capítulo, nós abordamos a presença rara de uma espécie não cinegética de pequeno felino em áreas de agricultura familiar, e sugerimos seu status de conservação no bioma Amazônia.

Abstract

The impact of subsistence agriculture and hunting on mid and large sized terrestrial mammals in a Sustainable Development Reserve, Central Amazon

The Amazon fauna is being threatened by several human activities. Mechanized agriculture and overhunting are two of the main threats in the Tropics. About 20% of the Amazon has been already deforested. However, the Amazon villages depend strongly on agricultural production and subsistence hunting, as their source of food. Here, we assess how 16 terrestrial mammal species responded to the effects of land-use change, induced by subsistence agriculture and to subsistence hunting in a Sustainable Development Reserve, Central Amazonia. For that, we monitored daily hunting activity for 13 years, intensely surveyed terrestrial mammals within 160 km^2 with camera-traps and mapped the agriculture activity in a traditional village to investigate the effects of these two anthropogenic pressures. Our main results showed that most game species are negatively related to the intensity of hunting, though three intensely hunted species are not responding to hunting at all. Although in apparent lower spatial stability than hunting, subsistence agriculture seems to be less important to determine the presence of mammal species, being positively related to the presence of two species, and negatively related to only one species. Our results highlight the importance of understanding the effectiveness of sustainable activities by traditional communities in the Brazilian Amazon and indicates the accomplishment of integrated management plans to maintain the use of forest resources in the long term by traditional communities.

Introdução Geral

Cerca de 20% da Amazônia já foi desflorestada, principalmente para a introdução de pastagens e agricultura de média e grande escala (ex. soja) (Silvério et al., 2015). Da porção preservada de Floresta Amazônica, 54% está protegida por lei, dentro de diversas categorias de proteção (Soares-Filho et al., 2010). A maior porção de floresta convertida em agricultura está no “Arco do Desmatamento”, na porção sul e oriental da Amazônia (Morton et al., 2006; Macedo et al., 2012), onde a conectividade com demais centros urbanos é facilitada por rodovias. Este desmatamento é principalmente causado por grandes proprietários de terra, que executam essa conversão em média e grande escala. Essas grandes conversões de terra tem tido seu efeito investigado quanto a diversos fatores, como modificação da qualidade do solo (Leite et al., 2015), contribuição para o aquecimento global (Silvério et al., 2015) e influência sobre diversas espécies da fauna, como morcegos (Estrada, 2002), aves (Penteado et al., 2004) e mamíferos (Magioli et al., 2016).

Diferindo deste contexto, a Amazônia ocidental possui poucas conexões por terra com grandes centros urbanos, e nesta área, predominam pequenas porções de floresta convertidas para plantios de subsistência, em um sistema conhecido como agricultura de *queima-e-corte* (Novaes & Júnior, 2008; Padoch & Pinedo-vasquez, 2010; Lima et al., 2012). A Amazônia possui cerca de 342.622 indígenas (IBGE 2010) e cerca de 325.398 ribeirinhos vivendo dentro de Unidades de Conservação (D’Antona et al., 2013), que certamente necessitam destas pequenas plantações de subsistência para prover seu alimento (Junqueira et al., 2016). O efeito destas pequenas conversões de terra, no entanto, é pouco conhecido, especialmente sobre espécies de fauna.

Para a maior parte das espécies ameaçadas da fauna em todo o mundo, a perda e fragmentação de habitat é a maior ameaça à conservação. Por isso a importância de compreender os mecanismos de adaptação e os efeitos da modificação da paisagem sobre espécies da fauna. Além disso, a sobre-exploração de recursos, como no caso da sobre-caça, é a segunda maior ameaça à biodiversidade no mundo.

Diferentemente dos efeitos de pequenas conversões de terra para agricultura de subsistência, que tem seus efeitos sobre a fauna pouco investigados, a caça de subsistência possui uma série de estudos que investigam o efeito da caça de subsistência especialmente sobre espécies cinegéticas, que a apontam como um fator importante para determinar a ocupação destas espécies na paisagem (Redford, 1992; Bodmer et al., 1997; Peres, 2000, 2007; Jerozolimski & Carlos A Peres, 2003).

Visando aliar o direito ao uso da terra por comunidades tradicionais e a preservação de recursos florestais, foi criada em 2000, a categoria de Reservas de Uso Sustentável dentro do Sistema Nacional de Unidades de Conservação (SNUC). Esta categoria de reservas reformula as estratégias de conservação até então empregadas pelos governos brasileiros, e propõe a conservação de ambientes naturais com a manutenção de atividades de populações tradicionais. Dentro elas, a Reserva de Desenvolvimento Sustentável, prevê que seus moradores (em sua maioria ribeirinhos), cacem para sua subsistência e convertam pequenas quantidades de terra para agricultura de subsistência.

Neste trabalho avaliei como 16 espécies de mamíferos terrestres respondem aos efeitos da agricultura de queima-e-corte e caça de subsistência na Reserva de Desenvolvimento Sustentável Amanã, na Amazônia Central. Para isso, nós monitoramos a atividade diária de caça por 13 anos através de um sistema de monitoramento comunitário do uso da fauna (SMUF), amostramos mamíferos terrestres com armadilhas fotográficas em 160km² e mapeamos a atividade de agricultura de subsistência com o objetivo de investigar os efeitos dessas duas pressões antrópicas sobre estas espécies de mamíferos.

Ainda no contexto da avaliação do impacto de atividades humanas sobre a fauna, obtivemos um registro de *Puma yagouaroundi* ao monitorarmos áreas manejadas para agricultura na Reserva de Desenvolvimento Sustentável Amanã. Assim, no segundo capítulo da dissertação, avaliei o *status* de conservação do *Puma yagouaroundi* na Amazônia Brasileira, bioma sugerido como *hotspot* para a conservação da espécie no Brasil.

Capítulo I:

Objetivo Geral

Compreender como a distribuição dos mamíferos é predita por atividade de caça de subsistência e agricultura de queima-e-corte na Reserva de Desenvolvimento Sustentável Amanã.

Objetivos Específicos

1. Avaliar o efeito da intensidade de caça na probabilidade de uso de sítios por médios e grandes mamíferos em uma comunidade tradicional na Reserva de Desenvolvimento Sustentável Amanã.

2. Avaliar o efeito da proximidade das áreas de agricultura na probabilidade de uso de sítios por mamíferos em uma comunidade tradicional na Reserva de Desenvolvimento Sustentável Amanã.

3. Avaliar a existência de interação do efeito da intensidade de caça e da proximidade das áreas manejadas para agricultura na probabilidade de uso de sítios por mamíferos.

4. Avaliar a dinâmica espaço-temporal da atividade de agricultura de *queima-e-corte* de três comunidades tradicionais na Reserva de Desenvolvimento Sustentável Amanã.

5. Avaliar a dinâmica espaço-temporal da atividade de caça de uma comunidade tradicional na Reserva de Desenvolvimento Sustentável Amanã.

Capítulo II:

Objetivo Geral:

Descrever o *status* de conservação de uma espécie rara de felino (*Puma yagouaroundi*) na Amazônia Brasileira

Objetivo Específico

Compilar e adicionar pontos de registro fotográfico de *Puma yagouaroundi* na Amazônia Brasileira

Capítulo I.

ILHA, R., RAMALHO, E.E., PEREIRA, P.M., FERRAZ, G., VALSECCHI, J., ROCHA, D.G., BACCARO, F.B. The impact of subsistence agriculture and hunting on mid and large sized terrestrial mammals in a Sustainable Development Reserve, Central Amazon.

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The impact of subsistence agriculture and hunting on mid and large sized terrestrial mammals in a Sustainable Development Reserve, Central Amazon.

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The Amazon fauna is being threatened by several human activities. Mechanized agriculture and overhunting are two of the main threats in the Tropics. About 20% of the Amazon has been already deforested. However, the Amazon villages depend strongly on agricultural production and subsistence hunting, as their main source of food. Here, we assess how 16 terrestrial mammal species responded to the effects of land-use change, induced by subsistence agriculture and to subsistence hunting in a Sustainable Development Reserve, Central Amazonia. For that, we monitored daily hunting activity for 13 years, intensely surveyed terrestrial mammals within 160 km^2 with camera-traps and mapped the agriculture activity in a traditional village to investigate the effects of these two anthropogenic pressures. Our main results showed that most game species are negatively related to the intensity of hunting, though three intensely hunted species are not responding to hunting at all. Although in apparent lower spatial stability than hunting, subsistence agriculture seems to be less important to determine the presence of mammal species, being positively related to the presence of two species, and negatively related to only one species. Our results highlight the importance of understanding the effectiveness of sustainable activities by traditional communities in the Brazilian Amazon and indicates the accomplishment of integrated management plans to maintain the use of forest resources in the long term by traditional communities.

Keywords: subsistence hunting, subsistence agriculture, terrestrial mammals, Amazon, occupancy.

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Introduction

The Brazilian Amazon is experiencing the highest rate of forest loss of the world. In fact, current threats to tropical forests are a consequence of different scales of structural and non-structural human disturbances that often operate synergistically, such as deforestation and defaunation [1,2]. These disturbances ranges from great land-cover changes, such as deforestation and mechanized agriculture that both affects the functionality of the ecosystems and leads to defaunation, to small-scale land-cover changes, such as slash-and-burn agriculture and subsistence hunting, often used for subsistence of traditional people.

The impact of land-use change for agriculture in the Amazon, the large tropical forested area in the world, has been investigated at different levels and time scales [3–5]. About 20% of the Amazon has been deforested, especially for the introduction of pastures and mechanized agriculture (e.g., soybean) [6]. Most forest portion converted to agriculture is in the “arc of deforestation” in the eastern and southern Amazon [7,8], where connectivity to urban centers and regional markets is facilitated by roads. These large forested areas converted to agriculture may change soil quality locally [15], contribute to climate change [6] regionally, and affect the abundance and occurrence of several forest animal species, such as bats [16], birds [17] and mammals [18]. The rest of the Brazilian Amazon, has few connections by road with large urban centers, and in these regions prevails smaller portions of land converted to subsistence plantations, in a system of shifting cultivation, known as "slash-and-burn" [9–11]. However, the effect of these small area conversions to agriculture on animal species received little attention [12–14].

The second main threat to biodiversity in the world is over-exploitation of natural resources, such as overhunting [19]. Therefore, hunting has been prohibited in Brazil in 1967 (Brazilian Federal Law No 5197, 1967), but such as subsistence agriculture, hunting remains an essential element in the livelihoods of diverse indigenous and riverine peoples, being an important source of protein to these villages [20,21].

Unlike the effects of land conversions to subsistence agriculture, which has its effects on the fauna little investigated, the subsistence hunting has a series of studies measuring its effects especially on game species. In general, these studies points hunting as an important factor in determining the occupancy of these species in the landscape [22–28] with great threats to functionality of ecosystems, such as profound changes in the landscape [19,29,30]. Most of these studies, however, assume differences in densities of terrestrial vertebrates comparing hunting and non hunting areas, and hardly consider the source-sink metapopulation dynamic to examine the sustainability of game harvest [12].

Assuming that subsistence hunting and agriculture can happen in a sustainable way, the Brazilian government created in 2000 the category of Sustainable Use Reserves within the National Conservation Areas System of Brazil. This category of reserves recasts conservation strategies previously employed by the Brazilian government, and proposes the conservation of natural environments maintaining traditional populations activities [31]. Within them, the Sustainable Development Reserve allows for its residents (most riverine people), to legally hunt for the subsistence of their livelihood and convert small amounts of land for subsistence farming.

Nowadays Brazil we have fifty four percent of the remaining portions of the Amazon protected by various protection categories, including Sustainable Use ones [32]. The Brazilian Amazon has about 342.622 indigenous people (IBGE 2010) and about 325.398 traditional non-indigenous people living in Conservation Units [31], which livelihoods depend strongly on agricultural production and subsistence hunting [3,20,21,27]. Therefore, it is crucial to detect the effects of game harvest and subsistence farming on those kind of Reserve to preserve not only the forest structure, but its functionality.

Here, we assess how 16 terrestrial mammal species responded to the effects of land-use change, induced by subsistence agriculture and to subsistence hunting in a Sustainable Development Reserve, Central Amazonia. For that, we monitored daily hunting activity for over 13 years, mapped the subsistence agriculture, and intensely surveyed terrestrial mammals within 160 km^2 with camera-traps to investigate the effects of these two anthropogenic pressures.

2. Materials and Methods

2.1 Study area

The terrestrial mammals survey was conducted in Amanã Sustainable Development Reserve (RDSA). RDSA covers an area of 2.350.000 ha in central Amazon between the Negro and Amazonas rivers. The reserve forms, with the Jaú National Park and the Mamirauá Sustainable Development Reserve, one of the largest continuous blocks of protected tropical forest in the world (Ayres et al. 2005; Rocha et al. 2015). RDSA is classified as an *Paleovárzea* area (Irion et al. 2010) and is formed by upland *terra firme* forests, *igapó* forests and *várzea* floodplain forests [35]. Terra firme forests cover the largest portion of the reserve (84%). The climate is tropical humid, with average temperature of 26°C and average annual rainfall of 2373 mm (Ayres, 1993).

2.2 Sampling desing

We installed 111 trap stations between January and May 2015 to measure the possible synergetic effects of subsistence agriculture and hunting on mammal species occurrence. We monitored 8 *slash-and-burn* areas, which still in use. To cover the heterogeneity of agriculture areas (crops, areas in recent regeneration, areas in late regeneration and transition areas), we installed a set of 6 camera-traps from 100 m to 1 km away from the *agriculture*, in each *slash-and-burn* areas counting a total of 48 cameras. One cameras was installed in each sampling point and was left operating for 30 days. We also installed 13 camera-traps at a similar distance from the river bank to control possible effects of distance from water on mammals occurrence, which in this region is strong correlated with forest structure, the flood regime and the human villages. These cameras were located 1 km to 1,5 km apart, and operated for 30 days. We also established 50 pairs of camera traps in upland forests 2 km apart following the small tributary, to cover the hunting area of the villagers (Figure 1). This grid of 50 camera-traps are part of a monitoring program that was also held in 2013 and 2014. These camera traps monitored mammal species during 45 days. Overall, the survey covered an area of 160 km² in a sampling effort of 3.690 trap nights.

2.2 Mapping Agriculture Activity

The slash-and-burn agriculture is commonly used in the tropics, especially in poor soil areas as in the case the Amazon. This dynamic consists of a shifting cultivation that leaves areas fallow for long periods for forest growth to use this burning organic material to nourish the soil and plant, in most cases, specimens of *Maniva sp*. Because slash-and-burn consists in a shifting cultivation, new areas can be cleared to enter into the rotation process, which can result in the growth of managed areas in the long-term.

To track the growth of agriculture of the last two decades, we used Landsat Surface Reflectance L7 ETM scenes from 1989 to 2011 (Figure 2). In this selected images, we perfomed a Supervised Classification using Envi Program, and divided our landscape into four classes (forest, agriculture, exposed soil and water). We then used the classified raster images to calculate the amount of agriculture growth in this period (Figure 3). To be more specific about the agriculture activity recently, we used on-ground mapped agriculture areas from 2013 of the Agroecosystems Monitoring Program of the Amazon Agriculture Research Group – IDSM (Figure 1). We calculate Cartesian distances from present agriculture areas, using “distance-point to feature” tool from our on-ground mapping using ArcGis 10.2.2 Program.

