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Relações ecológicas na distribuição de 25 espécies de vertebrados neotropicais em mesoescala

LINCOLN JOSÉ MICHALSKI

Manaus, Amazonas
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Orientador: Dra. Fernanda Michalski
Co-orientador: Dr. Tadeu Gomes de Oliveira

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Dr. Renato Cintra Soares (Instituto Nacional de Pesquisas da Amazônia/INPA)

Dr. Marcelo Gordo (Universidade Federal do Amazônas/UFAM)

Dr. Paulo Estefano Dineli Bobrowiec (Instituto Nacional de Pesquisas da Amazônia/INPA)

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Sinopse

Avaliei a riqueza e composição da assembleia de vertebrados terrestres de médio e grande porte em uma área de 25 km² na Floresta Nacional do Amapá, Amazônia Oriental, buscando entender as relações ecológicas entre as espécies e os grupos funcionais e a influência de variáveis ambientais sobre os vertebrados de médio e grande porte na escala avaliada. Para isso, utilizei 15 armadilhas fotográficas distribuídas em 30 pontos na grade do PPBio localizada nesta Unidade de Conservação de uso sustentável. Relacionei os registros das espécies com variáveis ambientais medidas em cada ponto/armadilha.

Palavras-chave: Amapá, armadilha fotográfica, aves, Floresta Amazônica, mamíferos amazônicos.

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Resumo

Os vertebrados são um componente vital da biodiversidade da floresta Amazônica. Apesar de serem uma parte importante da funcionalidade de vários serviços do ecossistema (suporte, reserva, cultural) continuam a ser ameaçados por perturbações antrópicas, incluindo caça e perda de habitat em toda a Amazônia. Aqui usamos um arranjo regularmente espaçado e padronizado dentro de uma área de 25 km², para fornecer uma avaliação inicial da diversidade de espécies de vertebrados em uma área protegida de uso sustentável na Amazônia brasileira oriental. Armadilhas fotográficas foram instaladas por 30 dias durante as estações seca e chuvosa, em 30 pontos separados por intervalos de um quilômetro ao longo de um sistema de trilhas pré-estabelecido. O teste de Mann-Whitney U foi usado para avaliar as diferenças sazonais no número de encontros por espécie (número de fotos por armadilha fotográfica e número de câmeras com fotos). Modelos Lineares Generalizados (GLMs) foram então usados para examinar a influência de cinco variáveis (altitude, abertura do dossel, área basal, distância até o rio de grande porte e distância até o rio de pequeno porte mais próximos) sobre o número de fotos por espécie e por grupos funcionais. GLMs também foram usados para examinar as relações entre grandes predadores [Jaguar (*Panthera onca*) e Puma (*Puma concolor*)] e as suas presas. Um total de 649 fotos independentes de 25 espécies foi obtido a partir de 1800 armadilhas-dia (900 em cada estação, chuvosa e seca). Somente ungulados e roedores mostraram diferenças sazonais significativas no número de fotos por câmera. O número de fotos variou entre as estações em apenas três espécies (*Mazama americana*, *Dasyprocta leporina* e *Myoprocta acouchy*), as quais foram fotografadas mais (3 a 10 vezes mais) durante a estação chuvosa. *M. americana* foi a única espécie em que uma diferença significativa foi encontrada em relação a ocupação, com mais fotos em mais câmeras durante a estação chuvosa. Para a maioria dos grupos e espécies, nossos GLMs tiveram pouco poder de explicação na variação no número de fotos por câmera (variando entre 10,3 e 54,4%). Aves terrestres (*Crax alector*, *Psophia crepitans* e *Tinamus major*) e roedores (*Cuniculus paca, Dasyprocta leporina* e *M. acouchy*) foram as exceções notáveis para os nossos GLMs, explicando de forma significativa a variação na distribuição de todas as espécies (variando entre 21,0 e 54,5%). Os GLMs para os grupos e espécies mostraram algumas informações ecológicas interessantes a partir desta "área relativamente intocada". No caso dos grupos não foi encontrada associação entre grandes felinos e suas presas em potencial. Descobrimos também que espécies de roedores e aves foram os mais registrados mais perto de córregos. Como caçadores têm acesso principalmente pelos rios em florestas tropicais, estes dados sugerem que atualmente há pouco impacto antropogênico nestas espécies na área de estudo. Nossos resultados fornecem uma base padronizada para comparação com outras áreas, e com os quais é possível planejar atividades de gestão e extrativismo.

Palavras chave: Amapá, armadilha fotográfica, aves, Floresta Amazônica, mamíferos amazônicos.

Abstract

Ecological relationships of meso-scale distribution in 25 Neotropical vertebrate species.

Vertebrates are a vital component of Amazon forest biodiversity. Although vertebrates are a functionally important part of various ecosystem services (supporting, provision and cultural) they continue to be threatened by anthropogenic perturbations including hunting and habitat loss across the Amazon. Here we use a standardized regularly spaced arrangement within $25km^2$ to provide a baseline assessment of vertebrate species diversity in a sustainable use protected area in the eastern Brazilian Amazon. Camera traps were placed for 30 days during both dry and wet seasons at 30 points separated by 1km intervals along a pre-established trail system. Mann-Whitney U tests were used to examine seasonal differences in the per species encounters (number of photos per camera trap and number of cameras with photos). Generalized linear models (GLMs) were then used to examine the influence of five variables (altitude, canopy cover, basal area, distance to nearest river and distance to nearest large river) on the number of photos per species and in functional groups. GLMs were also used to examine the relationships between large predators [Jaguar (*Panthera onca*) and Puma (*Puma concolor*)] and their prey. A total of 649 independent photos of 25 species were obtained from 1800 camera trap days (900 each during wet and dry seasons). Only ungulates and rodents showed significant seasonal differences in the number of photos per camera. The number of photos differed between seasons in only three species (*Mazama americana*, *Dasyprocta leporina* and *Myoprocta acouchy*) all of which were photographed more (3 to 10 fold increase) during the wet season. *M. americana* was the only species where a significant difference was found in occupancy with more photos in more cameras during the wet season. For most groups and species our GLMs only weakly explained variation in the number of photos per camera (deviance explained ranging from 10.3 to 54.4%). Terrestrial birds (*Crax alector*, *Psophia crepitans* and *Tinamus major*) and rodents (*Cuniculus paca*, *Dasyprocta leporina* and *M. acouchy*) were the notable exceptions with our GLMs significantly explaining variation in the distribution of all species (deviance explained ranging from 21.0 to 54.5%). The group and species GLMs showed some novel ecological information from this relatively “pristine area”. In the case of groups we found no association between large cats and their potential prey. We also found that rodent and bird species were more often recorded closer to streams. As hunters gain access via rivers this finding suggests that there is currently little anthropogenic impact on the species. Our findings provide a standardized baseline for comparison with other sites and with which planned management and extractive activities can be evaluated.

Key words: Amapa, Amazon Forest, Amazonian mammals, birds, camera trap.

Sumário

Introdução

Atualmente, aproximadamente 37% da Amazônia Brasileira recebe proteção legal, deste total cerca de 80,4% (~1,6 milhões de km2) permite alguma forma de uso humano (1). A criação destas áreas protegidas foi em muitos aspectos, um passo importante para proteger os recursos naturais (2). No entanto, a degradação destes esforços ameaça tanto a conservação da biodiversidade, quanto o bem estar humano (3). Tal degradação combinado com um futuro incerto (4) significa que há uma necessidade urgente de documentar o estado atual da "biodiversidade" dentro das áreas protegidas existentes (5).

Devido ao fato de que os mecanismos que mantêm a biodiversidade podem ser diferentes em inúmeros fatores, incluindo interações entre espécies (6), a sensibilidade das espécies às mudanças dentro e entre paisagens (7, 8), e com a sua mobilidade dentro delas (9), há uma necessidade de compreender os fatores ecológicos que afetam a distribuição de diferentes espécies, para uma efetiva gestão e proteção da biodiversidade. Por exemplo, os vertebrados de grande porte são essenciais para manter a estrutura e composição das florestas tropicais (10-12). No Escudo das Guianas e na Amazônia Central, os vertebrados frugívoros sozinhos dispersam mais de 94% de todas as espécies de plantas lenhosas (13). Estes vertebrados são, portanto, fundamentais para estudos que têm como foco a ecologia e conservação em Florestas Tropicais (10, 14).

