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USO DE HABITAT E OCORRÊNCIA DE ROEDORES CAVIOMORFOS NA AMAZÔNIA CENTRAL, BRASIL

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Manaus, Amazonas
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Sinopse:

Estudei o uso de habitat e o efeito da distribuição de castanhais sobre a ocorrência de pacas, cotias e cutiaras na Reserva de Desenvolvimento Sustentável Piagaçu - Purus. Para isso distribuímos 107 câmeras-trap em locais com e sem exploração de castanha-do-Brasil. As variáveis ambientais, utilizadas como preditoras da ocorrência das espécies, foram medidas em campo ou extraídas de bases geográficas digitais. Os resultados indicam que as três espécies de roedores ocorrem preferencialmente em áreas com alta densidade de drenagem e distantes de comunidades humanas. Os castanhais têm efeito negativo principalmente na ocorrência de pacas.

Palavras chave: *Cuniculus paca*, *Dasyprocta fuliginosa*, extração de castanha-do-Brasil, floresta neotropical, *Myoprocta pratti*, Reserva de Desenvolvimento Sustentável

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RESUMO

A compreensão do uso de habitat de uma espécie traz informações sobre sua ecologia, distribuição espacial e dinâmica populacional, que podem ser utilizadas em planos de conservação e manejo de populações. Os roedores caviomorfos atuam como predadores e/ou dispersores de sementes, garantindo a manutenção e regeneração de comunidades biológicas. Apesar da importância ecológica desses roedores, existem lacunas de conhecimento sobre suas preferências de habitat e efeitos de atividades antrópicas sobre seus comportamentos. O presente estudo foi realizado na Reserva de Desenvolvimento Sustentável Piagaçu-Purus, onde é permitido o uso direto dos recursos naturais, como a exploração de castanha-do-Brasil. Os objetivos foram avaliar as probabilidades de ocorrência de paca (*Cuniculus paca*), cutia (*Dasyprocta fuliginosa*) e cutiara (*Myoprocta pratti*) em função de variáveis ambientais medidas em duas escalas espaciais, em áreas com e sem exploração de castanha-do-Brasil. Para isso distribuímos 107 câmeras-trap em locais com e sem exploração de castanha-do-Brasil. As variáveis ambientais, utilizadas como preditoras da ocorrência das espécies, foram medidas em campo ou extraídas de bases geográficas digitais. Os resultados mostram que a paca ocorre preferencialmente em locais com alta densidade de drenagem, distantes de comunidades humanas e onde não há exploração de castanha-do-Brasil. Cotia ocorreu preferencialmente em áreas distantes de comunidades humana e com sub-bosque pouco denso. Cutiara ocorreu preferencialmente em áreas de alta densidade de drenagem e sem exploração de castanha-do-Brasil. Estes resultados contribuem para uma maior compreensão da ecologia dessas espécies, sobretudo em áreas de desenvolvimento sustentável onde atividades antrópicas influenciam diretamente a ocorrência e comportamento da fauna.

Palavras chave: *Cuniculus paca; Dasyprocta fuliginosa*; extração de castanha-do-Brasil; floresta neotropical; *Myoprocta pratti*; Reserva de Desenvolvimento Sustentável.

ABSTRACT

Habitat use and occupancy of caviomorph rodents in Central Amazonia, Brazil

Understanding the habitat use of a species reveals details about its ecology, spatial distribution, and population dynamics that can be used in conservation and population management plans. Caviomorph rodents act as seed dispersers and seed predators, influencing the maintenance and regeneration of biological communities. Despite their importance, caviomorph habitat preferences are not well understood, including how anthropogenic activities may affect habitat use. We studied caviomorph habitat use in relation to extractivist activities at the Piagaçu-Purus Sustainable Development Reserve, a reserve managed for so that local communities may directly use natural resources, such as Brazil nuts. We evaluated the probability of occupancy of lowland paca (*Cuniculus paca*), black agouti (*Dasyprocta fuliginosa*), and green acouchi (*Myoprocta pratti*), in relation to environmental variables at two spatial scales, in areas with and without Brazil nut harvesting. We used camera trap data to estimate species occupancy and used environmental variables measured in the field and extracted from digital geographic databases as predictors of species occupancy. We found lowland paca occured most often in areas with high drainage density, far from human communities, and outside of Brazil nut extraction areas. Black agouti were most common in areas far from human settlements with an open forest understory. Green acouchi occured most frequently in areas with high drainage density, where no Brazil nut harvesting occurs. Our results contribute to a better understanding of the ecology of these species and bring subsidies for conservation, mainly in areas managed for sustainable use.

Key words: Brazil nut extraction; *Cuniculus paca*; *Dasyprocta fuliginosa*; *Myoprocta pratti*; Neotropical forest; sustainable development reserve.

SUMÁRIO

APRESENTAÇÃO

Informações sobre como os mamíferos utilizam o habitat são importantes para a compreensão da ecologia de cada espécie, sua distribuição espacial e sua dinâmica populacional (Gentile & Cerqueira 1995, Philips *et al*. 2004). Sendo assim, a identificação dos habitats preferenciais de cada espécie é fundamental para elaboração de planos de conservação e manejo de populações (Brooks & Eisenberg 1999, Fragoso *et al*. 2000, Garshelis 2000, Rushton *et al*. 2004, Desbiez *et al*. 2009). Entretanto, os fatores que determinam o uso do habitat são praticamente desconhecidos (Graipel *et al*. 2003, Graipel & Glock 2003) e a maioria dos dados presentes na literatura contemplam os carnívoros predadores de topo (Di Bitetti *et al*. 2006, Ramalho & Magnusson 2008, Lyra-Jorge *et al*. 2010, Sampaio *et al*., 2010, Davis *et al*. 2011, Sarmento *et al*. 2011).

Cada grupo animal se associa de diferentes formas às características estruturais do habitat (Downes *et al*. 1998, Tews *et al*. 2004), como densidade de palmeiras (Beck & Terborgh 2002), presença de cursos d`água (Goulart *et al*. 2009) e cobertura de dossel (Davis *et al*. 2011). Contudo, é importante que a escolha da escala espacial de observação seja apropriada, tendo em vista os atributos ecológicos específicos da espécie em questão (Robison *et al*. 2000, Brown *et al*. 2000, Lyra-Jorge *et al*. 2010). Por exemplo, espécies que se movimentam pouco e consequentemente possuem uma área de vida pequena, satisfazem seus requerimentos em um espaço menor que espécies que têm uma grande área de vida.

Os roedores caviomorfos paca (*Cuniculus paca*), cutia (*Dasyprocta* sp.) e cutiara (*Myoprocta* sp.) desempenham papel fundamental na guilda dos grandes frugívoros terrestres, atuando como predadores e/ou dispersores de sementes e garantindo a manutenção e regeneração de comunidades biológicas (Peres & Baider 1997, Dubost & Henry 2006, Salm 2006, Muller-Landau 2007). Cutias e cutiaras possuem comportamentos semelhantes e fazem esconderijos onde enterram frutos ou sementes, fenômeno conhecido como scatter-hoarding. Esse comportamento garante a dispersão de diversas espécies de frutos lenhosos, pois as sementes não consumidas têm chance de germinar (Forget 1990, 1996, Dubost & Henry 2006). Já a paca é incapaz de abrir alguns frutos de casca dura, mas consome pericarpos mais macios quando os frutos já foram abertos por outros animais (Pérez, 1992).