2.3 Hunting Activity

Between 2002 and 2014, we monitored the hunting activity in Bom Jesus do Baré community using a Community-based Monitoring Hunting Program (SMUF). This program was carried out by a local resident that record daily hunting information communicated by community hunters. To calculate the hunt pressure in our study area, we spacialized 59 of the 75 locations observed in 13 years of the Monitoring Hunting Program (SMUF). For that, we had the help of the three main hunters of the community. After, we used the spatial hunting points to construct Kernel density maps using ArcGis 10.2.2 Program. To create the maps and estimate the area of hunting influence, we used buffers based on the hunters displacement mean starting from the edge of the watercourses to the place of harvesting. The values varied from 1,043 km to 12,473 km with mean 3,607 km ± SD 3,438 km. The Kernel estimator is a probabilistic estimator originally developed for a parametric estimation of both univariate and multivariate probability density of an observed sample (Bailey & Gatrell, 1995). Kernel densities classes were obtained using the number of slaughtered animals from the whole period of the monitoring program (13 years) and for the last 3 years. We also estimated our hunt intensity classes using the number of hunt occasions, either for the 13 years of monitoring and for last 3 years. For estimating the hunt pressure in our trap stations, we extract the value of the Kernels densities using ARCGIS 10.2.2.

2.5 Data analysis

To cover the heterogeneity of agriculture areas (crops, areas in recent regeneration, areas in late regeneration and transition areas) we installed nearby cameras, which may increase the dependency between each camera station (the same mammal individual can be registered in closer camera stations). Therefore, we used correlograms, based on Moran index to estimate the spatial auto-correlation of our trap stations for each mammal species around the agriculture areas. The correlation between distance from agriculture and hunt intensity was relatively low (~0.4), therefore both variables were included in the models (See Appendices below).

We obtained the site occupancy for all terrestrial mammals species considered in this study, based on the detection history constructed with detection by the camera traps. We choose to use a maximum likelihood approach (MacKenzie et al., 2002) because false absences are likely to occur during surveys and may underestimate site occupancy. In this approach, the proportion of occupied sites is estimated accounting for imperfect detection (<1). We analyzed site occupancy with a detection history (matrix of detection (1) and non-detection (0) for each species per occasions (5 days of camera-trap on) in all 111 sites). We used unmarked package for R Program to model site occupancy and detection probabilities for the terrestrial mammal species. We modeled detection probabilities considering 1) the number of trap nights and the number of cameras per site, as we assumed that detection probabilities would be different due to differences in sampling effort through the sampling area. For occupancy estimation, we hypothesized Single Season models (Mackenzie 2002) that could best explain site occupancy of each species. For that, we estimate site occupancy probabilities considering 1) distance from water (dist_water), 2) distance from agriculture areas (dist_agric), and one of each hunt intensity estimates 3) hunt intensity based on the number of slaughtered animals within the recent 3 years of monitoring program (hunt_3y_animals), 4) hunt intensity based on the number of slaughtered animals within 13 years of monitoring program (hunt_13y_animals). For the four predator species (*Panthera onca, Puma concolor, Leopardus pardalis, Leopardus wiedii*), we also used the number of prey detections (prey) as a variable to explain their occupancy. Hunt intensity based on the number of hunt events within 3 and 13 years of monitoring program were not used, because these values were at least 89% correlated we hunt intensity estimated using the number of animals killed (See Appendices below). For all species, we also created a "null model", which assumes constant species presence and detection probability across time and space. To rank the models and identify the most parsimonious model for our data set, we used Akaike's Information Criterion (AIC). We considered best models, those with Delta AIC < 2 (Burnham and Anderson, 2002). We selected the model with fewer parameters, when more than one competing model shows Delta AIC < 2. We plotted the occupancy probability and the 95% confidence intervals against the variables selected in the better models for each species modeled.

3. Results

3.1 Agriculture Activity

In our on ground mapping realized in 2013, we found an extension of agriculture activity of Bom Jesus do Baré community that covers an area of 64,3 ha (Figure 3). This amount of agriculture area bellows to 17 men and women that practice agriculture in the community, wich representes 3,7 ha per agricultor. Our Supervised Classification used to verify the growth of the agricultural areas in the three communities revealed a 1240% growth of the total deforested area between 1989 and 2013. (Figure 2 and 3). Although we have this result, it is important to mention that our analysis is not thin enough to differentiate deforested area for agriculture from deforested area for other purposes of the community.

3.3 Monitoring Hunting Program

For the 13 years of monitoring, we registered 48 hunted species, 30 mammal species (27 terrestrial and 3 aquatic), 14 birds and 4 reptiles. Between 2002 and 2014, 5.136 specimens were hunted in the Bom Jesus do Baré Community (Table 1). Mammal species represents 91,2% of the total slaughtered individuals. The most persecuted animal was the white-lipped peccary (*Tayassu pecari*) followed by black agouti (*Dasyprocta fuliginosa*) and lowland paca (*Cuniculus paca*). The total biomass removed for hunting during this period was 88.122,83 kg. In 2011, Bom Jesus do Baré had 13 houses with approximately 76 people living in the community. Assuming that the number of residences during the sampling was fixed, our result represents 247g of hunting meat per person/day.

3.2 Occupancy models

Within our camera-trap surveys, we registered 35 species. Twenty-one species were of terrestrial mammals, four arboreal mammals, seven birds and three reptiles. The agriculture trap stations registered the same number of species of the other sampled stations (Figures 8 and 9). Although we have registered 25 species of mammals, we modeled only 16 species that we consider our sampling method was appropriate (Table 1).

We found autocorrelation patterns in our agriculture trap stations for *Cuniculus paca*, *Dasyprocta fuliginosa*, *Myrmecophaga tridactyla* and *Tapirus terrestris* (See Appendices below). For that species, we grouped the related points, in order to remove the effect of spatial correlation. Therefore, occupancy models for these four species were based on 100 sampling points, rather 111 for the other species.

For six species (~40%), we found differences on the detectability when we tested it for the number of trap nights and number of cameras per site (Table 2). Game species like *Cuniculus paca* and *Dasypus kappleri* had increased their occupation probabilities close to managed areas for agriculture and the opposite effect were observed for species like *Myoprocta pratti*, *Didelphis marsupialis* and *Tapirus terrestris*. The distance from water were negatively related with *Cuniculus paca*, *Dasypus kappleri* and *Tapirus terrrestris*, and positively related with *Dasyprocta fuliginosa* occupation (Table 2, Figure 10 and 11).

Like distance from agriculture, hunting did not showed the same effect on all species. Most game species like *Cuniculus paca*, *Pecari tajacu*, *Mazama nemorivaga*, *Dasypus kappleri*, *Tapirus terrestris* and a predator species *Puma concolor* responded to the intensity of hunting, and their occupancy probabilities decreased with higher hunt intensity in the area (Table 2, Figure 10). Other game species, as *Dasypus novemcinctus*, *Mazama americana*, less hunted species like *Myrmecophaga tridactyla*, *Priodontes maximus,* and no-hunted species for comsuption like *Panthera onca* and *Leopardus pardalis,* however, did not respond to any of the hunting variables (Table 2). The predator species *Leopardus wiedii* was the only species that responded to the density of their potential prey (Table 2, Figure 11).

4. Discussion

In this study, we analyzed the effects of subsistence activities, like farming and hunting, in the occupancy probabilities of terrestrial mammal species. *Slash-and-burn* agriculture in the region showed a negative effect on site occupancy only for three species: *Myoprocta pratti*, *Didelphis marsupialis* and *Tapirus terrestris*. Despite a negative relationship with the proximity of agricultural areas, *M. pratti* and *D. marsupialis* are widely distributed in the study area (Figure 8 and 9). Both species can avoid areas close to agriculture, but are certainly present and abundant throughout the area. *Tapirus terrestris*, on the other hand, were less abundant, and unlike *M. pratti* and *D. marsupialis,* has a lower rate of population increase among neotropical mammals [36]. *Tapirus terrestris* is also more hunted compared with *M. pratti* and *D. marsupialis*, being indicated by hunters as the second preferred target species for slaughter in the BJB community [37]. Both information suggest that *T. terrestris* may be less resilient to these both human pressures [23].

Opposing these repletion effects, *Dasypus kappleri* and *Cuniculus paca* (both game species) were positively associated with distance to agricultural areas. The presence of these species on areas of agriculture may be linked to the food availability in the agriculture areas. Although *Dasypus kappleri* may not feed directly from agriculture crops, it is probably following an indirect effect caused by agriculture areas. *Dasypus kappleri* is a great consumer of ants and termites, which abundance may increase in disturbed areas, even those managed with fire [38]. *Cuniculus paca*, in the other hand, feeds mainly from fruits, like *Musa paradisiaca* and *Persea americana* [39] that are common planted species in the *slash-and-burn* systems. In our sampled systems, for example, *M. paradisiaca* and *P. americana* were present in 75% and 50% of the times, respectively. Still, lowland paca is locally known as a great predator of *Maniva* sp, the major planted species in slash-and-burn agriculture system. Even in high modified environments, *C. paca* can feed from agricultural matrix [40].

Subsistence farming activity held at BJB community in RDS Amanã is the most common traditional farming practices in this part of the Amazon, which consists of a shifting cultivation that demands constant attention from farmers to its maintenance. For the Amanã Sustainable Development Reserve human communities, agriculture represents the main economic activity (Valsecchi & Amaral, 2009). The exponential growth in the agricultural area during the last 22 years along the lake Amanã reveals that this activity, although for livelihood of the villages, probably accompanies population growth of human communities [12], Nevertheless, our results demonstrate that the agricultural areas of the three analyzed communities are concentrated in the edges of the water courses, limited to the areas close to the communities. Still, agriculture impacts surely interact with other human disturbances like selective logging, harvesting of non-timber resources and introduction of exotic species like *Canis familiaris* that were not investigated in this study. Despite this likely joint influence, our data indicate that most part of mammal species investigated (68%) did not vary their occupancy probability related with distance from agriculture and at least two species were more common found closer to agriculture areas. Therefore, the agricultural activity (small fragments scattered through a large area) does not seem to be an immediate threat to the maintenance of medium and large mammal populations of RDS Amanã. We suggest, however, that subsistence agriculture in the RDS Amanã must go through a planning to don't achieve scales that can start a representative pressure for medium and large mammal species.

Tayassu pecari was the most hunted species in BJB community. It is the preferred species for consumption pointed by hunters [37] and represents the largest number of individuals killed during the 13 years of monitoring. *Tayassu pecari* alone, represents 43% of the slaughtered individuals of 27 species of mammals that are hunted by BJB community. However, since the second monitoring sampling ran by the Iauaretê project, in 2014, we could not identify *T. pecari* in our camera-trap surveys. Coinciding with this lack of records on our camera-trap monitoring, after 12 years of uninterrupted hunting of the species, there was no register of any *T. pecari* slaughtered in 2014. Failure to capture *T. pecari* during 2014 and 2015 in our camera traps can be due to its migratory/nomadic pattern of movement (Altrichter & Almeida, 2002), the great flood of the Amanã lake in 2013, or it can be due to intense withdrawal of individuals by hunting. One possible direct effect of no *T. pecari* hunted in 2014 may be reflected in the *P. tajacu* hunting pressure. The number of *P. tajacu* slaughter increased 89% in 2014.

Unlike the agriculture activity, which grew significantly along the last years, the hunting activity seems to have remained constant in the region. During the 13 years of hunting monitoring there was no increase in the size of the area used ($p > 0.05$) or in the number of sites used for hunting

($p > 0.05$). This stability in hunting activity suggest a relatively stable dynamics of game stocks, as we would expect the increase of hunting areas or sites visited if stocks are depleted. *Dasyprocta fuliginosa* was the second most hunted species by BJB community, and did not respond to hunting pressure, which was registered in almost all cameras traps several times (Figure 8 and 9). However, the occupancy probability of *Cuniculus paca*, *Pecari tajacu*, *Dasypus kappleri*, *Mazama nemorivaga*, and *Tapirus terrestris* were negatively related with hunting intensity, suggesting a local effect of hunting or human presence on the habitat occupation of these species. These species combined represented the most hunted species in the area.

We would expect the predator species would be following the abundance of their potential prey [41], but abundance of prey was only important for *Leopardus wiedii*. *Puma concolor* was negatively affected by hunting pressure, probably because of this same response of their prey, or even because of more intense human presence in areas with more hunting pressure.

Analyzing the effects of hunting on terrestrial mammals is especially complicated. The activity depends on a number of structural factors, such as forest density, proximity to large urban centers and roads and changes in land use, as well as factors such as human density of traditional communities, culture of hunters and tools used for hunting [20,21,24,28,42–45]. In addition to all these features, it is still very difficult to quantify the source-sink metapopulation dynamics, which can have significant effect on the maintenance of sustainable hunting.

Assuming this, we considered that the Amanã Sustainable Development Reserve has a small area occupied by traditional dwellings, located mainly along Amanã Lake. The whole area between the Amanã Lake and Jaú National Park remains with no known human occupation and, although there may be disturbances in the area, the forest appears to be structurally undisturbed and away from present human interference. This fact in conjunction with our results, suggest that game held along Amanã Lake probably has its effect minimized by source-sink metapopulation dynamics. Still, the long-term and pervasive structural effects, such as those raised by Wright et al., 2007; Dirzo et al., 2014; Bello et al., 2015; Peres et al., 2015, such as loss of essential ecosystem functions caused by overexploitation of large animal may be happening in the Amanã Lake region, where are concentrated traditional communities. By this view, the possible indirect effects of hunting activity in the Amanã Reserve region should be investigated to ensure food security of traditional communities, which have high dependence on this protein source, in addition to ensuring the maintenance of environmental services and structural functioning of the forest.

Interestingly, two species of human interest are suffering opposing anthropogenic influences. While *D. kappleri* and *C. paca* were negatively related to the intensity of hunting, these two species were also more frequent closer to agriculture areas. Still, we need to focus our concerns for *T. terrestris*, which is the only species that responds negatively to both human activities. By having a long reproductive period and large body size, *T. terrestris*, is more susceptive to threats and is already endangered worldwide. The decrease in the population size of large seed dispersers, such as the case of the lowland tapir, white-lipped peccary and collared peccary is related by recent research on forest structural changes and lost of environmental services in the long and medium term, as the decrease in carbon stocks and large tree species biomass [1,13,19,30].

Our main results showed that subsistence agriculture seems to be less important to determine the site use of mammal species, compared with hunting intensity. As expected, most game species were negatively related to the intensity of hunting, though three intensely hunted species did not respond to hunting at all. Our results highlight the importance of understanding the effectiveness of sustainable activities by traditional communities in the Brazilian Amazon and indicates the accomplishment of integrated management plans to maintain the use of forest resources in the long term by traditional communities.