Apesar da sua importância, existe uma inconsistência nos métodos utilizados nos estudos com vertebrados de médio e grande porte na Amazônia (15, 16). Muitos utilizam transectos lineares e / ou armadilhas fotográficas com arranjo e esforço amostral diferente (15, 17-19). Tais diferenças metodológicas tornam difícil, se não impossível, a comparação dos resultados entre os estudos. Usando um desenho amostral espacialmente padrão, que pode ser repetido para toda a Amazônia, é possível melhorar a geração e comunicação do conhecimento, para tornar mais eficaz a conservação e gestão das florestas da Amazônia (20-22).

Neste estudo, foi utilizado um regime de amostragem padronizado, que tem sido utilizado em vários outros locais de estudo em regiões tropical, para o levantamento de vertebrados terrestres dentro de uma área de 25km². Nosso estudo teve quatro objetivos principais: (1) avaliar o esforço de amostragem e a riqueza de espécies estimada, (2) testar as diferenças entre os grupos funcionais em suas relações ecológicas, (3) testar as diferenças entre as espécies em suas relações ecológicas e (4) comparar os resultados de nosso estudo com outros semelhantes nos neotrópicos e em outras regiões tropicais. Finalmente, vamos explorar as considerações relevantes para as estratégias de manejo e conservação na Amazônia Brasileira.

Objetivo geral

Avaliar a relação existente entre uma assembleia de vertebrados de médio e grande porte e cinco variáveis ambientais em uma área de 25 km², durante dois períodos sazonais, em uma floresta de terra firme na Amazônia Oriental, utilizando dados obtidos através de armadilhas fotográficas.

Objetivos específicos

1) Avaliar o esforço amostral e o número de espécies identificado;

2) Avaliar a influência da sazonalidade na amostragem;

3) Avaliar a influência de variáveis ambientais sobre as detecções de vertebrados de médio e grande porte.

Capítulo 1

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Ecological relationships of meso-scale distribution in 25 Neotropical vertebrate species

Lincoln José Michalski[1,2], Darren Norris[1,2,5], Tadeu Gomes de Oliveira[3,4], Fernanda Michalski[1,2,4,5*]

[1] Programa de Pós-Graduação em Ecologia, Instituto Nacional de Pesquisas da Amazônia, Manaus, Amazonas, Brazil

[2] Laboratório de Ecologia e Conservação de Vertebrados, Universidade Federal do Amapá, Macapá, Amapá, Brazil

[3] Departamento de Biologia, Universidade Estadual do Maranhão, São Luís, Maranhão, Brazil

[4] Instituto Pró-Carnívoros, Atibaia, São Paulo, Brazil

[5] Programa de Pós-Graduação em Biodiversidade Tropical, Universidade Federal do Amapá, Macapá, Amapá, Brazil

* Corresponding author

E-mail: fmichalski@gmail.com (FM)

DN, TGO and FM are Joint Senior Authors

Running title: Meso-scale distribution of Neotropical vertebrates

Abstract

Vertebrates are a vital component of Amazon forest biodiversity. Although vertebrates are a functionally important part of various ecosystem services (supporting, provision and cultural) they continue to be threatened by anthropogenic perturbations including hunting and habitat loss across the Amazon. Here we use a standardized regularly spaced arrangement within 25km^2 to provide a baseline assessment of vertebrate species diversity in a sustainable use protected area in the eastern Brazilian Amazon. Camera traps were placed for 30 days during both dry and wet seasons at 30 points separated by 1km intervals along a pre-established trail system. Mann-Whitney U tests were used to examine seasonal differences in the per species encounters (number of photos per camera trap and number of cameras with photos). Generalized linear models (GLMs) were then used to examine the influence of five variables (altitude, canopy cover, basal area, distance to nearest river and distance to nearest large river) on the number of photos per species and in functional groups. GLMs were also used to examine the relationships between large predators [Jaguar (*Panthera onca*) and Puma (*Puma concolor*)] and their prey. A total of 649 independent photos of 25 species were obtained from 1800 camera trap days (900 each during wet and dry seasons). Only ungulates and rodents showed significant seasonal differences in the number of photos per camera. The number of photos differed between seasons in only three species (*Mazama americana*, *Dasyprocta leporina* and *Myoprocta acouchy*) all of which were photographed more (3 to 10 fold increase) during the wet season. *M. americana* was the only species where a significant difference was found in occupancy with more photos in more cameras during the wet season. For most groups and species our GLMs only weakly explained variation in the number of photos per camera (deviance explained ranging from 10.3 to 54.4%). Terrestrial birds (*Crax alector*, *Psophia crepitans* and *Tinamus major*) and rodents (*Cuniculus paca*, *Dasyprocta leporina* and *M. acouchy*) were the notable exceptions with our GLMs significantly explaining variation in the distribution of all species (deviance explained ranging from 21.0 to 54.5%). The group and species GLMs showed some novel ecological information from this relatively “pristine” area. In the case of groups we found no association between large cats and their potential prey. We also found that rodent and bird species were more often recorded closer to streams. As hunters gain access via rivers this finding suggests that there is currently little anthropogenic impact on the species. Our findings provide a standardized baseline for comparison with other sites and with which planned management and extractive activities can be evaluated.

Keywords: Amazon forest, birds, camera trap, community ecology, forest ecology, mammals, species diversity

Introduction

Currently, almost 37% of the Brazilian Amazon receives legal protection, with approximately 80.4% (~1.6 million km^2) of the protected areas in Brazilian Amazonia allowing some form of human use (1). The establishment of these protected areas was in many respects a world leading step to protect natural resources (2). However the degradation of these efforts threatens both the conservation of biodiversity and human well-being (3). Such degradation combined with an uncertain future (4) means there is an urgent need to document the current state of "biodiversity" within the existing protected area networks (5).

Because the mechanisms that maintain biodiversity can differ with myriad factors including species interactions (6), the sensitivity of species to changes within and between landscapes (7, 8) and with their mobility within them (9) there is a need to understand the ecological factors affecting the distribution of different species to effectively manage and maintain biodiversity. For instance, large-bodied vertebrates are essential to maintain the structure and composition of tropical forests (10-12). In the Guiana Shield and Central Amazonia frugivorous vertebrates alone disperse over 94% of all woody plant species (13). These vertebrates are therefore key to studies that focus on the ecology and conservation of Amazon forests (10, 14).

Despite their importance there is lack of consistency in the methods used in studies on mid-sized and large bodied Amazon vertebrates (15, 16). For example numerous studies used line transects and/or camera traps with different arrangements, lengths and sampling efforts (15, 17-19). Such methodological differences make it difficult, if not impossible, to compare results across studies. Using a spatially standard sampling design that can be repeated across Amazonia is likely to improve the generation and communication of knowledge for the effective conservation and management of Amazon forests (20-22).

In this paper, we used a standardized sampling regime that has been utilized in several other tropical study sites to survey terrestrial vertebrates within a 25km^2 area. Our study had four principal objectives: (1) to evaluate sampling effort and estimate species richness, (2) to test for differences between functional groups in their ecological relationships, (3) to test for differences between species in their ecological relationships, and (4) to compare the findings of our study to other similar studies in the neotropics and other tropical regions. Finally, we explore relevant considerations for management and conservation strategies in the Brazilian Amazon.

Materials and Methods

Ethics Statement

Data collection used non-invasive, remotely activated camera traps and did not involve direct contact or interaction with animals. Fieldwork was conducted under research permit number IBAMA/SISBIO 40355-1 to LJM, DN, and FM, issued by the Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio).

Study Area

This study was conducted in Amapá National Forest (Floresta Nacional Amapá – hereafter FLONA), a sustainable-use protected are of approximately 412,000 ha, located in the center of Amapá State in the extreme northeast of the Brazilian Amazon (0°55’29’’N, 51°35’45’’W, Fig. 1) (23).

The FLONA consists of continuous tropical rainforest vegetation, predominantly never-flooded “terra-firme” forest, with some areas of flooded forest, bamboo and rocky outcrops (24). The FLONA is part of a large (> 4 million hectares) connected group of protected areas (Fig. 1, (23)) that maintain both continuous undisturbed forests and the complete regional community of medium-sized and large-bodied vertebrates. FLONA currently experiences low levels of anthropogenic perturbations, in part because only eight families live on the reserve border, there are no major access roads and the nearest city is located 46 km away by river (25).

The regional climate is hot and humid, with annual rainfall ranging from 2,300 mm to 2,900 mm (26). During the months with highest precipitation levels (February, March and April), rainfall may exceed 500 mm/month. The dry season (September to November) is characterized by a maximum precipitation below 250 mm/month (26).