Apesar da importância ecológica dos roedores caviomorfos, existe uma lacuna de conhecimento a respeito de suas preferências de habitat e os efeitos de atividades antrópicas sobre seus comportamentos (Norris *et al*. 2010). Os estudos publicados contemplam temas como área de vida (Smythe 1978, Beck-King *et al*. 1999, Silvius & Fragoso 2003, Aliaga-Rossel 2004, Jorge & Peres 2005), dieta (Dubost 1988, Henry 1999, Asquith *et al*. 1999, Dubost & Henry 2006, Tuck Haugaasen *et al*. 2010, Galetti *et al*. 2010, Tuck Haugaasen *et al*. 2012), padrão de atividade (Smythe 1978, Dubost 1988, Norris *et al*. 2010, Michalski & Norris 2011) e comportamento (Morris 1962, Peréz 1992).

O presente estudo foi realizado em uma Reserva de Desenvolvimento Sustentável (RDS) na Amazônia Central brasileira. Esta categoria de área protegida tem a missão de conciliar o desenvolvimento de populações tradicionais com a conservação da biodiversidade, permitindo diferentes tipos e intensidades de manipulação humana (SNUC 2000). Dentre as diversas atividades extrativistas realizadas nessas áreas, a economia atrelada ao manejo da castanha-do-Brasil é uma das mais importantes, pois sua comercialização é uma importante fonte de renda para populações tradicionais como quilombolas, ribeirinhos e indígenas (Mori 1992, LaFleur 1992, Dominguez 1994, Broekhoven 1996, Peres *et al*. 2003, Scoles & Gribel 2011).

A castanheira (*Bertholletia excelsa*) é uma árvore de grande porte encontrada por toda a região amazônica e devido a sua super-exploração em determinadas regiões é classificada como uma espécie vulnerável (IUCN 2012). Já os castanhais são áreas de terra firme com alta agregação de castanheiras, encontradas em agrupamentos de 20 a 50 ha contendo de 50 a 300 indivíduos (Mori & Prance 1990, Peres *et al*. 2003),

Como a castanheira é uma Lecythidaceae com fruto indeiscente, sua dispersão natural depende da abertura do fruto por agentes externos. Os únicos agentes dispersores capazes de realizar esta tarefa são os roedores caviomorfos, que são apontados como indispensáveis para a manutenção da espécie em ambientes naturais (Peres & Baider 1997, Baider 2000, Peres *et al*. 2003, Tuck Haughaseen *et al*. 2010, 2012). Nesse contexto, é importante que estudos investiguem a ocorrência de roedores caviomorfos em áreas de exploração de castanha-do-Brasil, trazendo informações sobre como esta atividade pode afetar a ecologia destes animais.

Sendo assim, os objetivos deste estudo foram: (1) avaliar a relação dos roedores caviomorfos paca (*Cuniculus paca*), cutia (*Dasyprocta fuliginosa*) e cutiara (*Myoprocta pratti*) com variáveis ambientais em duas escalas espaciais na Reserva de Desenvolvimento Sustentável

Piagaçu Purus (RDS-PP) e, (2) estimar as probabilidades de ocorrência de paca, cutia e cutiara em áreas de extração de castanha-do-Brasil conjuntamente com variáveis ambientais.

OBJETIVO GERAL

Avaliar o uso do habitat e a ocorrência de três espécies de roedores caviomorfos na Reserva de Desenvolvimento Sustentável Piagaçu-Purus, Amazônia Central.

OBJETIVOS ESPECÍFICOS

(1) Avaliar a relação dos roedores caviomorfos paca (*Cuniculus paca*), cutia (*Dasyprocta fuliginosa*) e cutiara (*Myoprocta pratti*) com variáveis ambientais em duas escalas espaciais;

(2) Estimar as probabilidades de ocorrência de paca, cutia e cutiara em áreas de extração de castanha-do-Brasil conjuntamente com variáveis ambientais.

Capítulo 1

Meirelles, F.A., Pimenta, C., Haugaasen, T.. Mühlen, E., Venticinque, E.: Habitat Use and Occupancy of Caviomorph Rodents in Central Amazonia, Brazil, Manuscrito em preparação para *Biotropica*

Habitat Use and Occupancy of Caviomorph Rodents in Central Amazonia, Brazil

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Abstract

Understanding the habitat use of a species reveals details about its ecology, spatial distribution, and population dynamics that can be used in conservation and population management plans. Caviomorph rodents act as seed dispersers and seed predators, influencing the maintenance and regeneration of biological communities. Despite their importance, caviomorph habitat preferences are not well understood, including how anthropogenic activities may affect habitat use. We studied caviomorph habitat use in relation to extractivist activities at the Piagaçu-Purus Sustainable Development Reserve, a reserve managed for so that local communities may directly use natural resources, such as Brazil nuts. We evaluated the probability of occupancy of lowland paca (*Cuniculus paca*), black agouti (*Dasyprocta fuliginosa*), and green acouchi (*Myoprocta pratti*), in relation to environmental variables at two spatial scales, in areas with and without Brazil nut harvesting. We used camera trap data to estimate species occupancy and used environmental variables measured in the field and extracted from digital geographic databases as predictors of species occupancy. We found lowland paca occured most often in areas with high drainage density, far from human communities, and outside of Brazil nut extraction areas. Black agouti were most common in areas far from human settlements with an open forest understory. Green acouchi occured most frequently in areas with high drainage density, where no Brazil nut harvesting occurs. Our results contribute to a better understanding of the ecology of these species and bring subsidies for conservation, mainly in areas managed for sustainable use.

Key words: Brazil nut extraction; *Cuniculus paca*; *Dasyprocta fuliginosa*; *Myoprocta pratti*; Neotropical forest; sustainable development reserve.

INFORMATION ABOUT HOW MAMMALS USE THEIR HABITAT IS IMPORTANT TO THE understanding of species' ecologies, their spatial distribution, and population dynamics (Gentile & Cerqueira 1995, Philips *et al*. 2004). Therefore, identification of the preferred habitat of each species is fundamental for the creation of effective conservation programs and plans to manage populations (Brooks & Eisenberg 1999, Fragoso *et al*. 2000, Garshelis 2000, Rushton *et al*. 2004, Desbiez *et al*. 2009). Factors that determine habitat use are practically unknown for some Neotropical forest species (Graipel *et al*. 2003, Graipel & Glock 2003) and the majority of data presented in the literature deals with top carnivores (Di Bitetti *et al*. 2006, Ramalho & Magnusson 2008, Lyra-Jorge *et al*. 2010, Sampaio *et al*., 2010, Davis *et al*. 2011, Sarmento *et al*. 2011).

Each group of animal associates differently with structural characteristics of habitat (Downes *et al*. 1998, Tews *et al*. 2004), such as density of palms (Beck & Terborgh 2002), presence of watercourses (Goulart *et al*. 2009), and canopy cover (Davis *et al*. 2011). It is important to choose the appropriate spatial scale at which to make observations, considering the specific ecological attributes of the species in question (Robison *et al*. 2000, Brown *et al*. 2000, Lyra-Jorge *et al*. 2010). Species with small home ranges that only move very short distances across the landscape can satisfy their requirements in a smaller area than species that move widely across the landscape and have large home ranges, and data collection on habitat use should reflect those differences.