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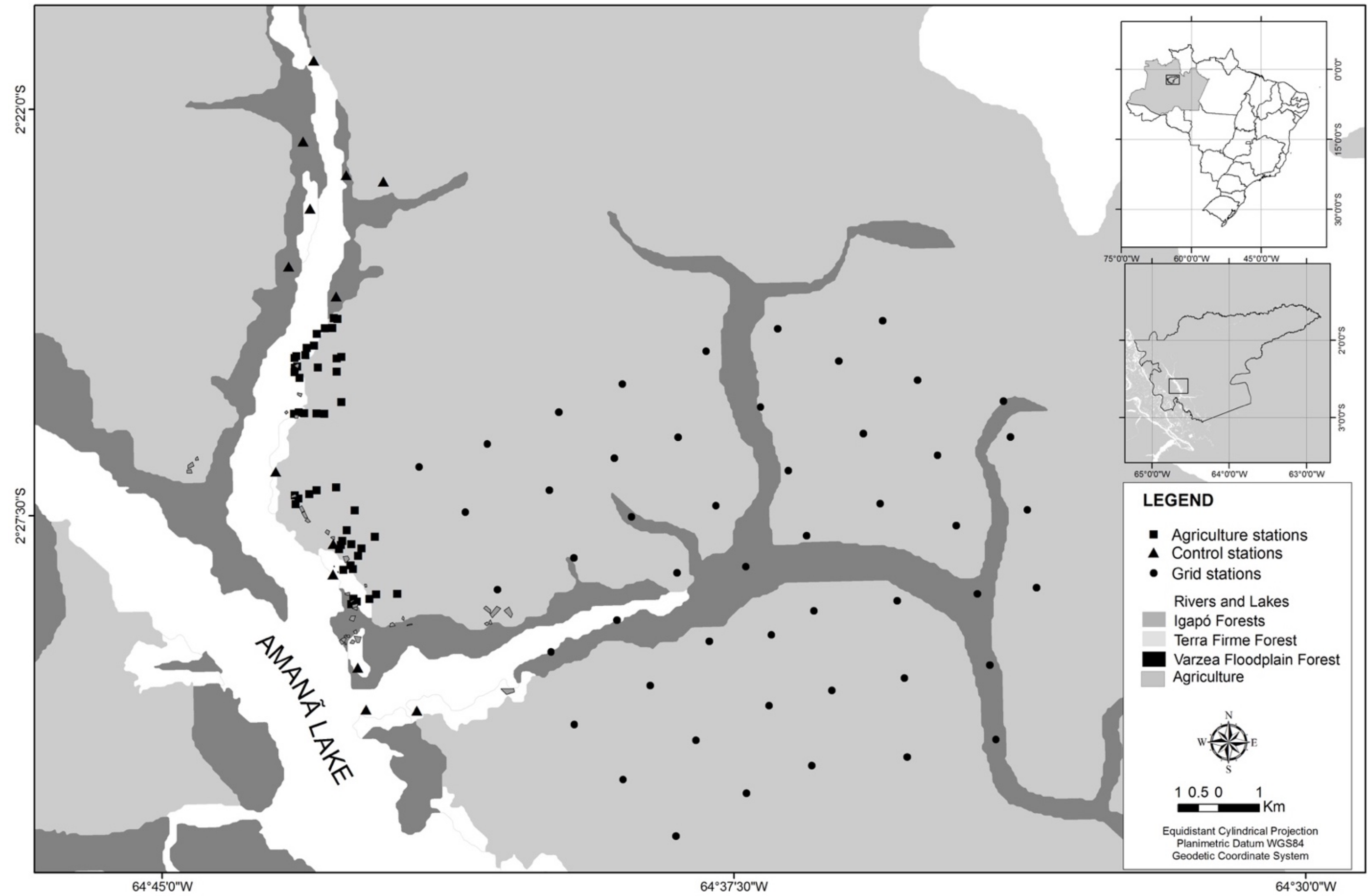

Figure 1: Design of the survey in Amanã Sustainable Development Reserve, between the Negro and Amazonas rivers, with 111 camera-trap stations located on agriculture areas, terra firme forests and "control" sites, that represents *várzea* and *igapó* forest stations.

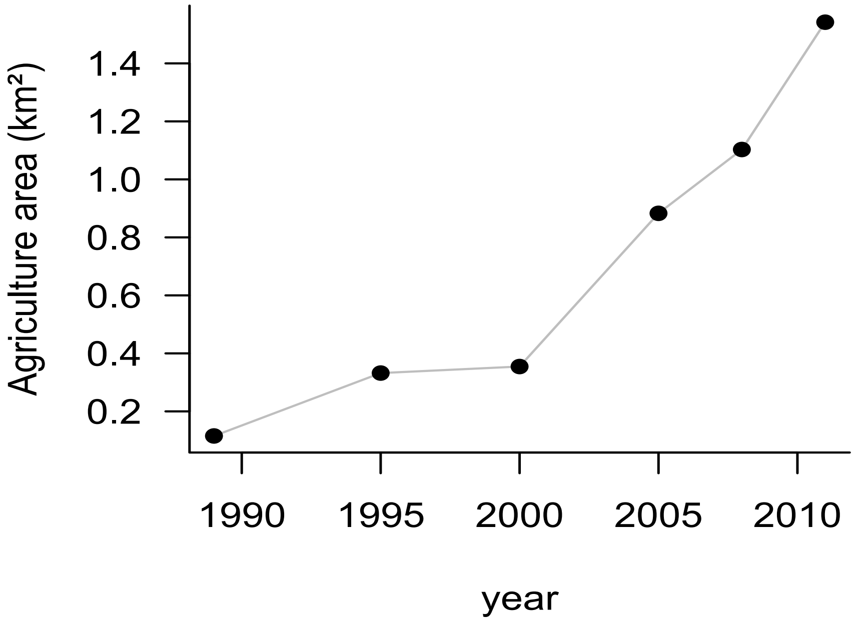

Figure 2: Agriculture growth of three communities of Amanã Sustainable Development Reserve. We used Landsat Surface Reflectance L7 ETM scenes from 1989 to 2011 to perform a Supervised Classification in Envi Program. The agriculture areas increased 1240% in this period.

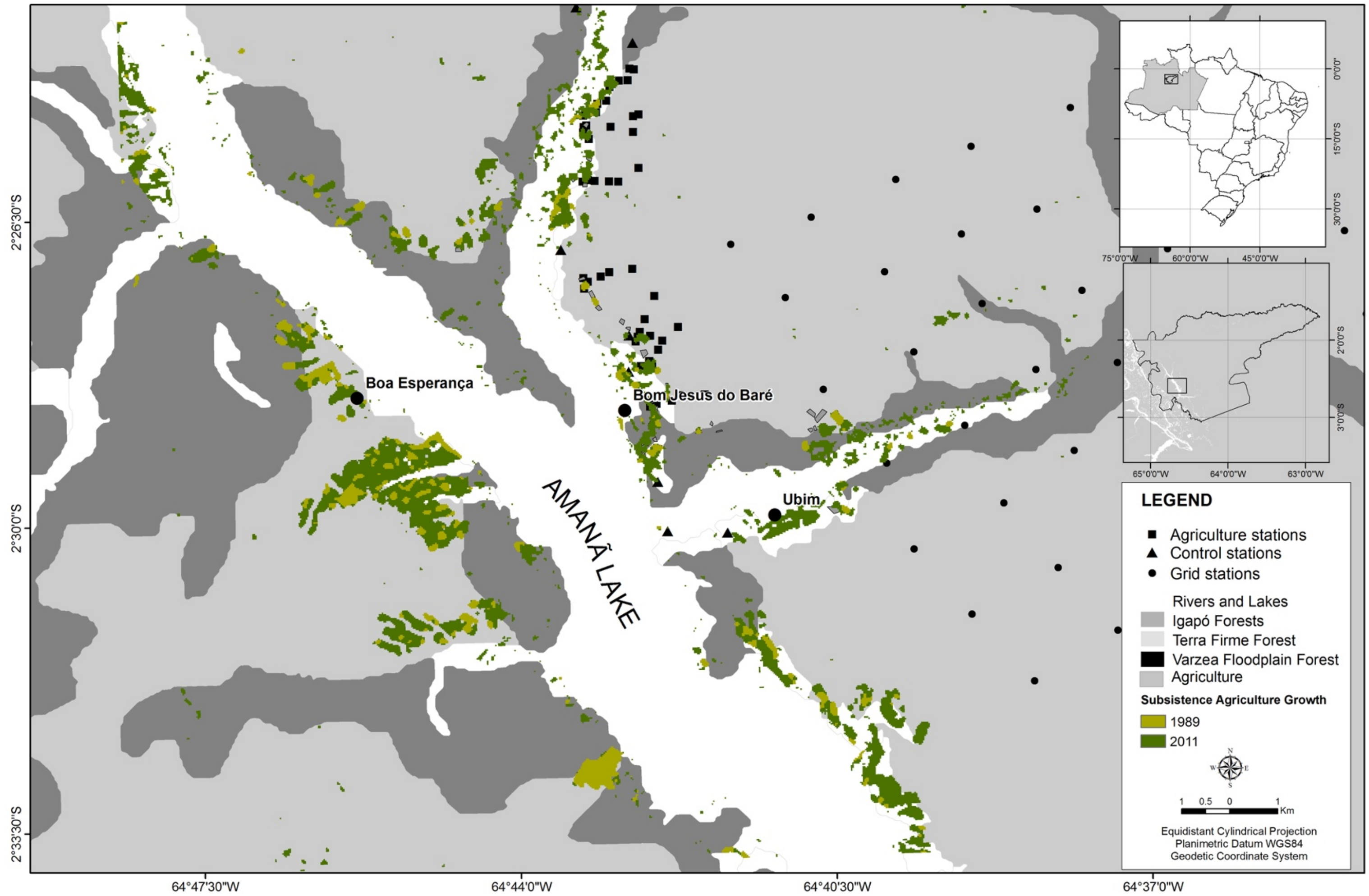

Figure 3: The agriculture growth mapped of three communities of Amanã Sustainable Development Reserve. We used Landsat Surface Reflectance L7 ETM scenes from 1989 to 2011 to perform a Supervised Classification in Envi Program. The agriculture areas increased 1240% in this period.

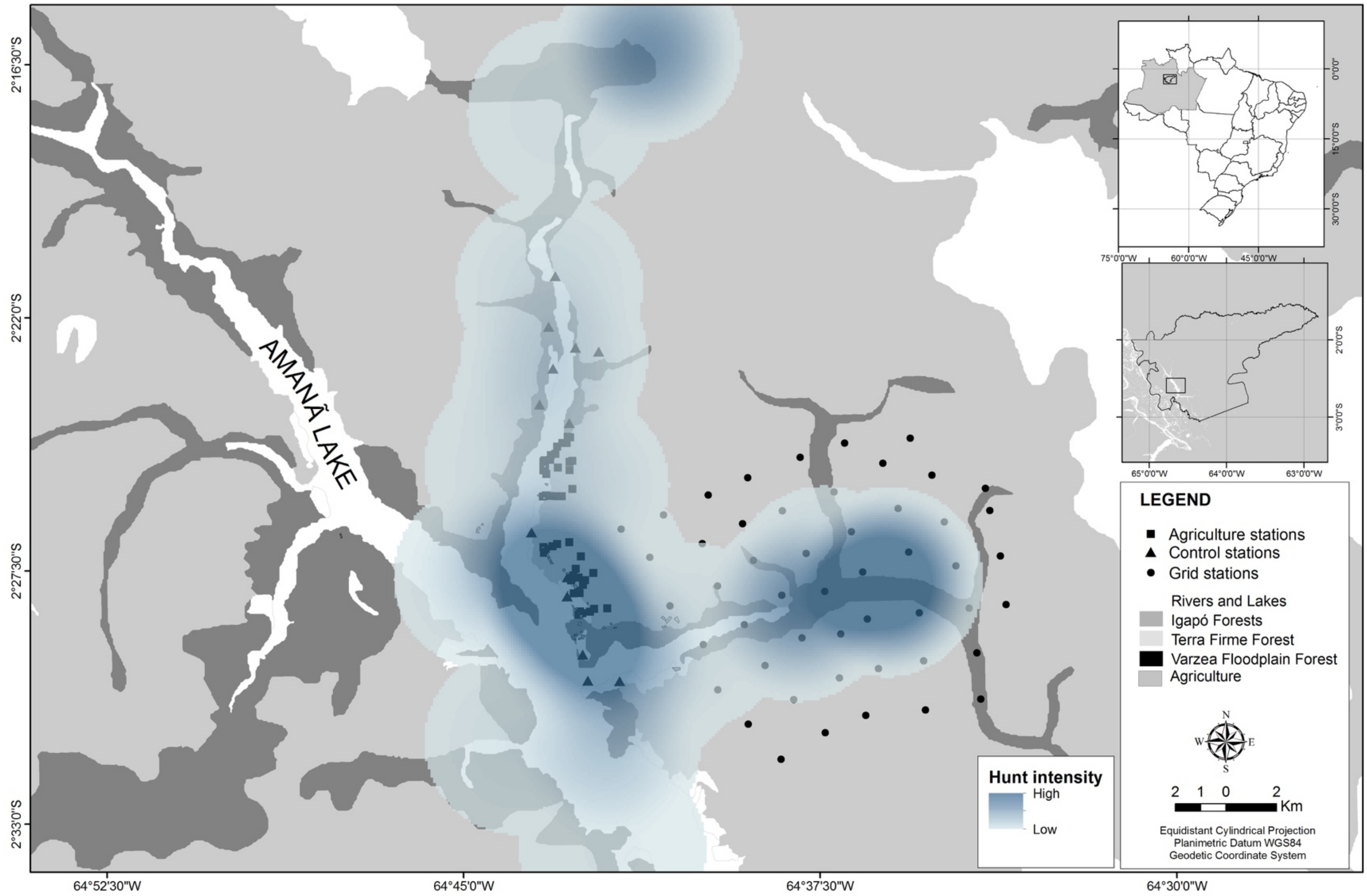

Figure 4: Our hunt intensity model performed using 3 years of hunted animals from the Monitoring Hunt Program (SMUF) of the BJB Community.

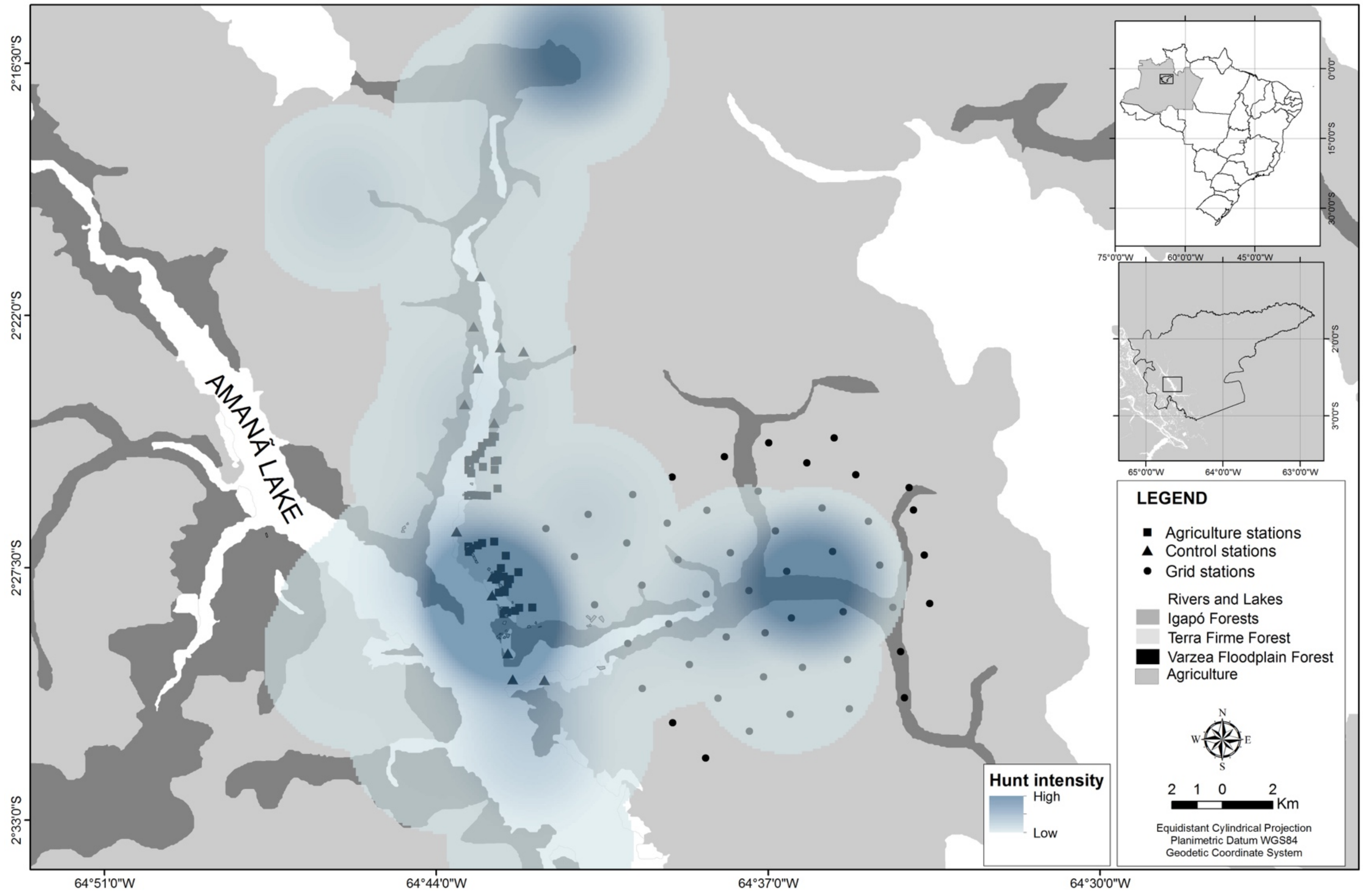

Figure 5: Our hunt intensity model performed using 13 years of hunted animals from the Monitoring Hunt Program (SMUF) of the BJB Community.