Sampling Design

Data were sampled in both dry (October to December 2013, with 182 mm cumulative precipitation) and wet (March to June 2014, with 789 mm cumulative precipitation) seasons. Data collection was conducted in a 25 km^2 RAPELD grid (RAP surveys in the Long-term Ecological Research Sites whose Brazilian acronym is PELD, hence RAPELD) of the Brazilian Program for Biodiversity Research (PPBio) (20-22) (Fig. 1). This standard grid consists of six north-south and six east-west 5 km trails. The current study used 30 regularly spaced sample points distributed at 1km intervals along the east-west trails (Fig. 1, (20, 22)).

Vertebrate Data

In order to sample vertebrates we installed camera traps equipped with infrared triggers (Bushnell Trophy Cam, 8MP, Overland Park, KS, USA) in the RAPELD grid. As often reported from tropical systems (e.g. (27)), financial constraints meant we did not have sufficient cameras to survey the 30 points simultaneously. Cameras were therefore placed at 15 points for 30 consecutive days then immediately transferred to the remaining 15 points. All cameras were unbaited and installed 30-40 cm above the ground, facing the trail. Cameras functioned continuously (24 hours a day) during the 30-day sample period, which provided a sampling effort of 900 trap-days in each season. Cameras were programmed to film for 40 seconds post-activation, with intervals of 15 second between videos.

To estimate the relative abundance of vertebrates, we considered only independent videos, with over 30 min intervals in case of the same species recorded during the same day on the same camera (28, 29). The species recorded by the camera traps were identified with the aid of standard field guides for regional mammals (30, 31) and birds (32, 33), with species identifications double-checked by 3 researchers each with more than 10 years regional experience (FM, TGO, and DN). Scientific names follow available checklists of mammals (34), and birds (35).

Environmental Variables

To estimate the influence of environmental variables on vertebrates in each place where cameras were deployed we measured the following variables: (i) canopy openness, (ii) number of trees, (iii) tree basal area, (iv) distance from the location of the cameras to the nearest large river, (v) distance from the location of the cameras to the nearest stream, and (vi) altitude.

Forest structure data (i.e., number of trees and basal area) were obtained from plots measuring 50 x 10 m, at the 30 points (at the same locations as camera traps). Canopy openness was quantified with a concave spherical canopy densiometer at five equidistant points (10 m) within each plot. Four readings were taken per point (one for each cardinal point: north, south, east and west), the values were multiplied by 1.04 according to the manufacturer guidance (36).The number of all trees ≥ 10 cm DBH (diameter at breast height at a standard 1.3 m above ground, or above tallest root buttress) was used to quantify the number of trees per area in each plot (m^2). This count included all trees which had at least half of their basal trunk inside the plot.

Tree Basal Area in each plot was obtained as the sum of the basal area value for each individual tree derived from the DBH of each tree following the formula BA (basal area in m^2/ha)= 0.00007854 X DBH^2.

To estimate the altitude of the terrain at the camera location, we used a digital elevation model (DEM SRTM) produced by the Shuttle Radar Topographic Mission (SRTM) (37) with spatial resolution of 3 arc-second (approximately 90 m on the Equator), consisting of a set of elevations in digital format freely available on the internet (http://seamless.usgs.gov/ or http://www.cgiar-csi.org/data/srtm-90m-digital-elevation-database-v4-1). The geographical coordinates of the location of each camera trap were used to obtain the altitude of the terrain (DEM SRTM).

The distance from the camera traps to the nearest large river was estimated by using shapefiles of the Araguari and Falsino rivers (Fig. 1, available at http://hidroweb.ana.gov.br/HidroWeb.asp?TocItem=4100), and measured as a straight line (Euclidian) distance with Quantum Gis version 2.4.0 (38).

Distances to the nearest river were derived from river locations within a GIS. This was done by using the SRTM DEM to generate river channel networks using standard GIS processes. We used SAGA (System for Automated Geoscientific Analyses) GIS ((39, 40), http://www.saga-gis.org/en/index.html), for data preprocessing and river channel network derivation (modules: “Fill Sinks (Wang & Liu)” and “Channel Network and Drainage Basins”).). We then calculated the straight-line distance from the location of each camera trap to the center of the nearest stream.

Data Analysis

The relative abundance of each species was expressed as the number of independent videos per 10 trap-days (8, 41). A Mann-Whitney U test was used to test for significant differences between the number of detections in the dry and rainy seasons, using a significance level of $p < 0.05$.

To assess whether the sampling effort in both seasons was sufficient to record the majority of species, we constructed and compared species cumulative curves with the *accumcomp* function of the *BiodiversityR* package (42). To predict the total number of species that could be potentially detected in the area, we used the First Order Jackknife estimator, which extrapolates the species richness based on the frequency of species recorded (function *specpool*, package *Vegan*) (41, 43).

To evaluate the correlation between the environmental variables, we examined pair-wise Spearman correlations between all variables. This preliminary analysis showed that there were no strong correlations (Spearman $r < 0.70$) between the environmental variables, with values ranging between 0.03 and 0.62, allowing all variables to be used in subsequent analyzes.

To test for differences in the ecological relationships of different functional groups and species we used Generalized Linear Models (GLMs, error distribution family = poisson). GLMs were preferred to alternatives such as occupancy models as the number of videos (i.e. potential recaptures) and naïve occupancy (proportion of cameras with records) was low for most species. For less common/rare species we can assume that differences in detectability were not affecting the GLM results (44). To avoid overly complex models (total degrees of freedom in species GLMs = 30 points), preliminary variable selection (45) was used to select the five variables that showed higher weight of importance in the GLMs: canopy openness, basal area, distance to the nearest stream, distance to the largest river, and terrain altitude.

The GLMs were run separately for each species and for species divided into six functional groups. We defined the six functional groups as follows: (i) Birds (all birds), (ii) Large terrestrial Birds (Cracidae+Psophiidae), (iii) Ungulates (Artiodactyla+Perissodactyla), (iv) Large-bodied felids (*Puma concolor* + *Panthera onca)*, (v) Felids (all felids), and (vi) Rodents (all rodents). In the case of functional groups we also ran two additional models. To test for seasonal effects in each functional group the model consisted of the five variables mentioned above, plus the categorical variable '*season'* with two levels (dry and rainy). Additionally we also used GLMs to examine the relationship between felids and potential prey species.

For individual species, we summed independent wet and dry season videos per camera. We then selected only those species with at least one video in five or more different cameras within the study area. All analyses were performed with the R language and environment for statistical computing (46).

Results

Sampling Effort and Species Richness

Following a sampling effort of 1800 trap-days (900 each for the dry and rainy seasons), we obtained 649 independent videos of 25 vertebrate species (Table 1).

This total included four bird and 21 mammal species, representing 10 orders: Aves – Tinamiformes, Galliformes, Gruiformes; Mammals – Artiodactyla, Perissodactyla, Carnivora, Cingulata, Pilosa, Didelphimorphia and Rodentia (Table 1).

The species accumulation curves show a tendency to stabilize in both dry and rainy season samples, suggesting that sampling effort was sufficient for both mammals and birds (Fig. 2). Comparison with the extrapolated species richness estimates showed that we obtained between 84.0 and 91.4% of the species pool for mammals and 67.8 and 91.7% for birds (S1 Table).

There were small differences between the species richness recorded in the wet and dry seasons (Fig. 2, S1 Table). For mammals the observed and extrapolated richness increased (insignificantly) during the wet season (Fig. 2, S1 Table). There were also seasonal differences in species composition (Table 1). Four species were recorded only in the dry season (*Crypturellus erythropus, Dasypus novemcinctus, Tamandua tetradactyla* and *Didelphis marsupialis),* and four exclusively in the rainy season (*Nasua nasua, Procyon cancrivorus, Speothos venaticus* and *Sciurus aestuans*).

The Mann-Whitney U test indicated that only three mammal species showed significant differences in the number of records (independent video records, Table 1) between the dry and rainy season sampling (*Mazama americana, Dasyprocta leporina* and *Myoprocta acouchy*). *Mazama americana* was the only species to show a difference between seasons in the number of cameras that recorded images of the species (Table 1).

We obtained an overall capture rate of 0.36 (649 independent videos/1800 trap-days). *Dasyprocta leporina* had the highest relative abundance with 141 records (0.78 records/10 trap-days), followed by *Psophia crepitans* with 110 records (0.61 records/10 trap-days), and *Myoprocta acouchy* and *Pecari tajacu*, both with 77 records (0.43 records/10 trap-days) (Table 1).