Caviomorph rodents lowland paca (*Cuniculus paca*), agouti (*Dasyprocta* spp.), and acouchi (*Myoprocta* spp.) play a fundamental role in the terrestrial frugivore guild. In their role as seed dispersers, as well as seed predators, they influence the maintenance and regeneration of biological communities (Peres & Baider 1997, Dubost & Henry 2006, Salm 2006, Muller-Landau 2007). Agoutis and acouchis exhibit behavior similar to one another, scatter-hoarding fruits and seeds, creating hidden stashes where they bury collected fruits and seeds. This behavior assures the dispersion of a diverse set of species, especially those with woody endocarps, as seeds that remain unconsumed in the hoard have a chance at germinating (Forget 1990, 1996, Dubost & Henry 2006). Pacas are unable to open some hard-shelled fruits, but consume fruits with softer pericarps, as well as woody fruits that have already been opened by other animals (Pérez 1992).

Despite their ecological importance, gaps exist in the understanding of caviomorph habitat use and effects of human activities on their behavior (Norris *et al*. 2010). Published

work includes studies on home range area (Smythe 1978, Beck-King *et al*. 1999, Silvius & Fragoso 2003, Aliaga-Rossel 2004, Jorge & Peres 2005), diet (Dubost 1988, Henry 1999, Asquith *et al*. 1999, Dubost & Henry 2006, Galetti *et al*. 2010, Tuck Haugaasen *et al*. 2010, Tuck Haugaasen *et al*. 2012), activity pattern (Smythe 1978, Dubost 1988, Norris *et al*. 2010, Michalski & Norris 2011), and behavior (Morris 1962, Peréz 1992).

Our study took place in a Sustainable Development Reserve (SDR) in the central Brazilian Amazon. This is a formal category of protection, designated and monitored by the federal government, with the mission to conciliate use of natural resources by traditional populations with the conservation of biodiversity, permitting different types and intensities of human manipulation of the landscape and its resources (MMA 2000). Among the diverse extractive activities carried out in these areas, Brazil nut extraction is one of the most important economic activities; its commercialization is an important source of income for traditional populations, such as *quilombolas*, *ribeirinhos* (river peoples), and indigenous peoples (Mori 1990, LaFleur 1992, Broekhoven 1996, Peres *et al*. 2003, Scoles & Gribel 2011).

The Brazil nut tree (*Bertholletia excelsa*) is a large tree found across the Amazon region and, due to its super-exploitation, in some regions it is classified as a vulnerable species (IUCN 2012). A *castanhal* is an area of *terra firme* forest where aggregations of Brazil nut trees are found, often covering 20-50 ha and holding 50-300 individual trees (Mori & Prance 1990, Peres *et al*. 2003). Brazil nuts are in the family Lecythidaceae and have indehiscent fruits, so that their dispersal depends upon an external agent opening the fruit. The only agents available to do this are caviomorph rodents, making them indispensable for the maintenance of this species in natural environments (Peres & Baider 1997, Baider 2000, Peres *et al*. 2003, Tuck Haughaseen *et al*. 2010, 2012). Given the interdependence of Brazil nut trees and caviomorphs, it is important that studies investigate the occupancy of caviomorph rodents in areas where Brazil nut extraction activities take place, to evaluate how these activities may affect caviomorph ecology.

The objectives of our study were to: (1) evaluate the relationship between the occupancy of the caviomorph rodents lowland paca (*Cuniculus paca*), black agouti (*Dasyprocta fuliginosa*), and green acouchi (*Myoprocta pratti*) and environmental variables at two spatial scales in the Piagaçu-Purus Sustainable Development Reserve (PP-SDR), and (2) estimate and compare probabilities of occupancy of lowland paca, black agouti, and green

acouchi in areas where Brazil nut extractivist activities take place and in areas not subject to extractivist activities.

METHODS

STUDY AREA.—This study took place in the Piagaçu-Purus Sustainable Development Reserve (PP-SDR, 4°05'–5°35' S and 61°73'–63°35'W) in the central Brazilian Amazon, lower Purus River region, Amazonas state (Fig. 1). The reserve is 834,245 ha, with the Terra Vermelha (6,928 ha) and the Itixi-Mitari Indigenous Reserves (180,850 ha) within its borders (Instituto Piagaçu 2010) and the Abufari Biological Reserve (288,000 ha) along its southern border.

The dominant vegetation is Dense Alluvial Forest with areas of *terra firme* forest (that do not flood) and flooded forest (that remain innundated for a large part of the year). The high water mark is usually reached at the end of June and the lowest water level occurs at the beginning of November (Haugaasen & Peres 2006). Mean annual precipitation is 2,644 mm, with a February-June rainy season and a July-October dry season (Haugaasen & Peres 2006).

There are approximately 4,000 individuals distributed in 57 communities within or near the PP-SDR limit (Instituto Piagaçu 2010). These community members depend upon a traditional economy, strongly linked to the seasonal variation in water levels (Instituto Piagaçu 2010). Brazil nut extraction is a very important activity for the families that occupy *terra firme* areas, as it supplies an important complement to their income (Bentes 2007). Brazil nut collection generally occurs between December and May (Tuck Haugaasen *et al*. 2010). The extractivists manage areas of *castanhal*, clearing vines and vegetation from the area beneath the Brazil nut trees, as well as eliminating termites and other competitive species (Bentes 2007).

Due to the large area and environmental and social heterogeneity, PP-SDR is divided into seven management sectors. This study took place in the sectors Uauaçu (205,630 ha) and Ayapuá (80,977 ha) in the northern region of PP-SDR.

DATA COLLECTION.—We used camera traps to sample our study area twice during the high water season, which is also the season of Brazil nut collection. The first sampling period occurred from 6 March-6 May 2011, in the Ayapuá sector and the second from 9 May-13 June 2011, in the Uauaçu sector. In total, we sampled twelve 4-km trails in each sector. Each trail was at least 4 km away from any other trail, so that the sampling area covered

approximately 1,380 km² (Fig. 1C). The majority of trails were rectilinear and ran perpendicular to the principal watercourses to facilitate access and increase distance between trails. In some cases, trails to deviate slightly from their route in order to avoid watercourses. Of the 24 trails sampled, ten were classified as running through areas of *castanhal*, due to the high abundance of Brazil nut trees and their use for the annual collection of Brazil nuts by members of nearby communities.

We used Cuddeback® Capture Digital (Non Typical, Wisconsin, USA) camera traps, installed along the trails, positioned approximately 30 cm above soil level (Srbek-Araujo & Chiarello 2005). Cameras were programmed to record the time and date of each photograph taken in intervals of 5 minutes between each shot taken, remaining continually active. Each trail had five camera traps installed, spaced every kilometer, for a total of 120 camera traps (Fig. 1c).