Table 1: Species hunted in Bom Jesus do Baré Community between 2002 and 2014, showing the environment the animals were killed, total biomass for the period and number of hunted animals.

Species	Environment	Nº of hunted specimens	Total Biomass (kg)
Mammals			
Pteronura brasiliensis	LAK	1	10
Trichechus inunguis	IGE, RIV	5	1190
Sotalia fluviatilis	-	2	72
Alouatta	IGO, TF	43	267
Ateles paniscus	TF	4	22
Lagotrix lagothricha	TF	2	24
Aotus nigriceps	-	2	4
Cebus apella	TF, IGO	21	75.6
Cacajao melanocephalus	IGO	42	126
Callicebus moloch	IGO, TF	12	22
Leopardus pardalis	IGO, TF	10	76
Panthera onca	IGO	2	96
Puma concolor	LAK	2	72
Nasua nasua	TF	38	148
Didelphis marsupialis	-	1	2
Cuniculus paca	AGR, IGO, ISL, LAK, AGR, TF, VAR	877	7021.05
Hydrochoerus hydrochaeris	TF	1	40
Dasyprocta fuliginosa	AGR, IGO, ISL, AGR, TF,	883	4175.1
Myoprocta pratti	AGR, ISL, TF	37	85
Sciurus igniventris	-	4	10
Dasypus sp.	AGR, IGO, ISL, AGR, TF	302	1697
Priodontes maximus	TF	5	153.3
Choloepus didactylus	TF	1	5
Pecari tajacu	AGR, IGO, ISL, LAK, AGR, TF, VAR	328	6437
Tayassu pecari	AGR, CHAV, ENSE, IGO, IGE, ISL, LAK, TF, VAR	2062	56910
Mazama sp.	AGR, IGO, ISL, TF,	51	1165.8
Tapirus terrestris	IGO, TF	51	6667.5
Raptiles			
Peltocephalus dumeriliana	IGO	25	294
Chelonoidis denticulata	ISL, TF	115	808.6
Tupinambis sp.	TF	1	1
Caiman crocodilus	RIV	3	72
Birds			
Penelope sp.	IGO, TF	11	11
Ara chloropterus	IGO, TF	15	15.5
Galbula sp.	-	4	0.4
Crax sp	IGO, TF, VAR	55	202.8
Psophia leucoptera	IGO, TF	19	18.6
Crypturellus sp.	TF	13	11.9
Aburria cujubi	IGO, TF	30	43.4
Other birds	IGE, TF, IGO, LAK, VAR, RIV	30	55.08
Total		**5136**	**88122.83**

Enrironment: CV: *Chavascal*, ENS: *Enseada*, IGO: *Igapó*, IGE: *Igarapé,* ISL: Island, LAK: Lake, RIV: River, AGR: Agriculture area, TF: *Terra Firme* forest, VAR: *Várzea*

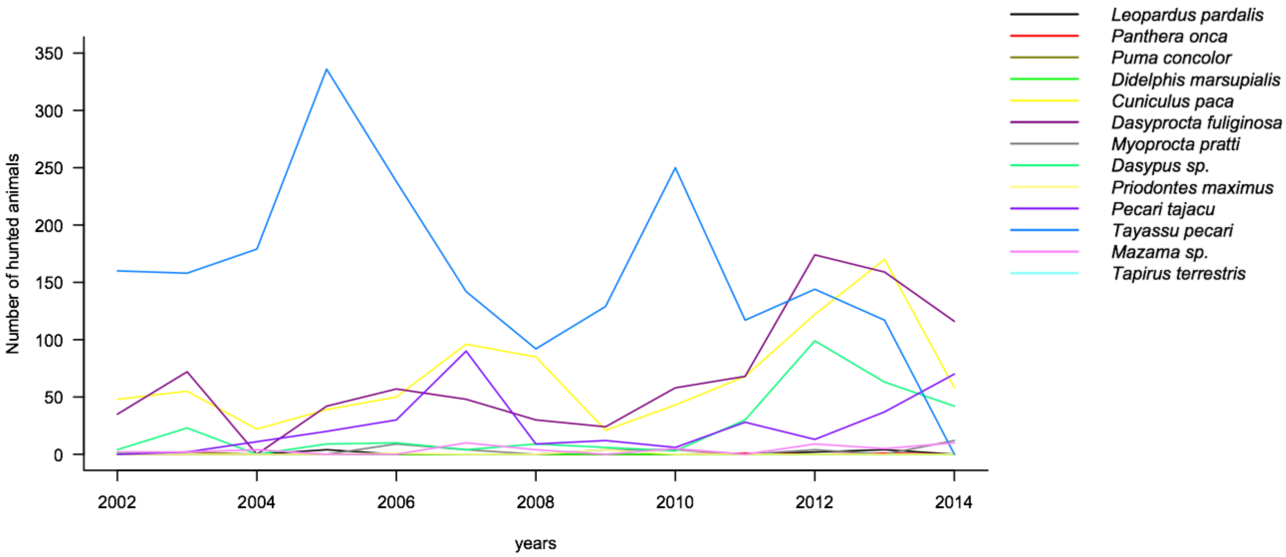

Figure 6: Number of mammal species hunted between 2002 and 2014 in Bom Jesus do Baré Community, Amanã Sustainable Development Reserve

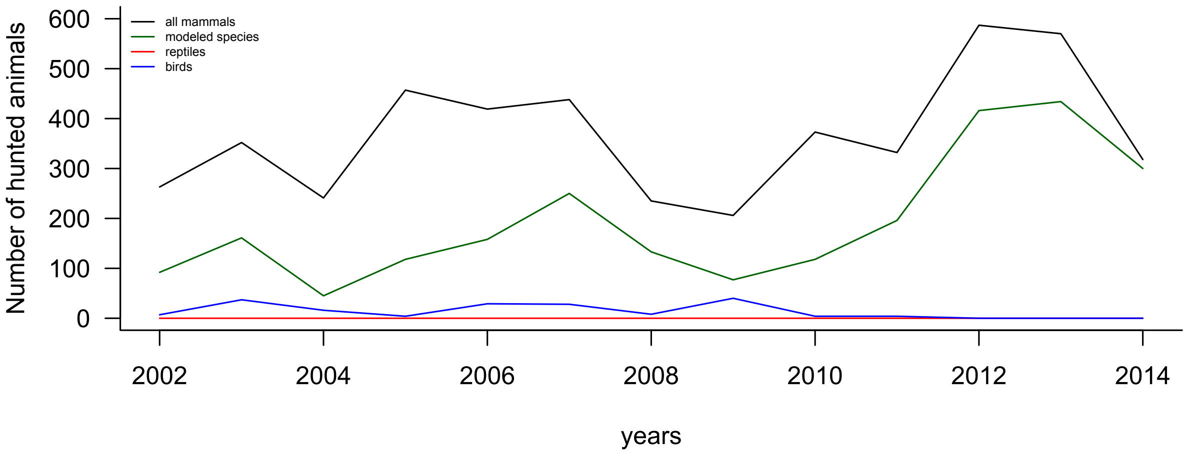

Figure 7: Number of group species hunted between 2002 and 2014 in Bom Jesus do Baré Community, Amanã Sustainable Development Reserve.

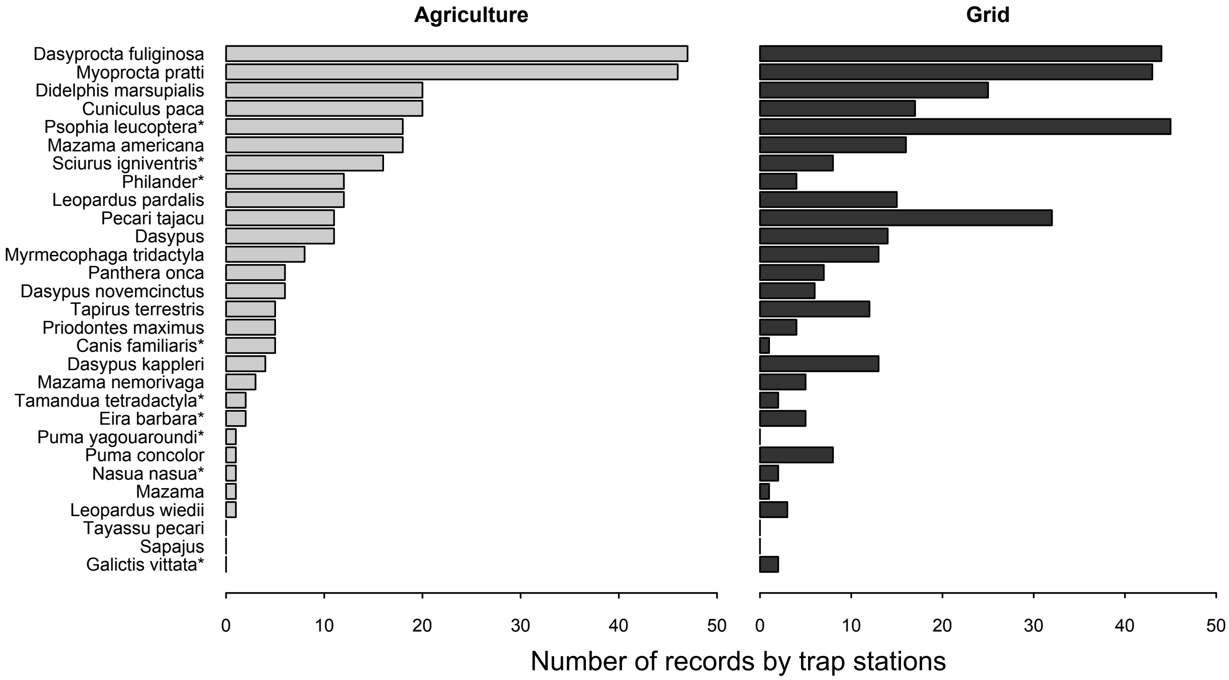

Figure 8: Patterns of observed occupancy for 29 vertebrate species found in our survey within 50 “grid” trap stations, all located in *terra firme* forests and in our 48 “agriculture” stations, all located in areas of direct interference of agriculture activity. Species or genus names are ordered top to bottom from the most to the least ubiquitous across agriculture sites.

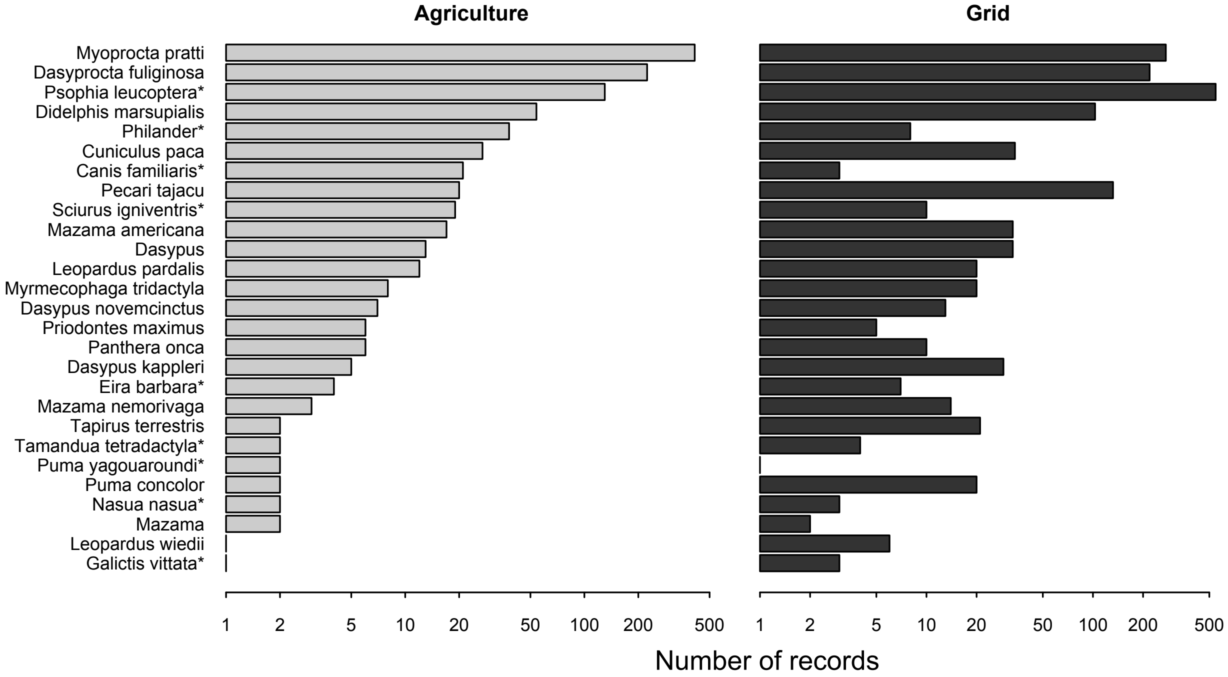

Figure 9: Number of records of 29 vertebrate species found in our survey within 50 “grid” trap stations, all located in *terra firme* forests and in our 48 “agriculture” stations, all located in areas of direct interference of agriculture activity. Species or genus names are ordered top to bottom from the most to the least ubiquitous across agriculture sites.

Table 2: Results of the occupancy models for sixteen species modelled, showing the best fitted models (AIC < 2)

Mammal Species	Estimated Occupancy (Ψ) (SE)	Detection Probability (p) (SE)	Best model			
			Model	AIC	ΔAIC	Weight
Myoprocta pratti			p (effort) Ψ (dist_agric)	1006.8	0.00	0.44
Dasyprocta fuliginosa			p (.) Ψ (dist_water)	1006.0	0.00	0.38
Cuniculus paca			p (.) Ψ (dist_agric + hunt_3y + dist_water)	412.2	0.00	0.94
Didelphis marsupialis			p (.) Ψ (dist_agric)	594.5	0.00	0.30
Dasypus kappleri			p (effort) Ψ (dist_agric + hunt_13y + dist_water)	253.8	0.00	0.44
Dasypus novemcinctus			p (.) Ψ (.)	170.3	0.00	0.22
Priodontes maximus			p (.) Ψ (.)	136.6	0.00	0.24
Myrmecophaga tridactyla			p (.) Ψ (.)	257.3	0.14	0.19
Mazama americana			p (.) Ψ (.)	357.4	0.00	0.18
Mazama nemorivaga			p (.) Ψ (hunt_13y)	127.0	0.00	0.22
Pecari tajacu			p (effort) Ψ (hunt_13y)	463.8	0.00	0.29
Tapirus terrestris			p (effort) Ψ (dist_agric + hunt_3y + dist_water)	204.2	0.00	0.47
Leopardus pardalis			p (.) Ψ (.)	290.3	1.31	0.09
Leopardus wiedii			p (effort) Ψ (prey)	53.4	0.00	0.30
Panthera onca			p (.) Ψ (.)	159.7	1.96	0.07
Puma concolor			p (effort) Ψ (hunt_13y)	142.6	0.00	0.15