Functional Groups

The Generalized Linear Models (GLM's) indicated that the explanatory power of the model was low for almost all groups (Table 2), with a maximum deviance explained of 40% (for rodents) and a minimum of 10% (for birds). The group representing total summed bird abundance (*All birds*) was negatively influenced by the variables *canopy openness*, *distance to major river* and *distance to nearest stream*. The avian group containing only large terrestrial birds (Cracidae and Psophiidae) was negatively influenced by *canopy openness*, *distance to major river* and *distance to nearest stream*, and was positively influenced by *tree basal area*. The group *Ungulates* was positively influenced only by the variable *distance to the nearest stream.* The two groups of felids were negatively influenced by *canopy openness* and *altitude*, while the group representing all felid records (*All felids*) was also positively influenced by *tree basal area* (S2 Table). The two prey categories (*Prey < 5kg* and *Prey > 5kg*) did not significantly explain variation in the felid groups (S3 Table). *Rodents* was the group with the greatest number of significant variables, showing negative associations with *canopy openness*, *distance to major river* and *distance to nearest stream*, while *altitude* was positively associated with abundance in this group (Table 2).

Species

Of the 14 species assessed in the GLMs, seven showed statistically significant results (Table 3).

However, the percentage variation explained by the model was low for almost all species, ranging from a minimum of 16% for *Tajacu peccari* to a maximum of 54% for *Cuniculus paca*. Of these 14 species, the birds *C. alector*, *P. crepitans* and *T. major*, and rodents *C. paca*, *D. leporina* and *M. acouchy* were the species where the model provided the highest percentage of explanation for their distributions, ranging from 21.0 to 54.51%.

The species with the greatest number of significant variables in the model was *M. acouchy* (four variables), followed by *C. paca, D. leporina* and *P. crepitans*, all with three significant variables. Four species (*Mazama nemorivaga, Leopardus pardalis, Panthera onca* and *Dasypus kappleri*) were not associated significantly with any of the environmental variables in the model (Table 3).

The variable canopy openness had a negative influence on abundance in *Crax alector*, *Psophia crepitans* and *Myoprocta acouchy*. This same variable positively influenced abundance in *Dasyprocta leporina* and *Tinamus major*. The variable altitude negatively influenced the abundance of *Mazama americana*, *Tapirus terrestris*, *Cuniculus paca* and *Myoprocta acouchy*. Tree basal area negatively influenced abundance in *Crax alector*, and positively influenced abundance in *Psophia crepitans*, *Puma concolor* and *Cuniculus paca*. Distance to nearest large river influenced negatively *Dasyprocta leporina* and *Myoprocta acouchy* abundance. Finally, distance to nearest stream negatively affected abundance in *Psophia crepitans*, *Cuniculus paca*, *Dasyprocta leporina* and *Myoprocta acouchy*, while positively affected those of *Mazama americana* and *Pecari tajacu* (Table 3).

Discussion

Our analysis of medium and large vertebrates in a 25 km^2 area of lowland tropical forest showed that, although overall the model explained little of the species composition in the area, the sampled environmental variables themselves are important for species composition, with meso-scale variations in forest structure, topography and watercourse proximity significantly influencing species occurrence. Linking presence and abundance to the ecological requirements of vertebrates in question, such fine-tuned ecological knowledge is fundamental to the effective conservation of these species (47, 48).

Sampling Effort and Species Richness

The differences between the observed and extrapolated species richness values obtained for birds and mammals combined indicates that we recorded between 80 and 90% of the species in the study area. This finding suggests that our sampling effort was sufficient to capture most of the species and that our results are suitable for within and between site comparisons.

We recorded the full range of terrestrial medium to large bodied mammals (from jaguars to agoutis), which was to be expected considering the remote location of our study area. Indeed, the 21 medium and large bodied mammal species recorded by our study is a similar number to that recorded for other Amazonian regions (49-51) and for other areas in the State of Amapá (52). However, we did not detect some species that have been widely recorded across the Guiana Shield such as *Tayassu pecari*, *Priodontes maximus*, and *Puma yagouaroundi* (53). Although thought to be relatively rare across Amazonia these three species were recorded for the FLONA in a rapid biological inventory (54).

The fact that we did not record some species is to be expected as many mammal species are difficult to detect and have relatively large home ranges, hence may require greater sampling effort (51) and/or the use of complementary techniques (8, 55). The rapid inventory (54) was based on a smaller sampling effort (20 days of fieldwork with 62 hours of active search), but used a combination of indirect and direct techniques. These techniques included five camera traps distributed in front of dens and places with signs of vertebrate activity. Additionally the camera traps were baited with honey, bacon, carrot and orange) (54). Thus, the reason for not recording some species that occur in our study area could be related with the use of only one method, as the use of complementary techniques have been proven to be more efficient for surveying vertebrates than single methods (55). It is also possible that, the sampling effort was not sufficient to detect locally rare species that have been recorded with camera traps elsewhere in Amazonia (51, 56). Also, some species that were not detected such as *T. pecari* are known to range widely (57) and follow seasonal changes in habitat and resource availability (58), which are both characteristics that could make it difficult to detect these species. Other non-detected species such as the *Puma yagouaroundi*, are also rare in the Amazon (51) and more associated with open habitats (59), although can also occur in dense forest cover (60). Thus, may not be so easily detected in core pristine forest areas.

We recorded four bird species, a much lower number than that described for the FLONA in a rapid biological inventory (61), which based on a combination of mist-nets and sound records documented nine large bird species (Tinamidae, Cracidae and Psophiidae) that are likely to be recorded by camera traps due to their large body size and habit of foraging on the ground. Thus (as suggested by our extrapolated bird richness values), we registered half of the bird species that could possibly be recorded with terrestrial camera traps in the study area. Nevertheless, other camera trap studies conducted in the Peruvian amazon (51), using more than double our survey effort over two years also recorded a similarly low richness (4 species) of large ground-dwelling birds. This low richness suggests that this technique might not be ideal for this group of birds. For example, only one large terrestrial bird (*Crax alector*) was recorded during 459 camera trap/days in a study conducted in FLONA to monitor latrines of giant otters (*Pteronura brasiliensis*) (62). The fact that some bird species were photographed only in the wet season and others only in the dry season is also likely a reflection of sampling effort, as there is no other plausible explanation given their known ecological features (30).

Differences between functional groups

Ungulates and rodents were the groups most strongly influenced by season, with greater numbers of records in the rainy season. Such differences may be associated with between-season fluctuations in the level of resource availability, and may not be due to an increase in the number of individuals but by an increase in the number of times resident animals are recorded as they increase their activities in the area when local resources abound (19). These seasonal differences agree with another study in the southern Amazon with medium and large-bodied vertebrates (49), but are contrary to the results of another in the same biome in Peru, with medium and large mammals (63), which had more records in the dry season. We suggest that future studies aiming to evaluate abundance and occupancy rates of medium and large terrestrial mammals and birds in the tropics, include rainy season sampling due to such seasonal differences.

Many camera trap studies (64) are often conducted during the dry season (months with less than 100 mm average rainfall) due to logistical constraints associated with rainy season surveys (e.g. restricted access and cameras malfunctioning). Due to such logistical constraints we still know very little regarding patterns in Amazon biodiversity during the rainy season. If camera traps were associated with phenological and resource availability studies (much of Amazon fruit production occurs during the rainy season (65-67)) it may also be possible to better understand the processes driving the spatial and temporal distribution of these species.

Birds and *Rodents* were negatively influenced by the variables *distance to nearest stream* and *distance to nearest large river*, showing an increase in the number of records closer to water bodies. This finding was in some way unsurprising as the preference of this group of birds for moister areas and the preference of rodents (particularly paca) for areas close to water have been documented previously (68-72). Although rivers are the main means of human transport in the region and these groups are hunted by local inhabitants (25, 73, 74) they were still recorded close to the large rivers, which suggests that there is little impact of humans within the FLONA.

Records of Galliformes, Gruiformes and Tinamiformes (*Birds*) were also positively associated with areas of denser canopy and with areas of denser ground vegetation (greater tree basal area), corroborating studies that found these ground dwelling birds to exhibit an expected preference for such habitats (68).

Large felids were associated with lowland areas and areas of denser vegetation, but unexpectedly showed no association with prey (variables *Prey <5kg* and *Prey> 5kg*). Although other studies have shown prey availability to influence the distribution of predators in rainforest habitats (75), this could not be detected at the FLONA, perhaps due to the broad distribution throughout the area of both predators and prey. It seems likely that with such a variety and number of potential prey species these predators are not limited by prey availability.

Differences between species

Overall, our capture rate was similar to those reported from other protected Amazon forests (51) and greater than those reported from fragmented/more disturbed/less productive Neotropical sites (see table 2 in (76)). The species relative abundances detected at the FLONA were also similar to those found using camera-traps in other Amazon sites (51, 56). Of the most commonly recorded species *Dasyprocta leporina* and *M. acouchy* showed a clear preference for low-lying areas near large rivers, a pattern well-known from previous studies of these rodents (69, 71, 72). In contrast the distributions of three bird species appeared to be most closely related to the variables describing forest structure (47). *C. alector* and *P. crepitans* were more frequently recorded in closed canopy areas with greater forest cover, while *T. major* was most often recorded from more open areas. This may be a result of behaviors associated mainly with ground foraging (68).