ENVIRONMENTAL VARIABLES.—We measured variables that may be associated with caviomorph rodent occupancy in the field between June and November 2011 and collected data from digital geographic databases for each sampling point using ArcGis 9.2 (Environmental Systems Research Institute, California, 2006). These variables were obtained at two distinct spatial scales: at the scale of the sampling point (approximately 50 ha), corresponding to the point where each camera trap was installed and at the local scale (approximately 1,100 ha), corresponding to each trail. We chose these scales because the study species vary in their home range size, body mass, and other ecological characteristics, which could affect the scale of response to environmental variables. We chose environmental variables we thought may play a role in predicting species occupancy based on published natural history studies that provided information on the ecology of each study species (Smythe 1978, Beck-King *et al*. 1999, Silvius & Fragoso 2003).

At the sampling point scale we used six environmental variables to predict species occupancy: (1) Drainage density. Using remotely sensed images, we created a 400-m buffer around each camera trap site, covering about 50 ha, and used a hydrographic map produced by Brazil's Protection System of the Amazon and the Brazilian Institute of Geography and Statistics (SIPAM/IBGE) at a scale of 1:250,000 to calculate linear meters of stream/ha. (2) Distance to community. We used remotely sensed images to calculate the shortest linear distance between the camera trap and the closest human community. The Piagaçu Institute

furnished the locations of the communities. (3) Elevation. In ArcGIS, we used the extract tool to collect elevation data from an SRTM (Shuttle Radar Topography Mission) image. (4 and 5) Understory density from 0-50 cm and understory density from 100-200 cm above soil level. We used the point intercept method to obtain these data (Canfield 1941). Two 50-m tape measures were laid parallel to the trail and 5 m from each camera trap, running in opposite directions from the camera trap. Every two meters, we placed a pole upright through the vegetation and counted the number of contacts with the pole between 0 and 50 cm above soil level and also between 100 and 200 cm above soil level. We calculated the mean number of vegetation contacts for each camera trap point. (6) *Castanhal*. This was a binary variable, a point was classified as a *castanhal* if it had a high density of *Bertolettia excelsa* and was used for Brazil nut extraction by community members (Mori & Prance 1990). A point was classified as non-*castanhal* if there were no stands of *B. excelsa* or extractivist activities in the area.

At the local scale, we used six environmental variables to predict the occupancy of caviomorph rodents: (1) Drainage density. Using remotely sensed images, we created a 1-km buffer around each trail, covering approximately 1,100 ha, and calculated linear meters of stream/ha. (2) Distance from access. We obtained this variable from remotely sensed images and measuring the distance from the nearest community to the trail entrance, if one was to travel by river or stream. For these two variables, we used the hydrographic database developed by SIPAM/IBGE at a 1:250,000 scale. (3) Elevation. We used the zonal statistics tool in ArcGIS to estimate the mean elevation of the area of a 1-km buffer around the trail. (4 and 5) Understory density from 0-50 cm and understory density from 100-200 cm above soil level. We used the means obtained from the five values collected at the sampling point scale. (6) *Castanhal.* A trail was classified as running through a *castanhal* if the trail had a high concentration of *Bertolettia excelsa* and was used for Brazil nut extractivist activities by community members; otherwise, trails were classified as non-*castanhal*.

Continuous variables were normalized and a Pearson correlation test with Bonferroni correction was applied in R (Development Core Team 2010). Significantly correlated variables were not analyzed in the same species occupancy models. These variables were drainage density and elevation at the local scale.

OCCUPANCY AND DETECTION ESTIMATION.—To determine which variables had the largest effect on the occupancy of species, we constructed two hierarchical models with imperfect probability of detection (MacKenzie *et al*. 2002). The models were based on the detection history of each species at each sampling point (Linkie *et al*. 2007, 2008, Abad-Franch *et al*. 2010). At the sampling point scale, the sampling unit was the camera trap (n=107), while at the local scale, the sampling unit was the trail (n=24). The 94 camera trap sampling days were divided into 5-day-long sampling occasions to increase the probability of detection of species in each temporal sampling unit.

To construct models for each species, we entered the detection history for each sampling point into the software PRESENCE 4.1 (Proteus Wildlife Research Consultans, New Zealand), together with the environmental predictor variables. We used single-season occupancy models, since we assumed that occupancy did not vary during the sampling period (MacKenzie *et al*. 2006), to estimate probability of occupancy (Ψ, probability that a species occurred at a specific sampling point) and detection (p, probability of detection of the species conditioned upon its occupancy).

First, we constructed a null model, in which probabilities of occupancy and detection were maintained constant ($\Psi(.)\ p(.)$). Posteriorly, we constructed models with logical combinations of variables that represented biological hypotheses that may explain species occupancy (Burnham & Anderson 2002).

We used Akaike's Information Criterion (AIC) to rank models by maximum likelihood, a process that favors models that correspond best to the data collected (Burnham & Anderson 2002, Rushton *et al*. 2004, Symonds & Moussalli 2011). Models with $\Delta AIC \leq 2$ were considered parsimonious, while models with $\Delta AIC > 2$ were considered imprecise representations of the collected data (Burnham & Anderson 2002). After the selection of the best models, we determined if the 95% confidence intervals of coefficients examined exceeded zero, for which the importance of each variable was analyzed in more detail (Burnham & Anderson 2002).

The sum of the ranks of the models (w) ranked in each analysis was equal to one, so that w can be used as an adjustment probability of a specific model to the data. The relative importance of each variable for each species was obtained by summing the AIC(w) of all the models in which the variables appeared (Doherty *et al*. 2010, Sarmento *et al*. 2011, Symonds & Moussalli 2011).

RESULTS

Of the 120 camera traps installed, 13 were defective and their data discarded. We analyzed camera trap data from 53 cameras in Ayapuá sector and 54 in Uauaçu sector, for a total of 107 traps. Sampling effort was 3,743 traps*day—2,189 traps*day in Ayapuá and 1,554 traps*day in Uauaçu. We obtained 334 photographic records of caviomorph rodents, with black agouti the most common species recorded (Table 1).

Lowland paca.—We analyzed nine models at the sampling point scale and nine at the local scale. At the sampling point scale, species occupancy was positively influenced by drainage density and distance to human communities. Being in an area of *castanhal* had a negative effect on this species' occupancy (Fig. S1). Drainage density was present in all models with $\Delta AIC<2$ and explained 76 percent of the data, so that it was the best predictor of species occupancy (Table 5). Occupancy of lowland paca varied when comparing areas of *castanhal* to areas not within *castanhal* (Fig. 2). Its probability of occupancy was greatest in areas of non-*castanhal*, with high drainage density and distant from communities (Fig. S2). At the local scale, drainage density was also the most explicative variable, appearing in three of the most parsimonious models and explaining 49 percent of the data obtained, followed by understory density between 100-200 cm and distance to access (Tables 3 and 4), all variables positively influenced the occupancy of the species.

Black agouti.—We analyzed nine models at the sampling point scale and six at the local scale. At the sampling point scale, the most parsimonious model was the null, $\Psi(.)\ p(.)$, followed by the other models that encompass all variables tested (Table 2). At the local scale, distance to access had a positive effect on species occupancy and occurred in the two of the most parsimonious models, explaining 46 percent of the data obtained, followed by a negative effect of understory density between 100-200 cm with a weight of 18 percent (Table 3 and 4).