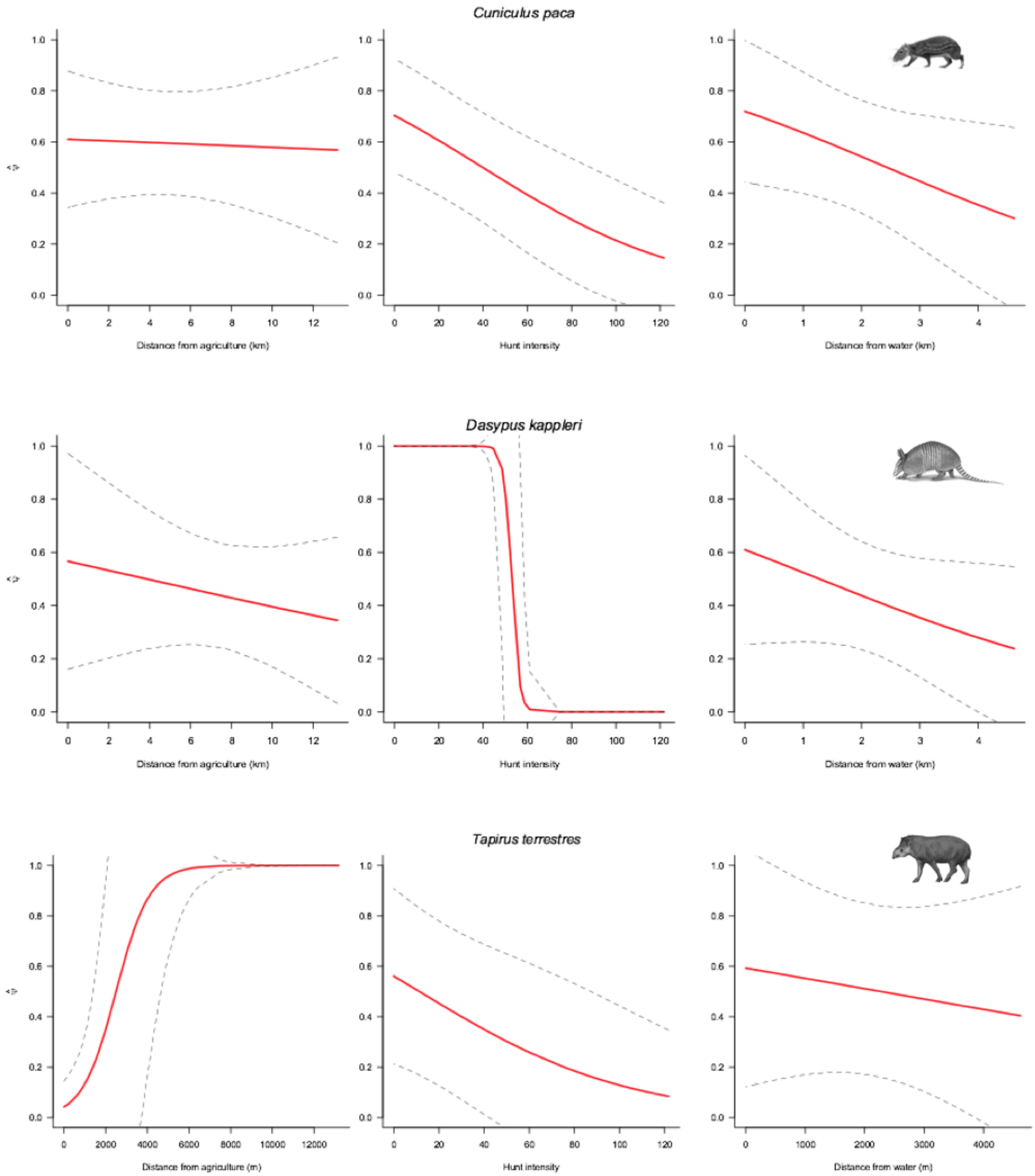

Figure 10: Occupancy probability of three mammal species modelled in our study as a function of the variables within best fitted models (see Material and Methods), predicted using logistic regression models based on estimated occupancy for each species.

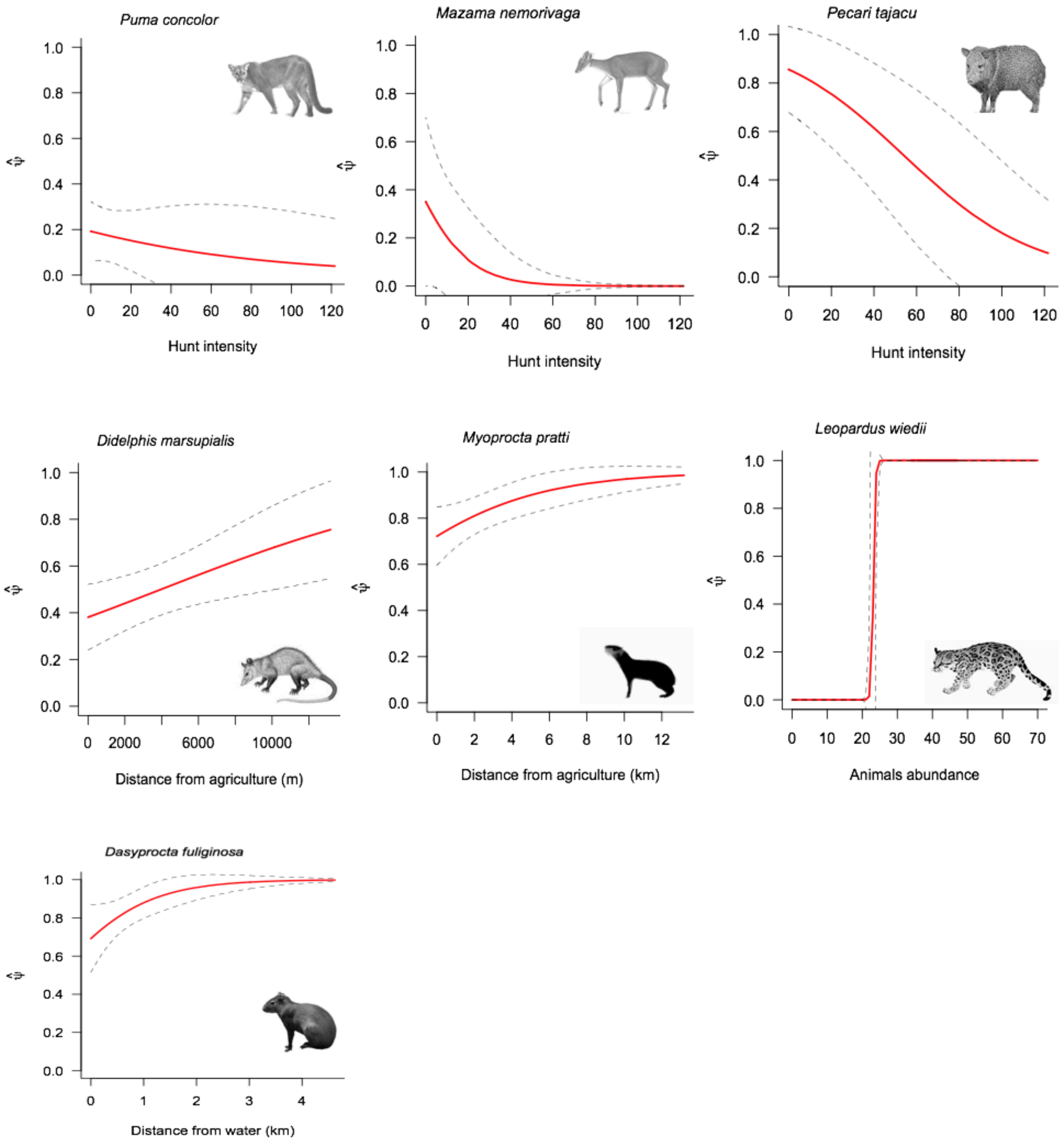

Figure 10 (continued): Occupancy probability of seven mammal species modelled in our study as a function of the variables within best fitted models (see Material and Methods), predicted using logistic regression models based on estimated occupancy for each species.

Capítulo II.

ILHA, R., RAMALHO, E.E., ROHE, F., ALVARENGA, G.C., GRABIN, D.M., ANTUNES, A., BACCARO, F.B. *Puma yagouaroundi* in the Amazon: Conservation challenges to preserve a rare species

Manuscrito submetido para Mammalian Biology

Puma yagouaroundi in the Amazon: Conservation challenges to preserve a rare species

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Abstract

Puma yagouaroundi is a mid-sized cat considered extinct in the USA, being nowadays distributed from northern Mexico to Central Argentina. Although its distribution covers the entire Amazon, large portions of this biome remain poorly sampled, making it difficult to determine if the species truly occupies the whole region. In this paper we present two new records of *P. yagouaroundi* in Central Amazon resulting from an effort of 18.560 trap nights. Our results corroborate assumptions of its natural low density, or at least its very low detection rates under currently available survey methods, and fill an important gap for the species occurrence in Amazon.

Keywords: Amazon, Camera-trap, Distribution, *Herpailurus yagouaroundi*, *Puma yagouaroundi*

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The jaguarundi *Puma yagouaroundi* (É. Geoffroy Saint-Hilaire, 1803) is a mid-sized cat that weighs 2-7 kg (Maffei et al., 2007; Jones et al., 2009) and feeds mainly on small mammals, birds, reptiles and invertebrates (Tófoli et al., 2009; Bianchi et al., 2011). Currently, the species is experiencing an great threat with agricultural and pastoral expansion throughout its area of occurrence and is classified as *Vulnerable* in the endangered species list of Brazil (MMA 2003), and as *Least Concern* by the Red List of Threatened Species of the IUCN (Caso et al. 2015). Major threats to the species are natural low population densities combined with fragmentation of natural ecosystems (Almeida et al. 2013).

P. yaguaroundi is considered extinct from the USA and today its geographic distribution extends from northern Mexico to central Argentina (Emmons 1997; Grigione et al. 2001; Grigione et al. 2007). Given this wide distribution is not surprising that *P. yagouaroundi* home range varies greatly among study sites, with males being able to occupy 17,6 km² in southern Brazil (Crawshaw 1995), 20 km² in southeastern Brazil (Michalski et al., 2006) and 88,3 km² in Belize (Konecny 1989). Moreover, the species has two different morphotypes for the whole range of occurrence (dark and reddish). In Brazil, the ancestral form (reddish) is restricted to southern and northeastern regions, with no records of the reddish form in Central Amazon (Silva 2014).

P. yagouaroundi is related with non-forest ecosystems (NFE), like savannas, but has a great distribution in Brazil, occurring in all biomes, from areas of grasslands (Corrêa et al. 2013), to more structured savannas (Bruna et al., 2010; Lyra-Jorge et al., 2008; Oliveira et al., 2009) and rainforests (Kasper et al. 2007; Melo et al., 2012; Michalski and Peres 2005; Santos and Oliveira 2012; Benchimol and Peres 2015). Those non-forest ecosystems, like the Brazilian's Cerrado and

Pampa, are the biomes that are suffering most from the lack of preservation (Overbeck et al., 2015), and has the largest proportion of area lost to the introduction of agriculture and livestock (Sano et al., 2010).

Because the lack of preservation of NFE, it comes up suggesting that large continuous Amazonian reserves could serve potentially as a refuge for the species, sustaining long-term viable populations of jaguarundis in the country (Caso et al., 2015). However, records of *P. yagouaroundi* in Amazon are rare, being restricted to *terra firme* forests. These uncertainties, caused by the very low detection rates of the species in Amazon, makes it difficult to determine the conservation status of the species in this biome.

Published photographic records of the species in Amazon come from Uatumã Biological Reserve (Benchimol & Peres, 2015), Urucu river basin, in the state of Amazonas (Santos and Oliveira 2012), and from fragmented forests in the Teles Pires river basin, at the border of Mato Grosso and Pará states (Michalski & Peres, 2005). The few records of the species may be due to the logistical challenges of surveying some Amazonian remote regions (Rocha et al., 2015), or to the fact that populations are naturally small, making the species difficult to observe (Michalski et al. 2006; Grigione et al. 2007; Maffei et al. 2007, Almeida et al. 2013).

Materials and methods

The records presented in this study are the result of five camera-trap surveys. The first survey with records of *P. yagouaroundi* was conducted in the interfluve of the Purus and Madeira Rivers between August 2011 and January 2012. The region is formed by a mosaic of vegetation types that ranges from upland *terra firme* forests, *igapó* flood forests, open lowland forests, *campinas* and *campinaranas* (white-sand forests) both composed of herbaceous vegetation on sandy soils. This survey was conducted under the area of influence of the BR-319 highway, which has 880 km long connecting the Amazonas State to Rondônia State. The area is covered by several State and Federal Protected Areas and Indigenous Reserves (Figure 11). The climate is tropical humid, with average temperatures around 27 °C and average annual rainfall of 2000-2400 mm (Schietti, 2013). In this survey we installed 96 camera-traps located 1 km distant from each other, distributed in six plots along 200 km from the central part of the highway (Figure 11). The survey covered an area of 96 km^2 in a sampling effort of 5.500 trap nights. In the period prior to the sampling that successfully captured an individual of *P. yagouaroundi*, we conduct a survey in the same area without records of the species. This sampling has occurred between October 2010 and January 2011, with 105 camera-traps disposed 500 meters distant from each other, totalizing a sampling effort of 4.506 trap nights.

The second survey that successfully recorded *P. yagouaroundi* was conducted in Amanã Sustainable Development Reserve (RDSA). RDSA covers an area of 2.350.000 ha in central Amazon between the Negro and Amazonas rivers. The reserve forms, with the Jaú National Park and the Mamirauá Sustainable Development Reserve, one of the largest continuous blocks of protected tropical forest in the world (Ayres et al. 2005; Rocha et al. 2015). RDSA is classified as an *Paleovárzea* area (Irion et al. 2010) and is formed by upland *terra firme* forests, *igapó* forests and *várzea* floodplain forests (Junk et al., 2012). The largest portion of the reserve is covered by *terra firme* forests, which represents 84% of the Reserve. The climate is tropical humid, with average temperature of 26°C and average annual rainfall of 2373 mm (Ayres, 1993).

For this survey we installed 111 trap stations between January and May 2015. 48 camera-traps were located on *slash-and-burn* agriculture areas with distance from 100 m to 1 km apart, 13 camera-traps located on *igapó* and *várzea* forests 1km to 1,5km apart and 50 pairs of camera traps in upland forests 2 km apart (Figure 12). The survey covered an area of 160 km² in a sampling effort of 3.690 trap nights. Before that survey, we had two consecutive camera trap surveys conducted in the same area with no records of *P. yagouaroundi*. These surveys were carried out from January to March 2013 and from December 2013 to April 2014 in a combined sampling effort of 4.894 camera traps nights (Rocha et al., 2015).

Results

We recorded two *Puma yagouaroundi* individuals (one individual in each sampled area). In the first survey the individual was photographed one kilometer from the BR-319 highway (4.452 S 61.064 W) in an open lowland forest (Figure 14). In the second survey, *P. yagouaroundi* was photographed in a *slash-and-burn* agriculture area located within a matrix of continuous *terra firme* forest (2.438 S 64.616 W), 50 meters from lake Amanã (Figure 15). Both individuals were captured in open forests, during the day (16:33 and 08:43 respectively), corroborating the diurnal habit of the species (Maffei et al. 2007; Di Bitetti et al. 2010; Almeida et al. 2013), and were melanic, which corroborates the distribution of dark phenotype pattern in forested areas (Emmons 1997, Silva 2014). In both survey areas we also recorded *Panthera onca*, *Puma concolor*, *Leopardus pardalis*, and *Leopardus wiedii*. Polling the results of both areas, all felid species were at least 20 times more frequently trapped than *Puma yagouaroudi.*

Discussion

P. yagouroundi has great habitat flexibility (Giordano, 2015; Michalski et al. 2006), being associated with abandoned agricultural fields and second-growth habitats in Belize (Konecny 1989), and also associated with active agricultural lands on heavily disturbed areas in southeastern Brazil (Magioli et al. 2013). Our record of *P. yagouaroundi* in active areas of family farming corroborate this hypothesis, suggesting that the species may be using resources associated with agricultural areas, or choosing open areas, even when inserted in a matrix of continuous forest.

As agriculture is one of the largest drivers of land conversion in Brazil (Azevedo-Ramos, 2013; Gollnow & Lakes, 2014), its important to better understand the relation of the species with different types of modified environments, such as small family fields and large areas of monoculture, that are likely to influence very differently in the species maintenance. However, given the naturally low density of *P. yagouaroundi*, determining the association of this species with agricultural or managed areas is challenging.