The ungulates and the two big cats (*P. concolor* and *P. onca*) did not appear to be greatly influenced by the sampled variables. Both groups comprise wide-ranging species with non-specialized habits (30, 77). It therefore appears that these species have enough ecological/behavioral plasticity for them not to be strongly affected/limited by the measured variables on a meso-scale. This lack of association with the environmental variables examined suggests that other factors such as biotic interactions and resource availability (78-80) maybe more important determinants of species distributions and densities in the FLONA.

We must of course remain cautious in our conclusions. While capture frequencies can give an idea of the relative abundance of different species, there is an ongoing discussion among scientists about the reliability of this index (81, 82) and how such indexes relate to population parameters. For example results from within any area may be affected by individual or species specific factors such as trail use or avoidance, vertical and horizontal space use (e.g. partly arboreal versus exclusively terrestrial), or habitat specialist versus generalist. Despite such uncertainty, we believe that a combination of a standardized survey and camera traps means that findings are comparable between sites using similar spatially standardized sample arrangements e.g. (16, 27, 51, 56, 64). Additionally our findings also serve as a robust baseline for monitoring the impacts of extractive activities proposed in the management plan of the FLONA (22, 83).

Conclusions

The inability of the causal model to explain the distribution of the recorded species suggests that at the meso-scale level (25 km^2) environmental variables had little influence on the abundance, richness and species distribution of medium and large terrestrial vertebrates at our study area. Individual environmental variables themselves are important for species composition, with meso-scale variations in forest structure, topography and watercourse proximity significantly influencing species occurrence of rodents and birds. Other factors may have more decisive roles at this scale, such as biotic interactions between species and the availability of resources (78-80). Our findings suggest environmental integrity within the protected area, and also indicate that there is currently little human disturbance. Continued monitoring is required to ensure that proposed extractive activities do not disrupt the apparently intact community or its ecological interactions.

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Tables

Table 1. Number of independent photos (Detection), number of cameras that recorded photos (NCP) and relative abundance in dry and wet seasons of all vertebrate species examined in this study.

Class	Order	Family	Species	Detection[a] (dry,wet)	NCP[b] (dry,wet)	RA[c] (dry,wet)
Birds						
	Galliformes					
		Cracidae	*Crax alector*	23 (9, 14)	13 (6, 9)	0.13 (0.1, 0.15)
	Gruiformes					
		Psophiidae	*Psophia crepitans*	110 (47, 63)	26 (17, 24)	0.61 (0.52, 0.70)
	Tinamiformes					
		Tinamidae	*Crypturellus erythropus*	11 (11, 0)	1 (1, 0)	0.06 (0.12, 0)
			Tinamus major	11 (4, 7)	6 (3, 3)	0.06 (0.04, 0.07)
Mammals						
	Artiodactyla					
		Cervidae	*Mazama americana*	37 (6, 31)*	17 (4, 14)*	0.20 (0.06, 0.34)
			Mazama nemorivaga	55 (36, 19)	25 (16, 14)	0.30 (0.4, 0.21)
		Tayassuidae	*Pecari tajacu*	77 (30, 47)	19 (13, 16)	0.43 (0.33, 0.52)
	Perissodactyla					
		Tapiridae	*Tapirus terrestris*	12 (5, 7)	8(5, 7)	0.06 (0.05, 0.07)
	Carnivora					
		Felidae	*Leopardus pardalis*	9 (1, 8)	6 (1, 5)	0.05 (0.01, 0.08)
			Leopardus wiedii	2 (1, 1)	2 (1, 1)	0.01 (0.01, 0.01)
			Panthera onca	14 (7, 7)	12 (7, 6)	0.08 (0.07, 0.07)
			Puma concolor	15 (5, 10)	10 (3, 8)	0.09 (0.05, 0.11)

	Mustelidae	*Eira barbara*	7 (4, 3)	4 (3, 2)	0.04 (0.04, 0.03)
	Procyonidae	*Nasua nasua*	2 (0, 2)	2 (0, 2)	0.01 (0, 0.02)
		Procyon cancrivorus	2 (0, 2)	1 (0, 1)	0.01 (0, 0.02)
	Canidae	*Speothos venaticus*	1 (0, 1)	1 (0, 1)	0.00 (0, 0.01)
Cingulata					
	Dasypodidae	*Dasypus kappleri*	8 (4, 4)	6 (3, 3)	0.04 (0.04, 0.04)
		Dasypus novemcinctus	2 (2, 0)	2 (2, 0)	0.01 (0.02, 0)
Pilosa					
	Myrmecophagidae	*Myrmecophaga tridactyla*	7 (4, 3)	5 (4, 2)	0.04 (0.04, 0.03)
		Tamandua tetradactyla	2 (2, 0)	2 (2, 0)	0.01 (0.02, 0)
Didelphimorphia					
	Didelphidae	*Didelphis marsupialis*	3 (3, 0)	1 (1, 0)	0.01 (0.03, 0)
Rodentia					
	Cuniculidae	*Cuniculus paca*	18 (15, 3)	7 (5, 3)	0.10 (0.16, 0.03)
	Dasyproctidae	*Dasyprocta leporina*	141 (32, 109)*	23 (16, 19)	0.78 (0.35, 1.21)
		Myoprocta acouchy	77 (6, 71)*	13 (4, 10)	0.43 (0.06, 0.78)
	Sciuridae	*Sciurus aestuans*	3 (0, 3)	1 (0, 1)	0.01 (0, 0.03)

[a] Number of detections with independent photos.

[b] Number of cameras that recorded photos of the species.

[c] Average relative abundance (number of independent photos per 10 camera-trap days).

* Significant difference between seasons (Mann-Whitney test, p <0.05).

Table 2. Parameter (Slope) estimates of explanatory variables from the GLMs on the abundance of groups of vertebrates in the eastern Brazilian Amazon.

Groups	Canopy Openness		Altitude		Basal area		Distance to large rivers		Distance to stream		Model	
	Slope (SE)	Z value	Slope (SE)	Z Value	Slope (SE)	Z value	Slope (SE)	Z value	Slope (SE)	Z value	DE (%)	AIC
All birds	-0.174 (0.078)	-2.21*	0.002 (0.003)	0.71†	0.095 (0.067)	1.40†	-0.203 (0.093)	-2.18*	-0.000 (0.000)	-1.76†	15.27	190.39*
Birds (Cracidae + Psophiidae)	-0.186 (0.089)	-2.09*	0.020 (0.010)	1.95†	0.190 (0.084)	2.25*	-0.169 (0.112)	-1.51†	-0.001 (0.000)	-2.26*	11.9	266.7**
Ungulates[a]	0.071 (0.067)	1.05†	-0.006 (0.003)	-1.79†	-0.012 (0.072)	-0.16†	-0.025 (0.082)	-0.31†	0.000 (0.000)	2.61**	11.79	185.91†
Large bodied felids[b]	-0.476 (0.242)	-1.96*	-0.079 (0.035)	-2.25*	0.146 (0.148)	0.98†	0.276 (0.223)	1.23†	0.002 (0.001)	1.61†	23.41	110.59*
All felids	-0.239 (0.161)	-1.48†	-0.019 (0.008)	-2.45*	0.305 (0.131)	2.32*	0.001 (0.175)	0.00†	0.000 (0.000)	0.85†	29.59	91.68*
All rodents	-0.034 (0.077)	-0.44†	-0.029 (0.008)	3.39***	0.092 (0.072)	1.27†	-0.846 (0.103)	-8.20***	-0.002 (0.000)	-8.71***	39.78	445.62***

Slope for variables and Standard Error (SE); Z value for variables; Percentage of Deviance Explained for each model (DE (%)); Akaike Information Criterion value for each model (AIC); Significance values: †not significant, *p <0.05, **p<0.01, ***p<0.001.

[a] Includes all Artiodactyla and Perissodactyla recorded in the study area.

[b] Includes only large-bodied felids (*Puma concolor* and *Panthera onca*).

Table 3. Parameter (Slope) estimates from GLMs analysis of the abundance of vertebrate species in the eastern Brazilian Amazon.