Green acouchi.—We analyzed eight models at the sampling point scale and seven at the local scale. At the sampling point scale, three models were most parsimonious and explained 51 percent of the data (Table 2 and 4). Drainage density was the best predictor and positively affected species occupancy, followed by the negative effect of *castanhal.* At the local scale, the best model was the null, $\Psi(.)\ p(.)$, suggesting that species occupancy is independent of the variables measured at this scale. Coefficients obtained in the following models showed confidence intervals with values exceeding zero.

DISCUSSION

Lowland paca occurs most frequently in areas without *castanhal*, with a high density of drainages, far from human communities, and with a dense understory at 100-200 cm above soil level. It is the most hunted rodent in PP-SDR (Terra 2007) and areas of *castanhal* is often used for this hunting. During the Brazil nut management season, many extractivists equipped with shotguns travel by river in canoes to arrive at the *castanhal* before sunrise. This behavior facilitates spotting and opportunistically hunting lowland pacas, a species frequently encountered along river banks (Eisenberg & Redford 1999). It is also known that game species tend to decrease in abundance closer to human habitations, where hunting activities are concentrated (Robson & Bennett 2000, Sirén *et al.* 2004, Peres & Nascimento 2006). Many studies have shown that the lowland paca has a strong association with watercourses and with areas of dense vegetation, likely using these habitat characteristics to avoid predation (Pérez 1992, Trolle & Kéry 2005, Sabatini & Paranhos da Costa 2006, Goulart *et al.* 2009).

Black agoutis are characterized as generalists and possess a high behavioral plasticity. They can be found in a large variety of habitats in wet and dry Neotropical forests and can even occur in forest fragments (Jorge 2008). These characteristics may explain the fact that black agoutis were recorded at 53.27 percent of the sampling points and the null model best predicted their occupancy at the local scale, indicating that their occupancy was not related with the environmental variables measured at this scale. At the local scale, black agoutis were found most frequently in areas distant to access by human communities with a less dense understory at 100-200 cm above soil level. The black agouti is the second most hunted rodent in PP-SDR (Terra 2007), which may explain its greater probability of occupancy in areas difficult to access by local communities (Robson & Bennett 2000, Peres & Lake 2003). Our results on the understory characteristics corroborate previous studies showing that this species avoids areas with dense vegetation close to the ground, opting for locations where visibility is better, like forests with tall trees and low understory density (Smythe 1978, Dubost 1988, Silvius & Fragoso 2003).

Despite black agoutis being frugivorous, consuming fruits and seeds that have fallen to the forest floor and being the principal dispersal agents of seeds with woody endocarps (Forget 1990, 1996, Peres & Baider 1997, Asquith 1999, Wright *et al*. 2001, Dubost & Henry 2006), inclusive *B. excelsa* (Peres & Baider 1997, Jorge & Peres 2005, Tuck Haugaasen *et al*.

2010, 2012), their occupancy was not different between areas of *castanhal* and areas of non-*castanhal*. Jorge and Peres (2005), in a study in the eastern Amazon, showed that density of black agoutis was greater in areas of *castanhal.* However, the areas of *castanhal* they used were not experiencing extractivist activities during their study and likely had high *B. excelsa* fruit availability. Other previous studies have shown that there is a low availability of Brazil nuts for rodents to consume in areas with intensive extractive activities and in these areas black agoutis alter their behavior to consume more Brazil nuts and scatter-hoard less (Forget 1996, Zudeima & Boot 2002).

The occupancy of green acouchis was not explained by the variables examined at the local scale. At the sampling point scale, the species occurred most often in areas with high drainage density, outside of *castanhal.* Previous studies affirm that green acouchis prefer areas with high drainage density and are generally absent from anthropogenically influenced environments, mainly inhabiting mature forests (Dubost 1988, Jorge 2008). These characteristics may explain the low occupancy of green acouchis in areas of *castanhal,* since these areas are often used for hunting and suffer disturbance throughout the year, as extractivists clean trails and eliminate potential competitive vegetation in order to guarantee Brazil nut tree productivity (Bentes 2007) and to facilitate visualization of fruits fallen to the ground. This management makes it so that in areas of *castanhal,* large trees of *B. excelsa* dominate, to the exclusion of other food resources. Previous studies have noted that green acouchis are not often recorded using trails (Dubost 1988, Jorge 2008), so the fact that camera traps were installed near or on trails may have made this species more difficult to detect during our study.

Overall, in PP-SDR the lowland paca, black agouti, and green acouchi had higher probabilities of occupancy in areas with high drainage density, far from human habitation. These results can help indicate priority zones for the conservation of these species (Sirén *et al*. 2004, Ohl-Schacherer *et al*. 2007). In the Amazon, the zoning of sustainable development reserves is an important management tool. This type of zoning may be effective in achieving the concurrent objectives of socioeconomic development of local communities and conservation of biodiversity (Nepstad *et al*. 2006, Ohl-Schacherer *et al*. 2007).

Since medium and large rodents have important impacts on ecosystem structure, their conservation implies the maintenance of diverse ecological processes, like seed dispersal, herbviory, and seed predation (Wright *et al*. 2001, Muller-Landau 2007, Jorge & Howe 2009).

In areas where there is no human intervention, caviomorph rodents, principally black agoutis, are the only species capable of opening Brazil nut fruits (Peres & Baider 1997, Tuck Haugaseen *et al*. 2010), because of this they are indispensable for the maintenance of *B. excelsa* populations in natural areas.

The collection of Brazil nuts is usually accompanied by subsistence hunting (Rumiz & Maglianesi 2001, Zudeima 2002, Tuck Haugaasen *et al*. 2010) and the results of our study show that the occupancy of lowland pacas, black agoutis, and green acouchis are negatively affected by the presence of areas of *castanhal.* Although our camera trap data was collected at the end of the Brazil nut tree's fruiting season and all areas of *castanhal* sampled were under exploitation, it is possible that the behavioral plasticity of these species contributed to their persistence in these anthropogenically altered areas (Norris *et al*. 2010). Since the commercialization of Brazil nuts is one of the principal sources of incomes for millions of families in Amazônia (Clay 1997, Stoian 2004) and we found extractivist activities to influence caviomorph occupancy, it is important that future studies of mammalian habitat use also examine areas of *castanhal* and evaluate the effects of extractivist activities on mammal populations.

Our results also may contribute to future monitoring projects in PP-SDR. The estimates of occupancy we obtained can be used to evaluate the status of caviomorph rodent populations and inform management decisions for different areas of the reserve. Managers and local communities can use these data to establish zones of protection, use, and rules for use, especially in areas of *castanhal.*

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TABLES

Table 1. Number of photographs, percent occuppied camera trap stations, percent occuppied sites (at sampling point and local scales), and frequency of capture (records for 1000 traps*day) of three species of caviomorph rodents in the Piagaçu-Purus Sustainable Development Reserve, central Amazon, Brazil.

Species	Number of photos	Percent occupied sites		Frequency of capture
		Sampling point	Local	
Lowland paca	97	25.23	66.67	25.91
Black agouti	220	53.27	95.83	58.78
Green acouchi	17	6.54	25.00	4.54

Table 2. Model selection and estimation of probability of occurrence (Ψ) of three species of caviomorph rodents with environmental variables obtained at the sampling point and local scales in the Piagaçu-Purus Sustainable Development Reserve, central Amazon, Brazil. Only models with ΔAIC<2 are shown. -2Log (L): two times the negative value of the log maximum likelihood, ΔAIC: difference between the AIC values of each model and of the best model, K: number of parameters, *w*: model weight.