Small felids are known to have intra-guild interactions that significantly influence their spatial and/or temporal activities, with subordinate species being restricted to suboptimal habitats (Di Bitetti et al., 2010). Also, the dominant species can regulate the number of individuals of the subordinate species (Oliveira et al. 2010). Our low capture rates of *P. yaguaroundi* can be due to intra-guild competition with *Leopardus pardalis* and *Leopardus wiedii* as seen in other locations where the presence of *P. yagouaroundi* was related to the presence of these two species (Di Bitetti et al. 2010; Oliveira et al. 2010).

Our observations corroborate the knowledge that *P. yagouroundi* occurs throughout Amazon and at low densities (Almeida et al., 2013). The results reported here also fill an important gap of the species distribution in Central Amazon. The small number of records (two) after a combined effort of 18.590 trap nights highlights the importance of conducting long-term monitoring programs to understand the ecology of cryptic and low-density species in Amazon.

Although the Amazon is a great spot to preserve several species little preserved in other brazilian biomes, the few records of *P. yagouaroundi* in Amazon, all of the dark phenotype, brings out the importance of reviewing conservation and sustainable land use policies in overlooked biomes of Brazil. Its necessary to rethink the conservation strategy of non-forest ecosystems like grasslands and savannas in Brazil, not only to preserve this species, but to guarantee the genetic variability of the two phenotypes found in Brazil (dark and red). We also need to increase the efforts of research in the Amazon to deepen our understanding of the species conservation status in this biome.

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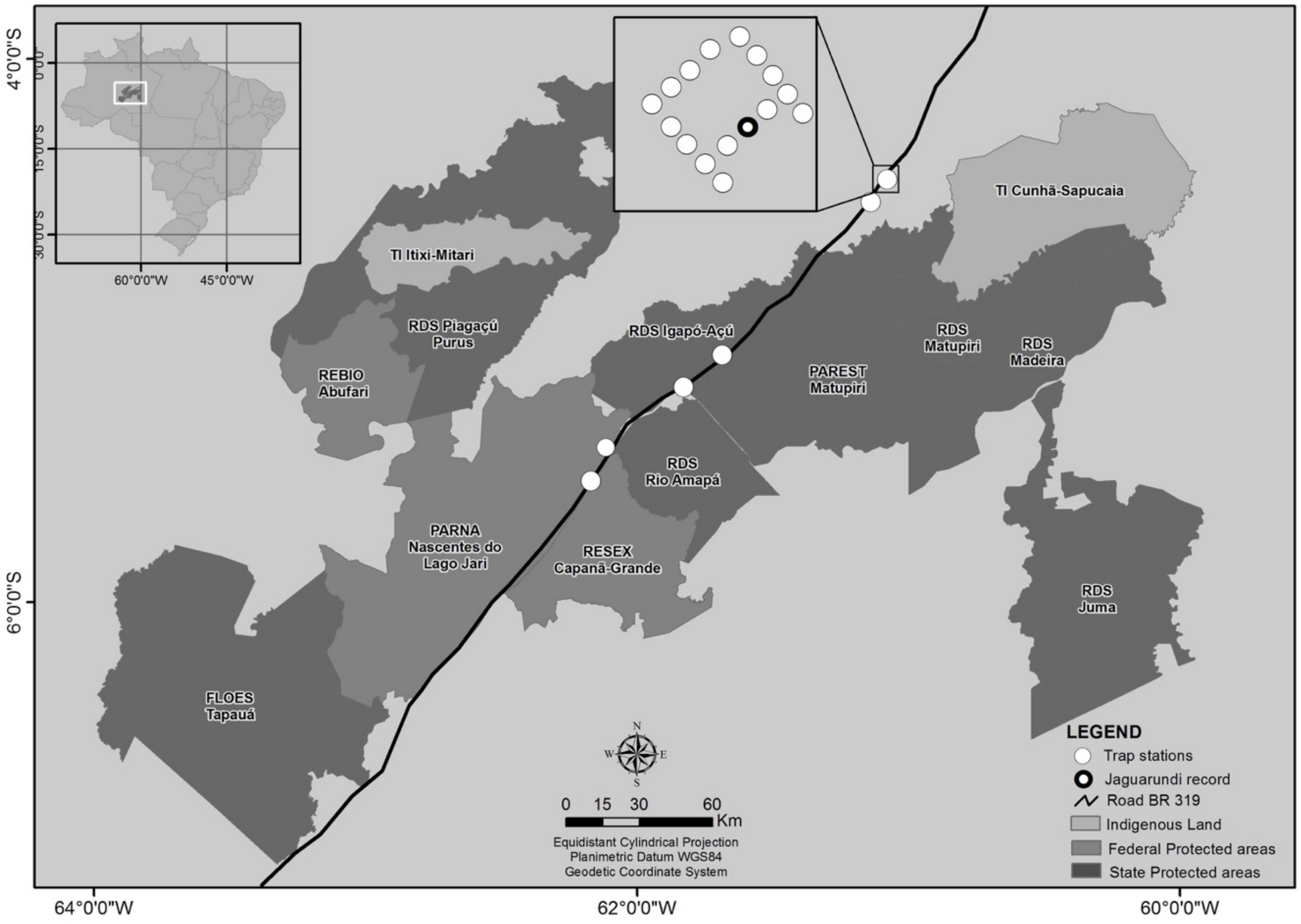

Figure 11: Design of the survey that successfully recorded *P. yagouaroundi* along the BR-319 highway in Purus and Madeira rivers interfluve. The six white dots along the highway are plots sampled with 16 camera-trap stations as shown in the inset. The black dot indicates location of *P*. *yagouaroundi* record.

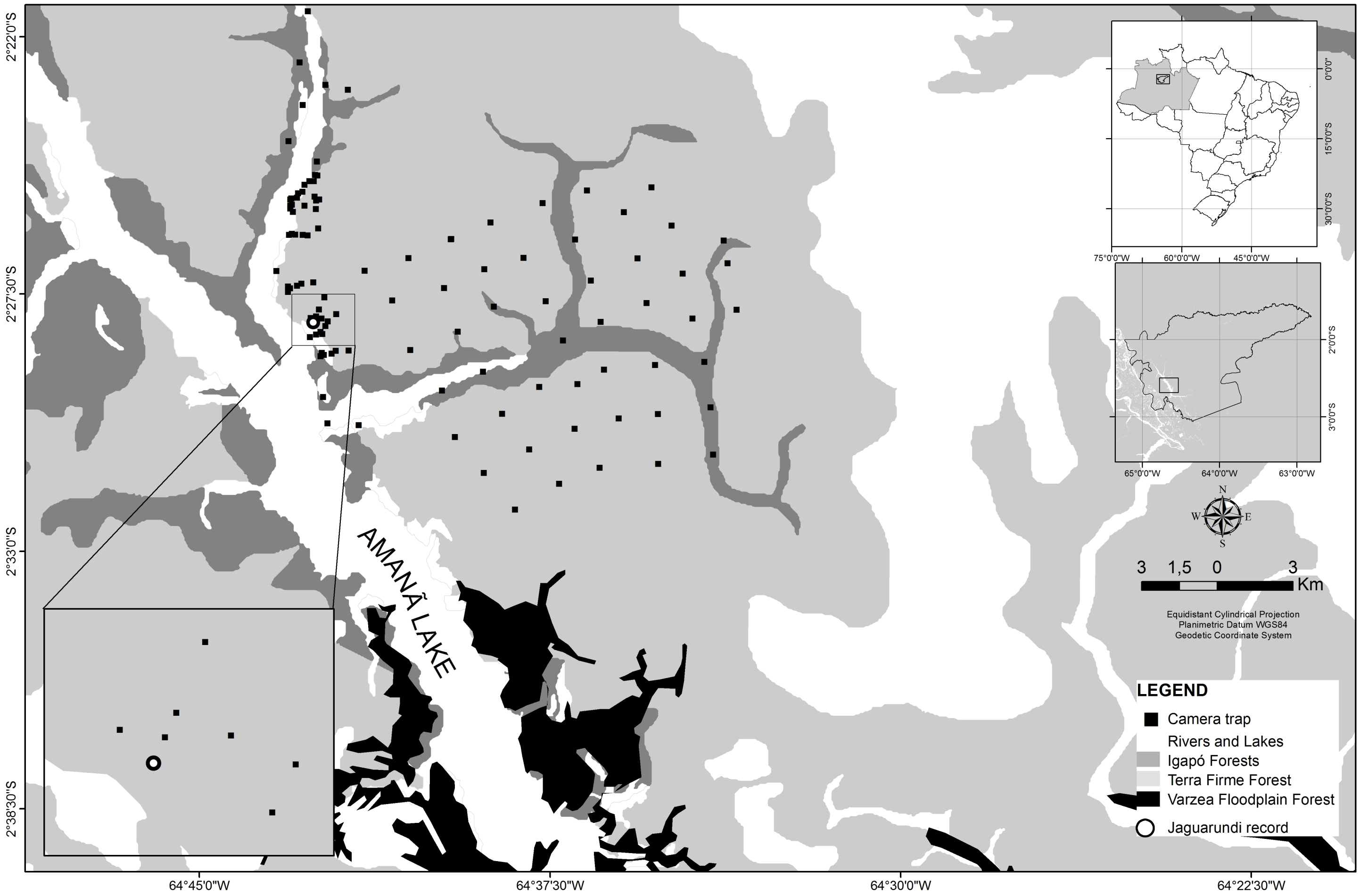

Figure 12: Design of the survey that successfully recorded *P. yagouaroundi* in Amanã Sustainable Development Reserve, between the Negro and Amazonas rivers, with 111 camera-trap stations and inset showing location of *P. yagouaroundi* record.

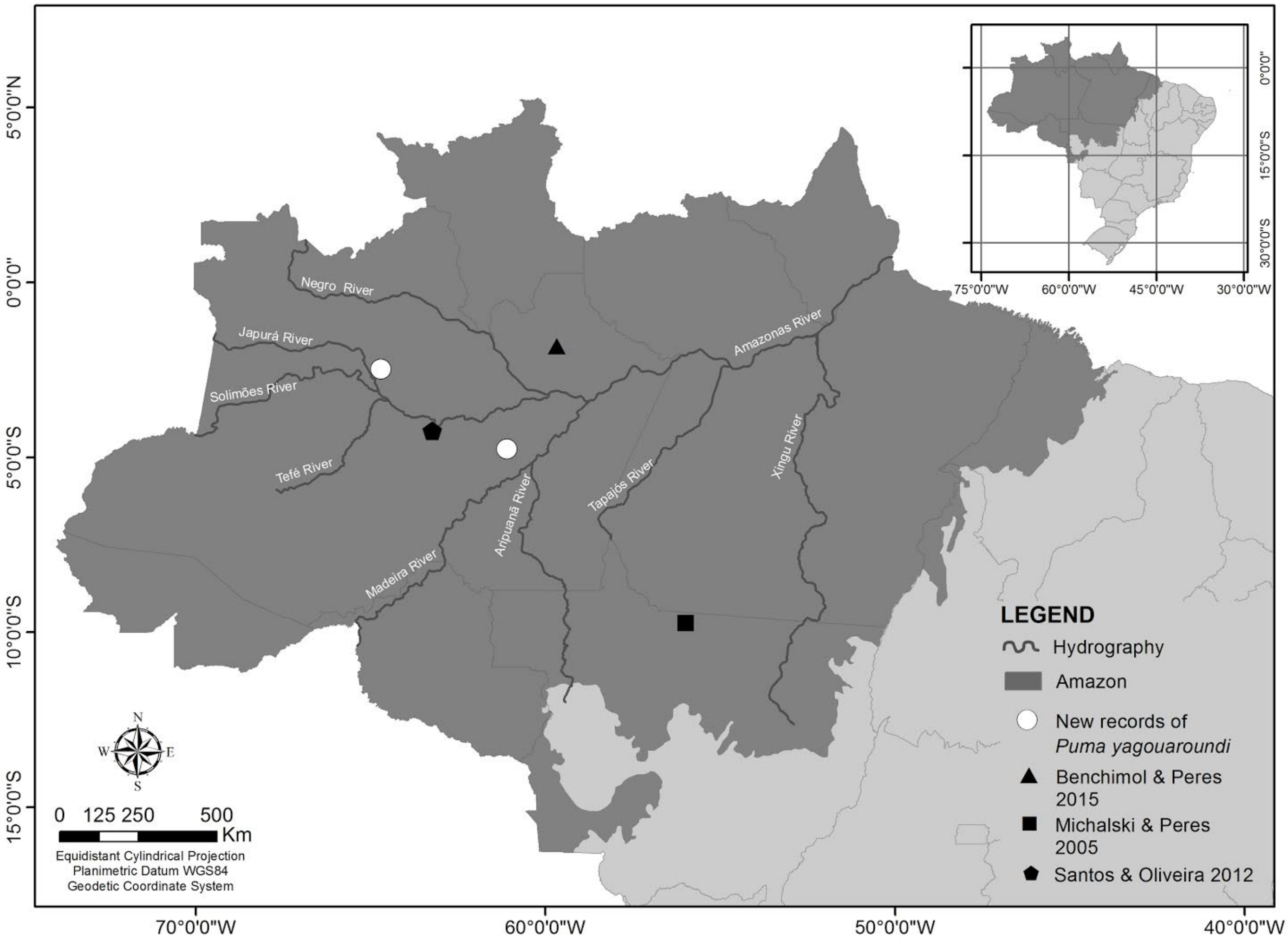

Figure 13: Published photographic records of *Puma yagouroundi* in the Brazilian portion of Amazon (black symbols) and two new records present in this paper (white dots).

Figure 14: *P. yagouaroundi* photographed in the BR-319 highway survey on an open lowland forest, in the interfluve of the Madeira river and the Purus river, central portion of Brazilian Amazon.

Figure 15: *P. yagouaroundi* photographed in a *slash-and-burn* agriculture area in Amanã Sustainable Development Reserve, central portion of Brazilian Amazon.

Conclusão Geral

No primeiro capítulo desta dissertação, nosso principal objetivo foi avaliar o efeito de atividades de subsistência (caça e agricultura) sobre espécies de mamíferos de médio e grande porte. O crescimento da área de agricultura mapeado em três comunidades tradicionais classificadas ao longo do lago Amanã nos últimos 22 anos indicam que a atividade, embora seja de subsistência, apresenta um elevado crescimento em termos de área plantada, o que provavelmente acompanha o crescimento populacional das comunidades. No entanto, somente cinco espécies, das quinze modeladas, apresentaram relação com a distância das áreas de agricultura, sendo duas delas espécies muito abundantes na área de estudo, e embora negativamente relacionadas à agricultura, são comumente encontradas em toda a área amostrada. Ainda, duas espécies cinegéticas possuem relação positiva com áreas de agricultura, sendo possivelmente relacionadas à estas áreas pela disponibilidade de recursos para alimentação. A atividade de agricultura no Amanã merece atenção para *Tapirus terrestris* (anta), uma espécie de ungulado que apresenta baixa taxa intrínseca de crescimento, baixa abundância e está negativamente relacionada à agricultura. É possível que *T. terrestris* esteja evitando áreas manejadas pela constante presença humana nestas áreas, além das demais atividades exercidas pelos moradores da comunidade, que frequentemente estão relacionadas às áreas de agricultura, como exploração de recursos não madeireiros e madeireiros. Tendo em vista o crescimento das áreas de agricultura na região de estudo nos últimos 22 anos, acredito que a atividade deva passar por um plano de manejo que delimite a extensão do seu crescimento, a fim de evitar que o crescimento das áreas manejadas exerça uma força importante de afugentamento da fauna acerca das comunidades. A caça, entretanto, parece atualmente já possuir maior efeito sobre as populações de mamíferos de médio e grande porte na Reserva de Desenvolvimento Sustentável Amanã, apesar de que nossa análise espaço-temporal indica que a atividade seja realizada de maneira mais estável do que a agricultura. Nossos resultados indicam que a atividade deva ser exercida com planejamento que inclua a participação dos caçadores, principalmente no que tange o número de indivíduos retirados de espécies com baixa taxa reprodutiva, como no caso da anta (*Tapirus terrestris*) e de espécies que comumente são caçadas em um número muito elevado de indivíduos, como no caso da queixada (*Tayassu pecari*), que atualmente são as espécies aparentemente mais afetadas pela caça realizada na comunidade Bom Jesus do Baré, na RDS Amanã.