Family	Species	Canopy Openness		Altitude		Basal area		Distance to large rivers		Distance to stream		Model	
		Slope (SE)	Z Value	Slope (SE)	Z value	Slope (SE)	Z value	Slope (SE)	Z Value	Slope (SE)	Z value	DE (%)	AIC
Birds													
Cracidae	*Crax alector*	-0.435 (0.219)	-1.98*	-0.004 (0.009)	-0.43†	-0.627 (0.307)	-2.04*	0.288 (0.267)	1.08†	0.001 (0.001)	1.70†	23.87	76.64***
Psophiidae	*Psophia crepitans*	-0.233 (0.093)	-2.48*	-0.008 (0.004)	1.74†	0.169 (0.074)	2.28*	-0.170 (0.111)	-1.52†	-0.001 (0.000)	-2.53*	21.21	167.43**
Tinamidae	*Tinamus major*	0.871 (0.276)	3.15**	0.013 (0.016)	0.80†	-0.239 (0.300)	-0.79†	-0.003 (0.452)	-0.00†	-0.003 (0.002)	-1.55†	42.99	48.27**
Mammals													
Cervidae	*Mazama americana*	0.053 (0.156)	0.34†	-0.020 (0.007)	- 2.71**	-0.108 (0.179)	-0.60†	0.285 (0.183)	1.56†	0.001 (0.000)	2.06*	15.83	107.75†
	Mazama nemorivaga	0.052 (0.118)	0.44†	0.006 (0.006)	1.01†	0.166 (0.104)	1.60†	-0.026 (0.153)	-0.17†	-0.000 (0.000)	-0.86†	12.05	109.53†
Tayassuidae	*Pecari tajacu*	0.040 (0.107)	0.37†	-0.003 (0.005)	-0.63†	-0.209 (0.137)	-1.52†	-0.171 (0.131)	-1.30†	0.001 (0.000)	2.96**	16.19	158.23**
Tapiridae	*Tapirus terrestris*	0.315 (0.293)	1.07†	-0.033 (0.014)	-2.30*	0.065 (0.303)	0.21†	-0.101 (0.327)	-0.31†	0.002 (0.001)	1.46†	19.54	58.72†
Felidae	*Leopardus pardalis*	-0.850 (0.459)	-1,84†	-0.027 (0.010)	-1.55†	-0.090 (0.425)	-0.21†	-0.069 (0.408)	-0.17†	0.001 (0.001)	0.85†	26.79	47.79†
	Panthera onca	-0.562 (0.294)	-1.91†	-0.024 (0.014)	-1.75†	0.284 (0.238)	1.19†	0.187 (0.301)	0.62†	0.000 (0.001)	-0.08†	29.55	56.16†
	Puma concolor	0.057 (0.245)	0.23†	-0.015 (0.014)	-1.07†	0.519 (0.187)	2.77**	0.002 (0.290)	0.00†	0.001 (0.001)	0.83†	20.87	64.11†
Dasypodidae	*Dasypus kappleri*	-0.655	-1.38†	0.011	0.61†	0.071	0.19†	-0.790	-1.72†	-0.000	-0.34†	26.69	45.74†

		(0.474)		(0.018)		(0.373)		(0.458)		(0.002)			
Cuniculidae	*Cuniculus paca*	-0.080	-0.25†	-0.032	-2.33*	0.397	2.15*	-0.703	-1.85†	-0.006	-2.57**	54.51	58.28**
		(0.318)		(0.013)		(0.184)		(0.379)		(0.002)			
Dasyproctidae	*Dasyprocta leporina*	0.007	0.91*	0.000	0.11†	-0.123	-1.45†	-0.000	-5.03***	-0.001	-2.95**	21.00	250.13***
		(0.087)		(0.004)		(0.084)		(0.000)		(0.000)			
	Myoprocta acouchy	-0.364	-2.35*	-0.134	-2.35*	0.213	2.09†	-0.848	-5.48***	-0.001	-2.29*	31.06	214.52***
		(0.154)		(0.666)		(0.102)		(0.154)		(0.000)			

Slope for variables and Standard Error (SE); Z value for variables; Percentage of Deviance Explained for each model (DE (%)); Akaike Information Criterion value for each model (AIC); Significance values: †not significant, *p <0.05, **p<0.01, ***p<0.001.

Figure Legends

Figure 1. Location of the study region in Amapá National Forest (ANF), Amapá State, eastern Brazilian Amazon. A LANDSAT TM image (25 October 2009) shows the grid system and the location of camera traps in 30 regularly spaced sample points. Green and pink areas represent native forest and disturbed areas, respectively.

Figure 2. Cumulative curves for mammal and bird species sampled with camera traps in the dry and rainy seasons in the Amapá National Forest. Detection of species recorded in the 30 sample points is randomized 1000 times and results used to derive mean (dark blue line) 95% confidence intervals of the mean (light blue polygon). a) Cumulative curve for mammal species in the dry season; b) Cumulative curve for bird species in the dry season; c) Cumulative curve for mammal species in the rainy season; d) Cumulative curve for birds species in the rainy season.

Figure 3. Number of photos per sampling point for vertebrate species sampled on a 25 km² grid, Amapá National Forest, Brazil. A) Galliformes; B) Gruiformes; C) Tinamiformes; D) Artiodactyla; E) Perissodactyla; F) Carnivora; G) Cingulata; H) Rodentia.