Species	Models	-2Log (L)	K	ΔAIC	*w*
	Ψ(drainage dens.[a] + community dist.[b])				
Lowland paca	*p*(.)	369.13	4	0.00	0.38
	Ψ (drainage dens.) *p*(.)	370.21	3	1.08	0.22
	Ψ (drainage dens. + *castanhal*) *p*(.)	370.44	4	1.31	0.20
Black agouti	Ψ (.) *p*(.)	692.48	2	0.00	0.21
	Ψ (drainage dens.) *p*(.)	690.94	3	0.46	0.17
	Ψ (drainage dens. + elevation) *p*(.)	689.53	4	1.05	0.12
	Ψ (community dist.) *p*(.)	691.90	3	1.42	0.10
	Ψ (veg. dens. 100-200 [c]) *p*(.)	692.03	3	1.55	0.10
	Ψ (elevation) *p*(.)	692.27	3	1.79	0.09
	Ψ (veg. dens. 0-50[d]) *p*(.)	692.28	3	1.80	0.08
	Ψ (*castanhal*) *p*(.)	692.40	3	1.92	0.08
Green acouchi	Ψ (drainage dens.) *p*(.)	105.96	3	0.00	0.29
	Ψ (.) *p*(.)	108.83	2	0.87	0.19
	Ψ (drainage dens. + *castanhal*) *p*(.)	105.73	4	1.77	0.12

[a] *drainage dens. = drainage density.*

[b] *community dist. = distance to nearest human community.*

[c] *veg. dens. 100-200 = understory vegetation density between 100-200 cm above soil level.*

[d] *veg. dens. 0-50 = understory vegetation density between 0-50 cm above soil level.*

Table 3. Model selection and estimation of probability of occurrence (Ψ) three species of caviomorph rodents with environmental variables obtained at the local scale in the Piagaçu-Purus Sustainable Development Reserve, central Amazon, Brazil. Only models with ΔAIC<2 are shown. -2Log (L): two times the negative value of the log maximum likelihood, ΔAIC: difference between the AIC values of each model and of the best model, K: number of parameters, *w*: model weight.

Species	Models	-2Log (L)	K	Δ AIC	*w*
Lowland paca	Ψ(drainage dens.[a] + veg. dens. 100-200[b]) p(.)	2026.64	4	0.00	0.19
	Ψ(drainage dens.) p(.)	2028.96	3	0.32	0.16
	Ψ(drainage dens.+ access dist.[c]) p(.)	2027.25	4	0.61	0.14
	Ψ(.) p(.)	2031.29	2	0.65	0.14
	Ψ(veg. dens. 100-200) p(.)	2029.68	3	1.04	0.11
	Ψ(access dist.) p(.)	2030.24	3	1.60	0.09
Black agouti	Ψ(access dist.) p(.)	284.75	3	0.00	0.28
	Ψ(.) p(.)	286.89	2	0.14	0.26
	Ψ(access dist.+ veg. dens. 100-200) p(.)	283.59	4	0.84	0.18
Green acouchi	Ψ(.) p(.)	51.17	2	0.00	0.24
	Ψ(elevation) p(.)	50.09	3	0.92	0.15
	Ψ(drainage dens.) p(.)	50.62	3	1.45	0.12
	Ψ(*castanhal*) p(.)	50.72	3	1.55	0.11
	Ψ(veg. dens. 100-200) p(.)	51.09	3	1.92	0.10
	Ψ(access dist.) p(.)	51.16	3	1.99	0.10
	Ψ(veg. dens. 0-50[d]) p(.)	51.16	3	1.99	0.10

[a] *drainage dens. = drainage density.*

[b] *veg. dens. 100-200 = understory vegetation density between 100-200 cm above soil level.*

[c] *access dist. = distance to access from nearest community by river.*

[d] *veg. dens. 0-50 = understory vegetation density between 0-50 cm above soil level.*

Table 4. Sum of AIC (*w*) weights and effect (positive, +, or negative, -) of environmental variables at the sampling point and local scales on the occurrence of three species of caviomorph rodents in the Piagaçu-Purus Sustainable Development Reserve, central Amazon, Brazil.

Species	Sampling point scale			Local scale		
	Variable	Sum *w*	Effect	Variable	Sum *w*	Effect
Lowland paca	drainage dens.	0.80	+	dens. drenagem	0.49	+
	community dist.	0.38	+	sub100-200	0.30	+
	castanhal	0.20	-	dist. acesso	0.23	+
Black agouti	drainage dens.	0.29	+	dist. acesso	0.46	+
	elevation	0.21	+	sub100-200	0.18	-
	community dist.	0.10	+			
	veg. dens. 100-200	0.10	-			
	veg. dens. 0-50	0.08	-			
	castanhal	0.08	-			
Green acouchi	drainage dens.	0.41	+	altitude	0.15	+
	castanhal	0.12	-	dens. drenagem	0.12	+
				castanhal	0.11	-
				sub100-200	0.10	+
				dist. acesso	0.10	-
				sub50	0.10	-

[a] *drainage dens. = drainage density.*

[b] *community dist. = distance to nearest human community.*

[c] *veg. dens. 0-50 = understory vegetation density between 0-50 cm above soil level.*

[c] *veg. dens. 100-200 = understory vegetation density between 100-200 cm above soil level.*

[d] *access dist. = distance to access from nearest community by river.*

LEGENDS TO FIGURES

FIGURE 1. Map of the Piagaçu-Purus Sustainable Development Reserve. (A) South America, with Amazonas state in grey and the reserve location indicated with a black dot. (B) The reserve is indicated in grey and indigenous areas in white. (C) Lakes Uauaçu and Ayapuá, with black dots representing where each camera trap was located.

FIGURE S1. Probabilities of occupancy of green acouchi, lowland paca, and black agouti in areas of *castanhal* and non-*castanhal*, obtained at the sampling point scale in the Piagaçu-Purus Sustainable Development Reserve. The white points represent areas of *castanhal* and black points areas of non-*castanhal*.

FIGURE S2. Probability of occupancy of lowland paca in relation to drainage density (A) and distance to communities (B) obtained at the sampling point scale in areas of *castanhal* and non-*castanhal* in the Piagaçu-Purus Sustainable Development Reserve. The white points represent areas of *castanhal* and black points areas of non-*castanhal*.