Ainda, no segundo capítulo da dissertação, nós avaliamos o *status* de conservação de uma espécie rara de felino (*Puma yagouaroundi*) e ponderamos a possibilidade da Amazônia ser o bioma prioritário para a preservação de *P. yagouaroundi* no Brasil. Apesar de ser o bioma mais bem preservado do país, a Amazônia está provavelmente sub-amostrada para a espécie, o que nos limita avaliar sua efetiva participação na manutenção de populações viáveis do *P. yagouaroundi.* Ainda que seja efetiva, a espécie apresenta dois padrões principais de coloração, e a Amazônia registra apenas um padrão de coloração da espécie. A manutenção de biomas não florestais, como a Caatinga e o Pampa são de extrema importância para a manutenção da diversidade genética da espécie.

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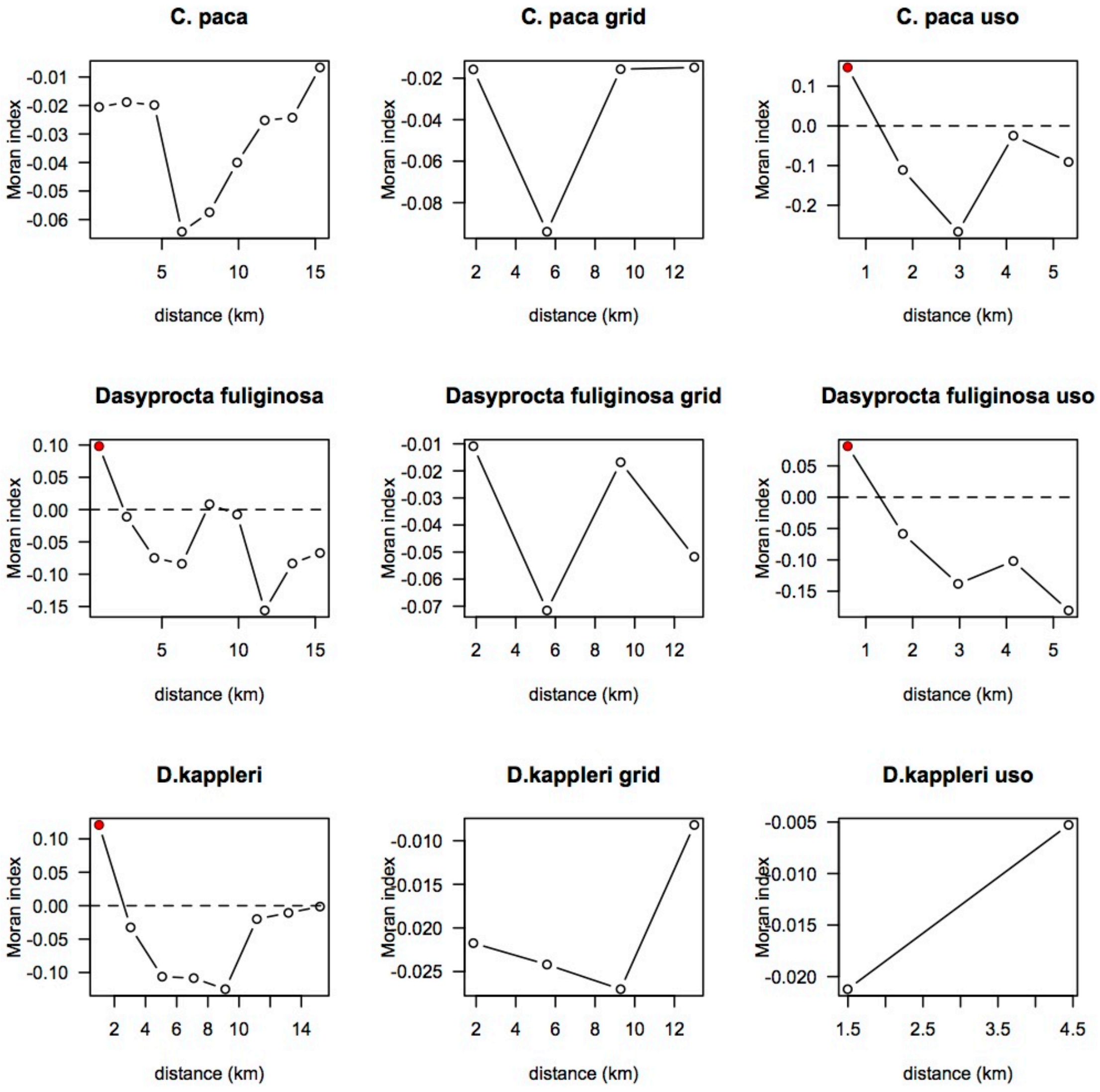
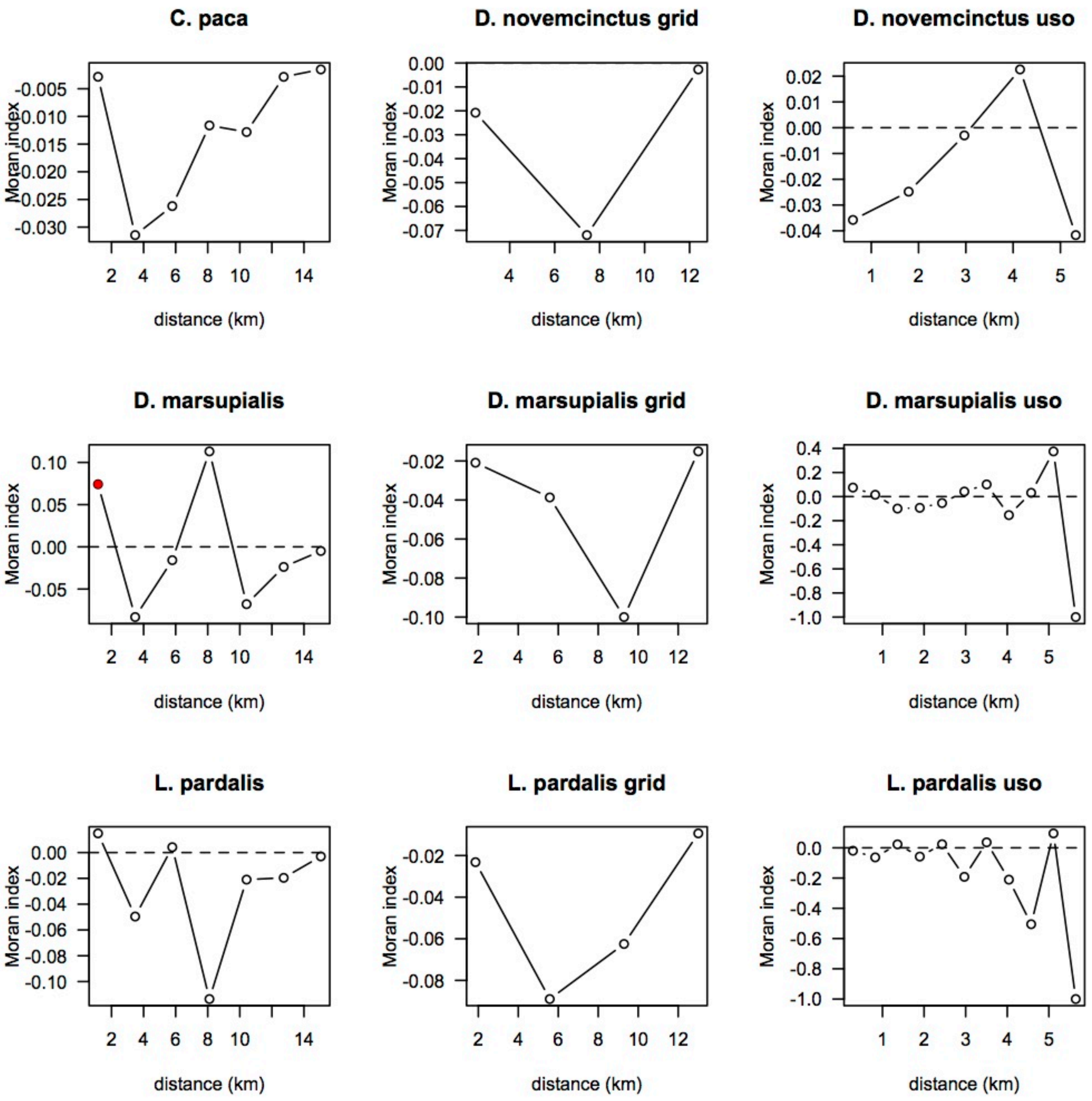
APÊNDICE 1
Material Suplementar do Manuscrito submetido para PlosOne (Capítulo I)

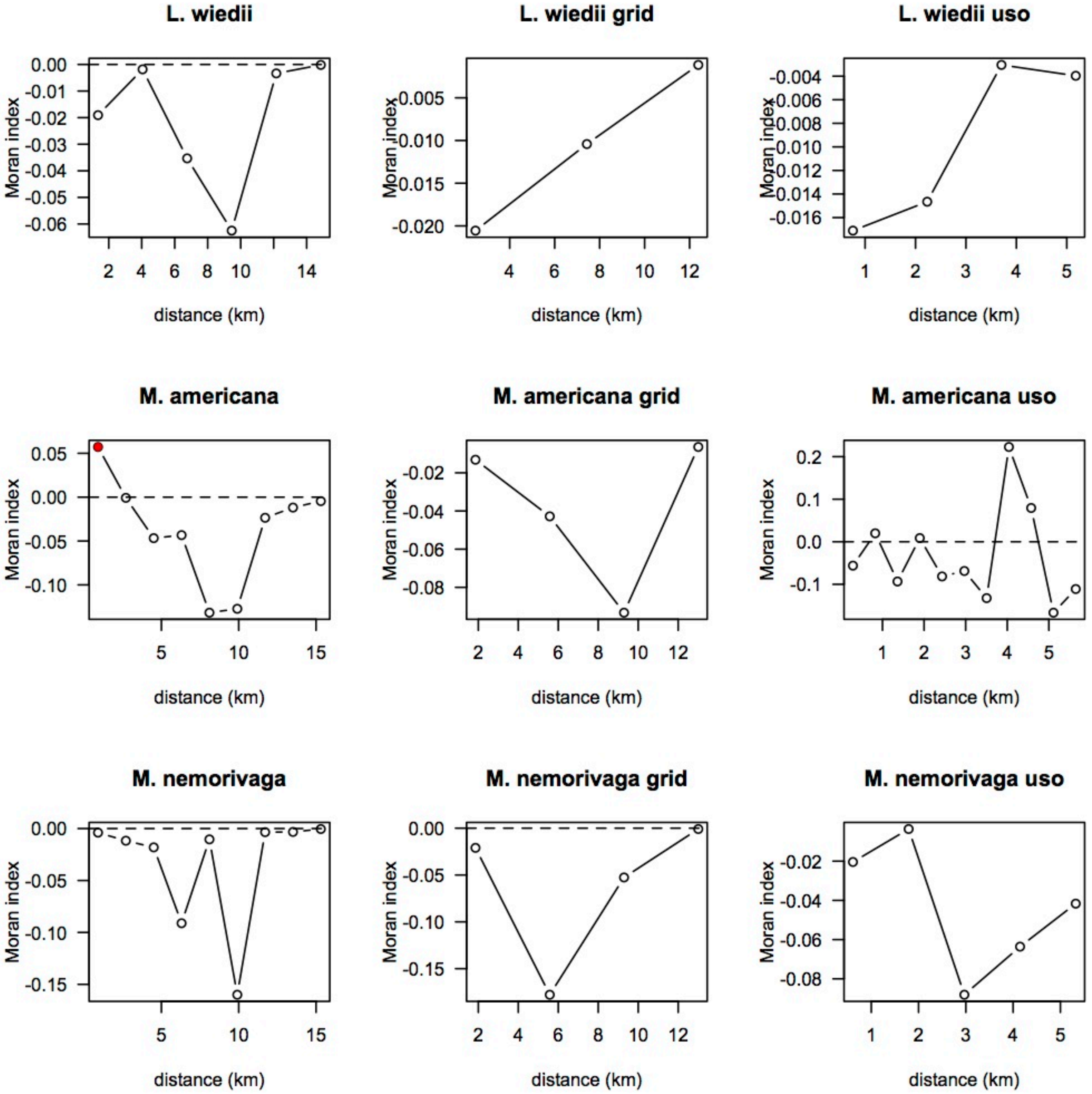
SUPPORTING INFORMATION

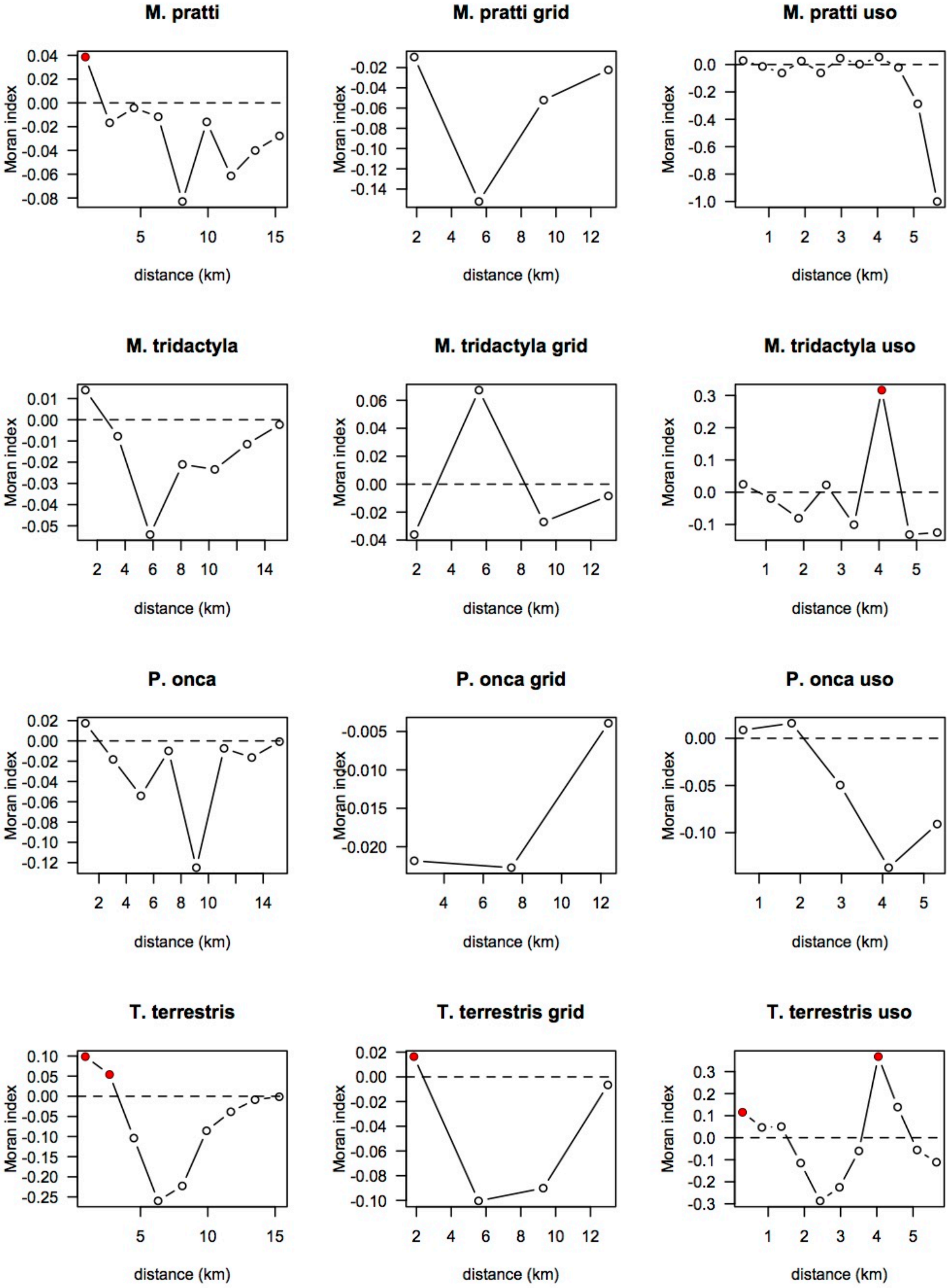
The impact of subsistence agriculture and hunting on mid and large sized terrestrial mammals in a Sustainable Development Reserve, Central Amazon.