Figures

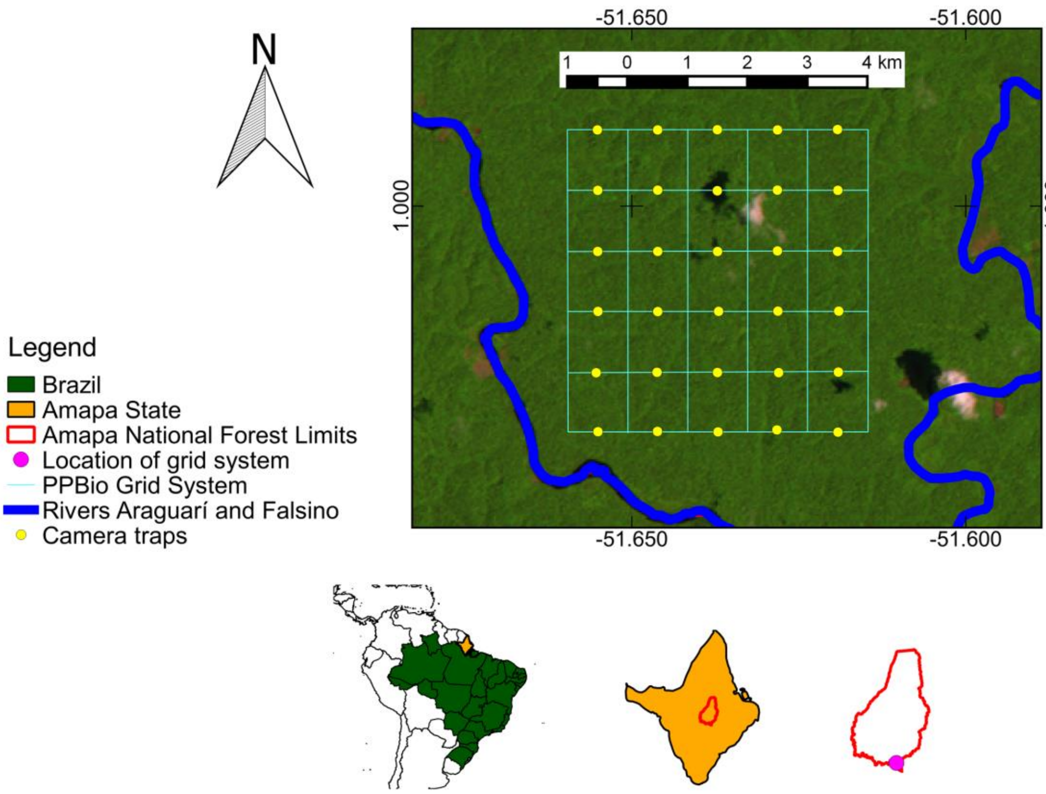


Figure 1

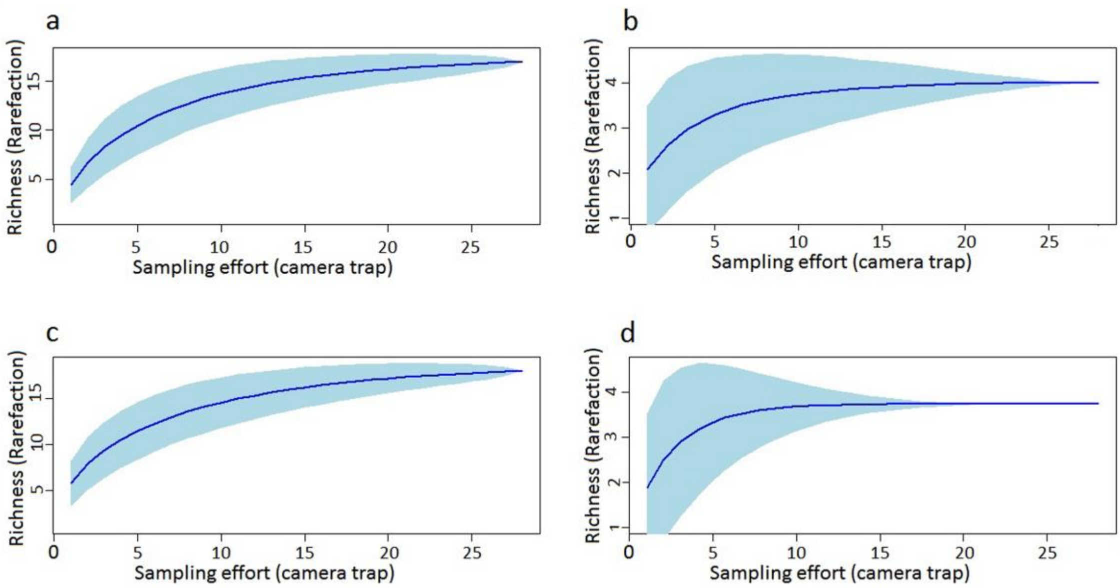
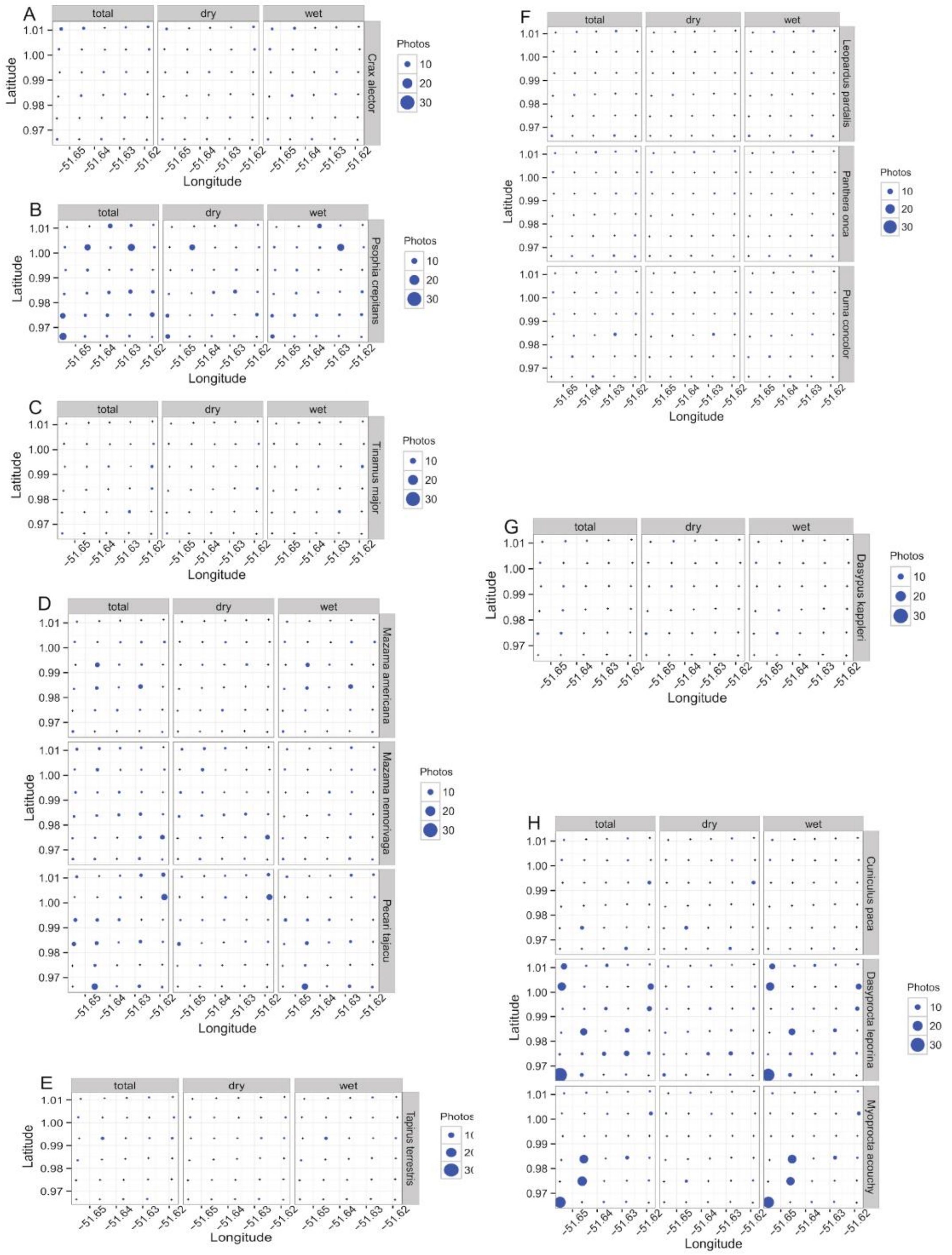


Figure 2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Pecari tajacu
E
Tapirus terrestris
F
Leopardus pardalis
Panthera onca
Puma concolor
G
Dasypus kappleri
H
Cuniculus paca
Dasyprocta leporina
Myoprocta acouchy
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-51.64
-51.63
-51.62

Figure 3

Supporting Information

S1 Table. Observed and extrapolated species richness.

Species richness of medium to large bodied mammals and birds sampled with camera traps in the dry and rainy seasons in the Amapá National Forest. Extrapolations based on four estimators with standard errors (“SE”) in parenthesis.

	Observed	Extrapolated richness estimates[a]			
		Chau (SE)	First order jackknife (SE)	Second order jackknife [b]	Bootstrap (SE)
All	**25**	**28.1 (3.7)**	**29.8 (2.2)**	**30.9**	**27.3 (1.3)**
Dry	21	25.0 (5.3)	24.9 (1.9)	26.8	22.9 (1.2)
Rainy	21	23.7 (3.5)	24.9 (1.9)	25.9	23.0 (1.2)
Mammals	**21**	**23.0 (2.6)**	**24.9 (1.9)**	**25.0**	**23.0 (1.3)**
Dry	17	19.3 (3.4)	19.9 (1.7)	20.9	18.5 (1.1)
Rainy	18	20.7 (3.5)	21.9 (1.9)	22.9	19.9 (1.2)
Birds	**4**	**4.0 (0.0)**	**5.0 (1.0)**	**5.9**	**4.4 (0.5)**
Dry	4	4.0 (0.0)	5.0 (1.0)	5.9	4.4 (0.6)
Rainy	3	3.0 (0.0)	3.0 (1.0)	3.0	3.0 (0.2)

[a] Extrapolations calculated using incidence-based estimates i.e. the frequencies of species in the collection of 30 sample points. Four different variants were used to estimate the extrapolated species richness in the species pool.

[b] Variance estimator not yet implemented.

S2 Table. Parameter (Slope) estimates of explanatory variables (adding seasonality) from the GLMs on the abundance of groups of vertebrates in the eastern Brazilian Amazon.

Groups	Canopy Openness		Altitude		Basal area		Distance to large rivers		Distance to stream		Season		Model	
	Slope (SE)	Z value	Slope (SE)	Z value	Slope (SE)	Z value	Slope (SE)	Z value	Slope (SE)	Z value	Slope (SE)	Z value	DE (%)	AIC
All birds	-0.121 (0.082)	-1.51†	0.019 (0.009)	1.91†	0.169 (0.078)	2,16*	-0.281 (0.105)	-2.67**	-0.001 (0.000)	-2.46*	0.168 (0.161)	1.04†	10.33	310.4**
Birds (Cracidae + Psophiidae)	-0.186 (0.089)	-2.09*	0.020 (0.010)	1.95†	0.190 (0.084)	2.25*	-0.169 (0.112)	-1.51†	-0.001 (0.000)	-2.26*	0.318 (0.175)	1.81†	14.15	265.3**
Ungulates[a]	0.078 (0.072)	1.08†	0.001 (0.009)	0.11†	-0.010 (0.080)	-0.11†	-0.066 (0.089)	-0.74†	0.000 (0.000)	1.47†	0.300 (0.150)	1.99*	11.79	319.02†
Large-bodied felids[b]	-0.476 (0.242)	-1.96*	-0.079 (0.035)	-2.25*	0.146 (0.148)	0.98†	0.276 (0.223)	1.23†	0.002 (0.001)	1.61†	0.348 (0.377)	0.92†	23.41	110.59*
All felids	-0.425 (0.194)	-2.18*	-0.062 (0.027)	-2.31*	0.068 (0.137)	0.49†	0.142 (0.191)	0.74†	0.001 (0.001)	0.65†	0.619 (0.331)	1.86†	21.12	133.38*
All rodents	-0.034 (0.077)	-0.44†	-0.029 (0.008)	3.39***	0.092 (0.072)	1.27†	-0.846 (0.103)	-8.20***	-0.002 (0.000)	-8.71***	1.555 (0.178)	8.71***	39.78	445.62***

Slope for variables and Standard Error (SE); Z value for variables; Percentage of Deviance Explained for each model (DE (%)); Akaike Information Criterion value for each model (AIC); Significance: †not significant, *p <0.05, **p<0.01, ***p<0.001.