FIGURES

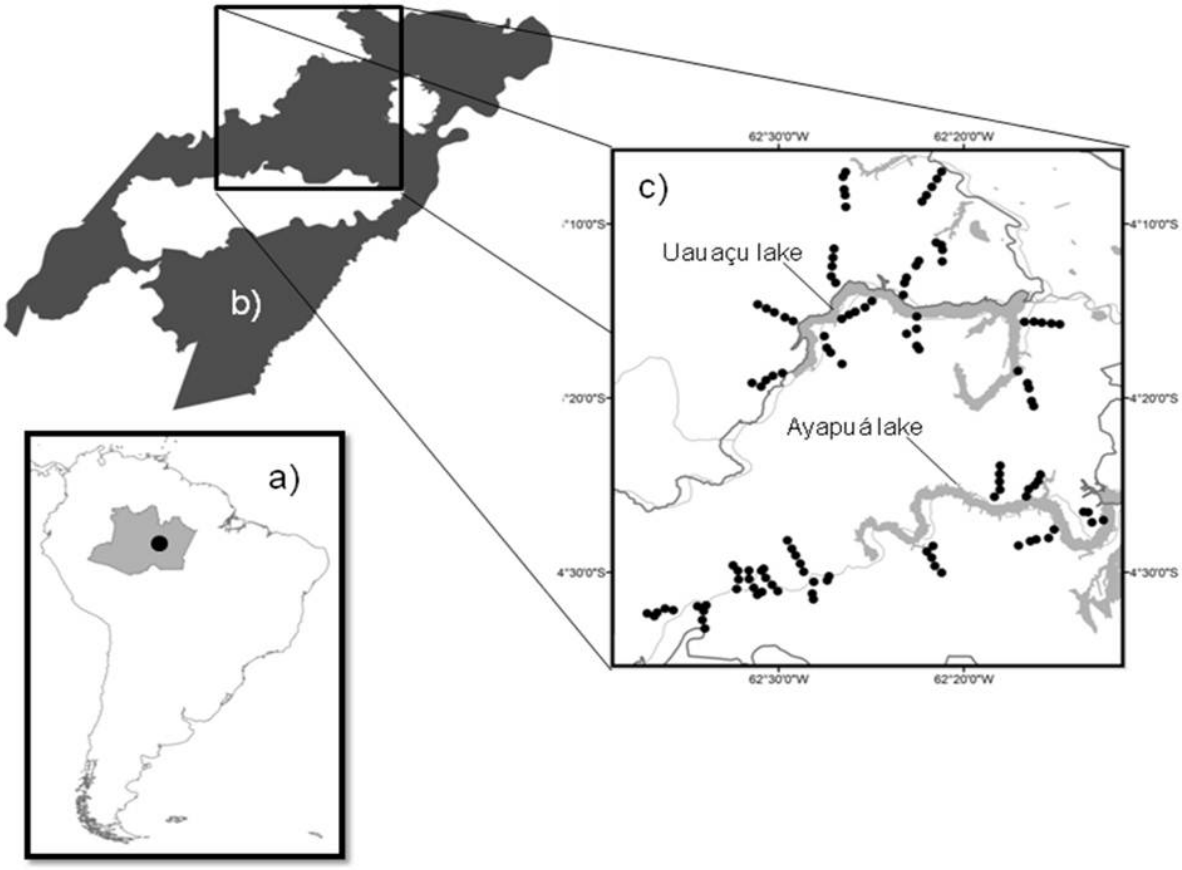
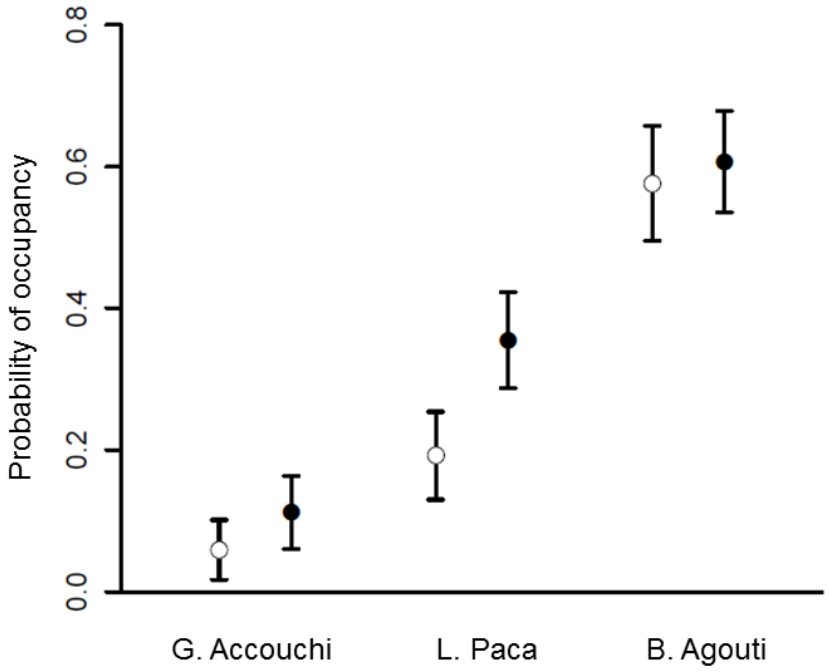


FIGURE 1



FIf

FIGURE S1.

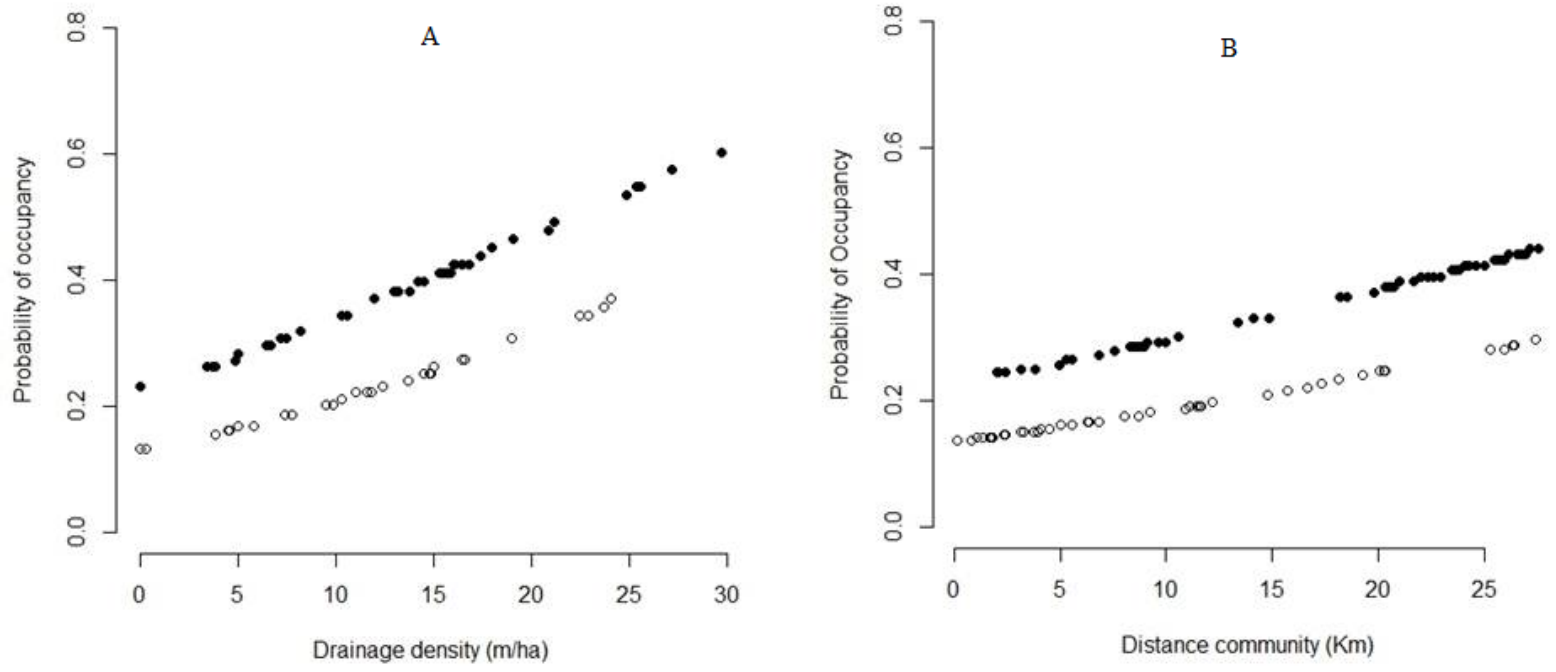

A
Probability of occupancy
0.0
0.2
0.4
0.6
0.8
0
5
10
15
20
25
30
Drainage density (m/ha)
B
Probability of Occupancy
0.0
0.2
0.4
0.6
0.8
0
5
10
15
20
25
Distance community (Km)

FIGURE S2.