Renata Ilha, Emiliano E. Ramalho, Priscila M. Pereira, Gonçalo Ferraz, João Valsecchi, Daniel G. Rocha, Fabrício B. Baccaro




C. paca
D. novemcinctus grid
D. novemcinctus uso
D. marsupialis
D. marsupialis grid
D. marsupialis uso
L. pardalis
L. pardalis grid
L. pardalis uso
Moran index
distance (km)
-0.005
-0.010
-0.015
-0.020
-0.025
-0.030
0.00
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
0.02
0.01
0.10
0.05
-0.05
-0.08
-0.10
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
1
2
3
4
5
6
8
10
12
14


L. wiedii
Moran index
0.00
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
2 4 6 8 10 14
distance (km)
L. wiedii grid
Moran index
-0.005
-0.010
-0.015
-0.020
4 6 8 10 12
distance (km)
L. wiedii uso
Moran index
-0.004
-0.006
-0.008
-0.010
-0.012
-0.014
-0.016
1 2 3 4 5
distance (km)
M. americana
Moran index
0.05
0.00
-0.05
-0.10
5 10 15
distance (km)
M. americana grid
Moran index
-0.02
-0.04
-0.06
-0.08
2 4 6 8 10 12
distance (km)
M. americana uso
Moran index
0.2
0.1
0.0
-0.1
1 2 3 4 5
distance (km)
M. nemorivaga
Moran index
0.00
-0.05
-0.10
-0.15
5 10 15
distance (km)
M. nemorivaga grid
Moran index
0.00
-0.05
-0.10
-0.15
2 4 6 8 10 12
distance (km)
M. nemorivaga uso
Moran index
-0.02
-0.04
-0.06
-0.08
1 2 3 4 5
distance (km)


M. pratti
Moran index
0.04
0.02
0.00
-0.02
-0.04
-0.06
-0.08
5
10
15
distance (km)
M. pratti grid
Moran index
-0.02
-0.04
-0.06
-0.08
-0.10
-0.12
-0.14
2
4
6
8
10
12
distance (km)
M. pratti uso
Moran index
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
1
2
3
4
5
distance (km)
M. tridactyla
Moran index
0.01
0.00
-0.01
-0.02
-0.03
-0.04
-0.05
2
4
6
8
10
14
distance (km)
M. tridactyla grid
Moran index
0.06
0.04
0.02
0.00
-0.02
-0.04
2
4
6
8
10
12
distance (km)
M. tridactyla uso
Moran index
0.3
0.2
0.1
0.0
-0.1
1
2
3
4
5
distance (km)
P. onca
Moran index
0.02
0.00
-0.02
-0.04
-0.06
-0.08
-0.10
-0.12
2
4
6
8
10
14
distance (km)
P. onca grid
Moran index
-0.005
-0.010
-0.015
-0.020
4
6
8
10
12
distance (km)
P. onca uso
Moran index
0.00
-0.05
-0.10
1
2
3
4
5
distance (km)
T. terrestris
Moran index
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
5
10
15
distance (km)
T. terrestris grid
Moran index
0.02
0.00
-0.02
-0.04
-0.06
-0.08
-0.10
2
4
6
8
10
12
distance (km)
T. terrestris uso
Moran index
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
1
2
3
4
5
distance (km)

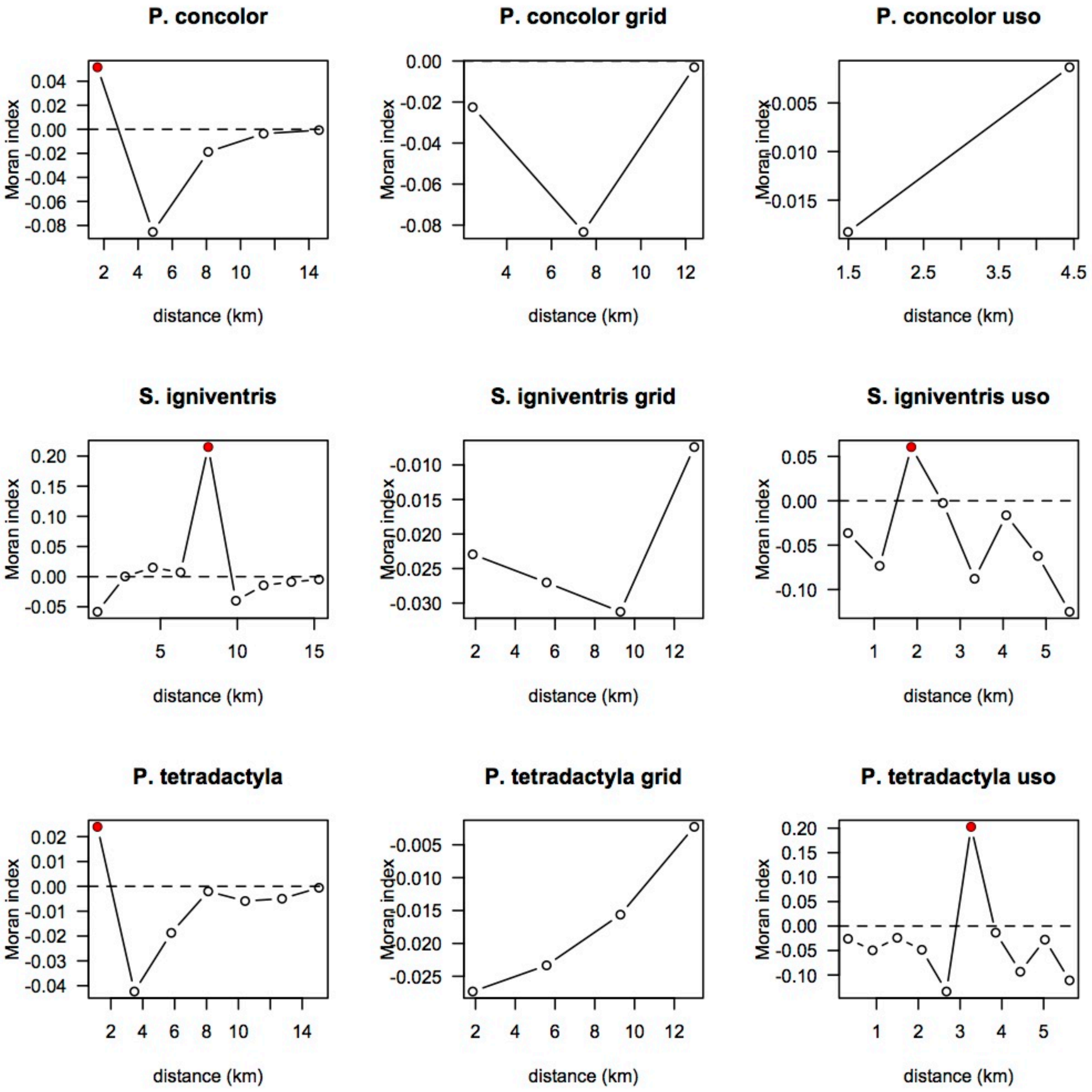


Figure S1.1. Correlation between trap stations using Moran index. The first correlation is between all trap stations, the second corresponds to the trap stations located in *terra firme* forests and the last corresponds to the agriculture stations. The trap stations that had a positive correlation is highlighted in red. Red dots represents a significative autocorrelation p<0,05.

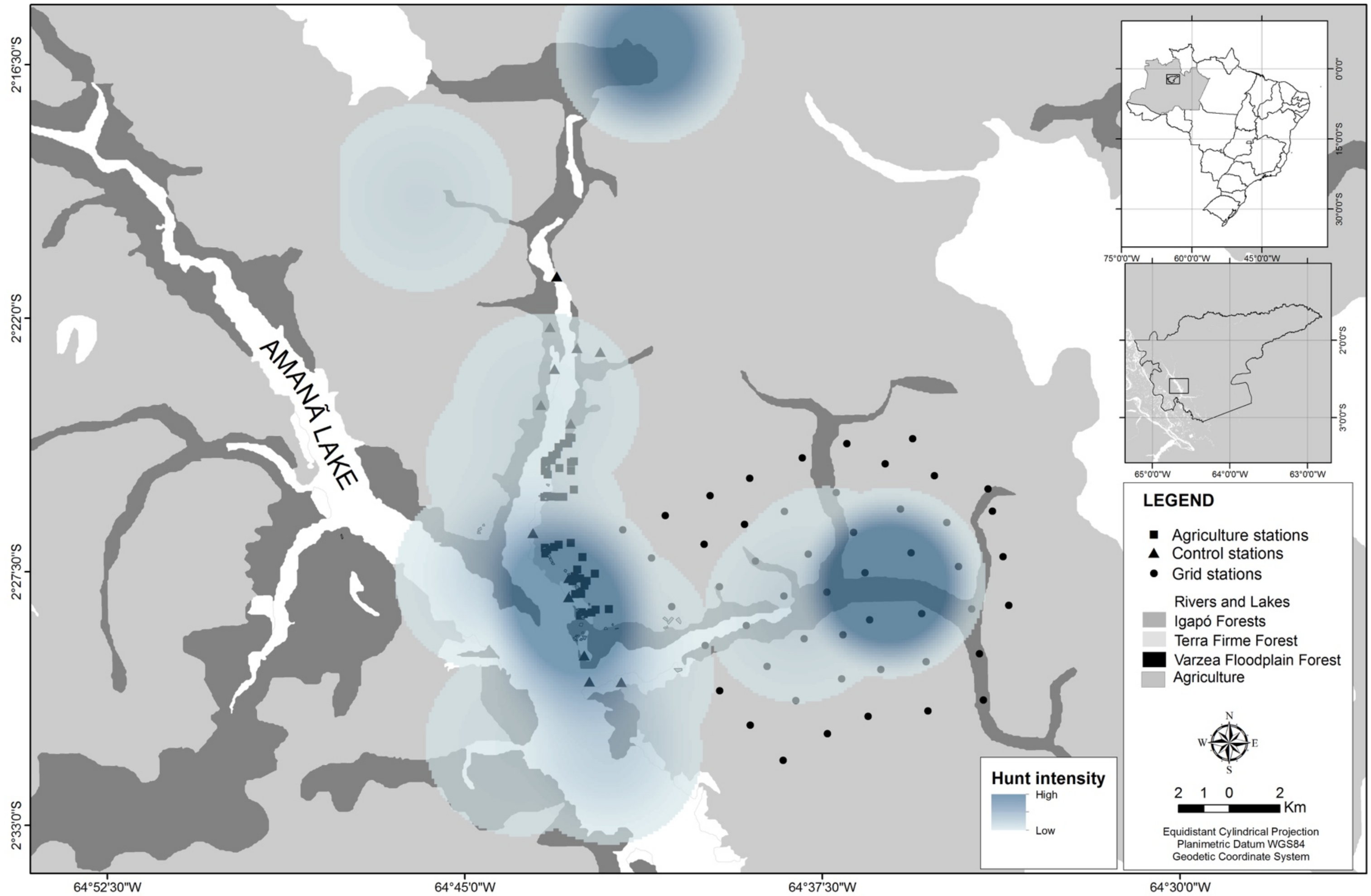


Figure S1.2 Hunt intensity model performed using 3 years of events of hunting from the Monitoring Hunt Program (SMUF) of the BJB Community.

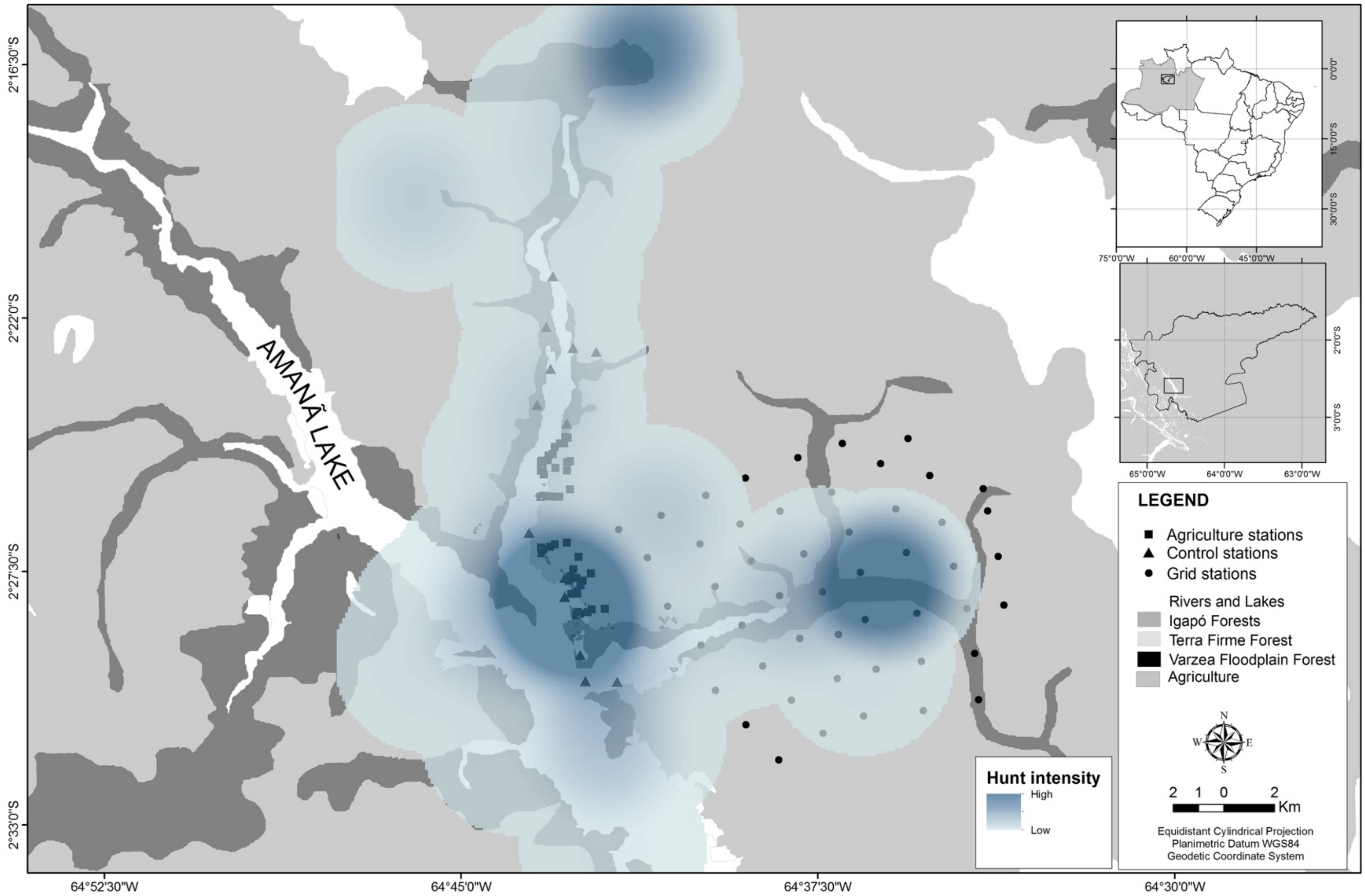


Figure S1.3 Hunt intensity model performed using 13 years of events of hunting from the Monitoring Hunt Program (SMUF) of the BJB Community.