S3 Table. Parameter (Slope) estimates of prey variables from the GLMs on the abundance of felid groups in the eastern Brazilian Amazon.

Groups	Canopy Openness		Altitude		Basal area		Distance to large rivers		Distance to stream		Prey <5kg		Prey >5kg		Model	
	Slope (SE)	Z value	Slope (SE)	Z value	Slope (SE)	Z value	Slope (SE)	Z value	Slope (SE)	Z value	Slope (SE)	Z value	Slope (SE)	Z value	DE (%)	AIC
Large bodied felids[a]	-0.495 (0.249)	-1.98*	-0.078 (0.036)	-2.19*	0.142 (0.151)	0.93†	0.274 (0.235)	1.16†	0.002 (0.001)	1.54†	0.291 (0.398)	0.73†	0.004 (0.024)	0.17†	24.95	113.61*
All felids	-0.449 (0.203)	-2.20*	-0.064 (0.028)	-2.28*	0.066 (0.142)	0.46†	0.186 (0.203)	0.91†	0.002 (0.001)	1.68†	0.490 (0.352)	1.39†	0.013 (0.016)	-0.78†	24.1	135.16*

Slope for variables and Standard Error (SE); Z value for variables; Percentage of Deviance Explained for each model (DE (%)); Akaike Information Criterion value for each model (AIC); Significance values: †not significant, *p <0.05.

[a] Includes only *Puma concolor* and *Panthera onca*.

Conclusões

Este estudo forneceu informações a respeito da riqueza e composição da assembleia de vertebrados terrestres de médio e grande porte, sua relação com a sazonalidade e com as variáveis ambientais amostradas para 14 espécies, dentre as 25 presentes nesta assembleia, em uma área de 25 km² em floresta de terra-firme na Amazônia Oriental.

A distribuição das três espécies de aves aparentou estar mais estreitamente relacionada com as variáveis que descrevem a estrutura da floresta, isso pode ser um resultado de comportamentos associados, principalmente com o forrageamento no solo.

As espécies de Felinos e Ungulados não aparentaram relação com nenhuma das variáveis para a escala estudada, o que pode ser devido à plasticidade ecológica destas espécies pouco especializadas.

As espécies de roedores (*Cuniculus paca*, *Dasyprocta leporina* e *Myoprocta acouchy*) apresentaram uma clara relação com as áreas de baixio e próximos aos cursos de água.

Em relação à sazonalidade, o aumento significativo no número de registro de algumas espécies de Ungulados e Roedores na estação chuvosa, chama a atenção para a importância da amostragem em ambas as estações, principalmente para estudos que levem em consideração a abundância e a taxa de ocupação.

O fato de que muitas das espécies consideradas cinegéticas apresentaram um incremento no número de registros próximos aos grandes rios, pode chamar a atenção para a integridade ambiental da área, levando em consideração que em florestas tropicais os rios são usados como porta de entrada por caçadores, o que causa a diminuição de espécies em sua proximidade.

De forma geral, as análises sugerem que em mesoescala (25 km²) a assembleia de vertebrados de médio e grande porte foi pouco influenciada pelas variáveis ambientais amostradas, sendo que outros fatores, como interações bióticas e disponibilidade de recursos podem ter maior relevância para a distribuição destas espécies nesta escala.

Apêndices

Apêndice 1. Ata da aula de qualificação.

PG·ECO·INPA
PÓS-GRADUAÇÃO EM ECOLOGIA

INPA
INSTITUTO NACIONAL DE PESQUISAS DA AMAZÔNIA

GOVERNO FEDERAL
BRASIL
PAÍS RICO É PAÍS SEM POBREZA

AULA DE QUALIFICAÇÃO

PARECER

Aluno(a): LINCOLN JOSÉ MICHALSKI
Curso: ECOLOGIA
Nível: Mestrado
Orientador(a): Dra. Fernanda Michalski (UNIFAP)
Co-orientador (a): Dr. Tadeu Gomes de Oliveira (UEMA)

Título:

"EFEITOS DA DISPONIBILIDADE DE FRUTOS E DA HETEROGENEIDADE DE HABITAT SOBRE A FAUNA DE VERTEBRADOS DE MÉDIO E GRANDE PORTE NA AMAZÔNIA ORIENTAL"

BANCA JULGADORA:

TITULARES:
VALERIA DA CUNHA TAVARES (INPA)
IGOR LUIS KAEFER (UFAM)
RENATO CINTRA SOARES (INPA)

SUPLENTES:
FABRICIO BEGGIATO BACCARO (UFAM)
CAMILA RIBAS (INPA)

PARECER			ASSINATURA
VALÉRIA DA CUNHA TAVARES (INPA)	(✓) Aprovado	( ) Reprovado	[assinatura]
IGOR LUIS KAEFER (UFAM)	(✓) Aprovado	( ) Reprovado	[assinatura]
RENATO CINTRA SOARES (INPA)	(✓) Aprovado	( ) Reprovado	[assinatura]
FABRICIO BEGGIATO BACCARO	( ) Aprovado	( ) Reprovado	
CAMILA RIBAS (INPA) (INPA)	( ) Aprovado	( ) Reprovado	

Manaus(AM), 26 de fevereiro de 2014

OBS: SUGERIMOS AO ESTUDANTE DELIMITAR SUA HIPÓTESE ECOLÓGICA CENTRAL VISANDO O DESENVOLVIMENTO DE SUA DISSERTAÇÃO.

INSTITUTO NACIONAL DE PESQUISAS DA AMAZÔNIA INPA
PROGRAMA DE PÓS-GRADUAÇÃO EM ECOLOGIA PPG-ECO
Av. Efigênio Sales, 2239 – Bairro: Aleixo – Caixa Postal: 2223 – CEP: 69.060-020, Manaus/AM.
Fone/Fax:(+55) 92 3643-1909 / 1838
site: http://pg.inpa.gov.br e-mail: pgecologia@gmail.com

Apêndice 2. Ata da defesa pública.

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Ministério da Ciência, Tecnologia e Inovação

GOVERNO FEDE BRASI PÁTRIA EDUCAD

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

Aos 19 dias do mês de março do ano de 2015, às 09:00 horas, na Sala de Aula da Genética, Campus II, INPA/Aleixo, reuniu-se a Comissão Examinadora de Defesa Pública, composta pelos seguintes membros: o(a) Prof(a). Dr(a). **Renato Cintra Soares,** do Instituto Nacional de Pesquisas da Amazônia - INPA, o(a) Prof(a). Dr(a). **Marcelo Gordo,** da Universidade Federal do Amazonas - UFAM e o(a) Prof(a). Dr(a). **Paulo Estefano Dineli Bobrowiec,** do Instituto Nacional de Pesquisas da Amazônia - INPA, tendo como suplentes o(a) Prof(a). Dr(a). Ronis da Silveira, da Universidade Federal do Amazonas - UFAM, e o(a) Prof(a). Dr(a). Carlos Eduardo Barbosa, 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 **LINCOLN JOSÉ MICHALSKI,** intitulado: **"Relações ecológicas na distribuição de 25 espécies de vertebrados neotropicais em mesoescala"** orientado pelo(a) Prof(a). Dr(a). Fernanda Michalski da Universidade Federal do Amapá – UNIFAP e coorientado pelo(a) Prof.(a) Dr(a). Tadeu Gomes de Oliveira da Universidade Estadual do Maranhão – UEMA.

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

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

[X] POR UNANIMIDADE [ ] POR MAIORIA

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

Prof(a).Dr(a). Renato Cintra Soares ______________________

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

Prof(a).Dr(a). Paulo Estefano Dineli Bobrowiec Paulo Bobrowiec ______________________

Prof(a).Dr(a). Ronis da Silveira ______________________

Prof(a).Dr(a). Carlos Eduardo Barbosa ______________________

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Coordenação PPG-ECO/INPA