CONCLUSÕES

Nossos estudo indica que na RDS PP os roedores caviomorfos paca, cutia e cutiara ocorrem preferencialmente em áreas com alta densidade de drenagem e distantes de comunidades humanas. Esse resultado pode contribuir com a delimitação de zonas prioritárias para a conservação destas espécies, que serviriam como áreas fonte (Sirén *et al*. 2004, Ohl-Schacherer *et al*. 2007). No contexto amazônico, o zoneamento de reservas de desenvolvimento sustentável é uma importante ferramenta. Ao proteger determinadas espécies em algumas zonas da reserva, o objetivo de desenvolvimento socioeconômico local com o mínimo impacto para a biodiversidade pode ser alcançado, garantindo assim, a conservação efetiva e a sustentabilidade destes locais (Nepstad *et al*. 2006, Ohl-Schacherer *et al*. 2007).

Os castanhais têm efeito negativo principalmente na ocorrência da paca. Embora também tenha influenciado negativamente a ocorrência de cutiara na escala Local, esta co-variável teve um peso explicativo baixo. A atividade de extração de castanha-do-Brasil tem efeito no padrão de atividade da paca e cutia. Estas mudanças comportamentais podem ser conseqüência do aumento do fluxo de pessoas na época de frutificação da castanheira, que pode afetar a pressão de caça nestas áreas e a competição por recursos alimentares. Contudo, a plasticidade comportamental destas espécies contribui para sua persistência nas áreas de castanhal e em outras áreas antropizadas (Norris *et al*. 2010). Tal constatação ressalta a necessidade de estudos que avaliem a extração de castanha na região, amostrando o número de pessoas, o horário e a frequência com que utilizam estas áreas, assim como o tamanho e a produtividade de cada castanhal, relacionando com os resultados de ocorrência dos roedores.

Por fim, nossos resultados também podem contribuir com futuros projetos de monitoramento em larga escala na RDS-PP. As estimativas de ocorrência podem ser utilizadas para avaliar o status dos roedores caviomorfos, trazendo informações que podem ser úteis na comparação entre áreas de diferentes intensidades de uso. Estas informações fornecem subsídios para que os gestores e comunidades locais estabeleçam zonas de proteção, uso e regras para o uso, principalmente nas áreas de castanhais.

APÊNDICES

PG-ECO-INPA

INPA

AULA DE QUALIFICAÇÃO

PARECER

Aluno(a): FERNANDA DE ALMEIDA MEIRELLES
Curso: ECOLOGIA
Nível: MESTRADO
Orientador(a): EDUARDO MARTINS VENTICINQUE

Título:

"Efeitos da estrutura de habitat sobre a assembleia de mamíferos dispersores e/ou predadores de sementes no baixo curso do rio Purus, Amazônia Central".

BANCA JULGADORA:

TITULARES:
Pedro Ivo Simões (INPA)
Leandro M. de Sousa (INPA)
Rafael Bernhard (INPA)

SUPLENTES:
William E. Magnusson (INPA)
José Francisco Gonçalves (INPA)

	PARECER		ASSINATURA
Pedro Ivo Simões (INPA)	(X) Aprovado	( ) Reprovado	
Leandro M. de Sousa (INPA)	(X) Aprovado	( ) Reprovado	
Rafael Bernhard (INPA)	(X) Aprovado	( ) Reprovado	
William E. Magnusson (INPA)	( ) Aprovado	( ) Reprovado	
José Francisco Gonçalves (INPA)	( ) Aprovado	( ) Reprovado	

Manaus(AM), 18 de abril de 2011

OBS:_____

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

Avaliação de dissertação de mestrado

Título: **Conservação de roedores cavimorfos em uma reserva de desenvolvimento sustentável na Amazônia: efeitos da estrutura do habitat e atividades extrativistas**

Aluno: **FERNANDA DE ALMEIDA MEIRELLES**

Orientador: **Eduardo M. Venticinque** Co-orientador: **Torbjorn Haugaasen**

Avaliador: **Camila Righetto Cassano**

Por favor, marque a alternativa que considerar mais apropriada para cada ítem 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)	( )	( )

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Avaliação de dissertação de mestrado

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29/06/2012 **Data**

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Avaliação de dissertação de mestrado

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Orientador: **Eduardo M. Venticinque** Co-orientador: **Torbjorn Haugaasen**

Avaliador: **José Manuel Vieira Fragoso**

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J. M. Fragoso

Stanford University, CA, USA, 6/6/ 2012, _____
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ATA DA DEFESA PÚBLICA DA DISSERTAÇÃO DE MESTRADO DO PROGRAMA DE PÓS-GRADUAÇÃO EM ECOLOGIA DO INSTITUTO NACIONAL DE PESQUISAS DA AMAZÔNIA.

Aos 26 dias do mês de novembro do ano de 2012, às 14:00 horas, no mini-auditório da Casa da Ciência, Bosque da Ciência/INPA, reuniu-se a Comissão Examinadora de Defesa Pública, composta pelos seguintes membros: o(a) Prof(a). Dr(a). **Marcelo Gordo**, da Universidade Federal do Amazonas - UFAM, o(a) Prof(a). Dr(a). **Paulo Estefano Dinelli Bobrowiec**, do Instituto Nacional de Pesquisas da Amazônia – INPA/CENBAM, 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). Igor Luis Kaefer, do Instituto Nacional de Pesquisas da Amazônia – INPA/CENBAM e o(a) Prof(a). Dr(a). Flávia Regina Capellotto Costa, do Instituto Nacional de Pesquisas da Amazônia – INPA, sob a presidência do(a) primeiro(a), a fim de proceder a argüição pública do trabalho de **DISSERTAÇÃO DE MESTRADO** de **FERNANDA DE ALMEIDA MEIRELLES**, intitulado "Conservação de roedores cavimorfos em uma reserva de desenvolvimento sustentável na Amazônia: efeitos da estrutura do habitat e atividades extrativistas", orientado pelo(a) Prof(a). Dr(a). Eduardo Martins Venticinque, da Universidade Federal do Rio Grande do Norte – UFRN e co-orientado pelo(a) Prof(a) Dr(a) Torbjørn Haugaasen, da University of Life Sciences, Noruega.

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

☒ APROVADO(A) ☐ REPROVADO(A)

☒ 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). Marcelo Gordo

Prof(a).Dr(a). Paulo E. Dinelli Bobrowiec

Prof(a).Dr(a). Pedro Ivo Simões

Coordenação PPG-ECO/INPA